



SINAMICS - Low Voltage Engineering Manual

SINAMICS G130, G150, S120 Chassis, S120 Cabinet Modules, S150

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SINAMICS Drives

SIEMENS

SINAMICS Engineering Manual

May 2008

Disclaimer

We have checked that the contents of this document correspond to the hardware and software described. However, as deviations cannot be totally excluded, we are unable to guarantee complete consistency. The information given in this publication is reviewed at regular intervals and any corrections that might be necessary are made in the subsequent editions.

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<u>Foreword</u>	
<u>List of Contents</u>	
<u>Fundamental Principles and System Description</u>	
<u>EMC Installation Guideline</u>	
<u>General Engineering Information for SINAMICS</u>	
<u>Converter Chassis Units SINAMICS G130</u>	
<u>Converter Cabinet Units SINAMICS G150</u>	
<u>SINAMICS S120, General Information about Built-in and Cabinet Units</u>	
<u>Modular Cabinet Unit System SINAMICS S120 Cabinet Modules</u>	
<u>Converter Cabinet Units SINAMICS S150</u>	
<u>Drive Dimensioning</u>	
<u>Motors</u>	
<u>Dimension Drawings</u>	

To all SINAMICS customers!

This engineering manual is supplementary to the SINAMICS catalog range and is designed to provide additional support to SINAMICS users. It focuses on drives with units in Chassis and Cabinet format in the output power range ≥ 75 KW operating in vector control mode.

The engineering manual contains a general analysis of the fundamental principles of variable-speed drives as well as detailed system descriptions and specific information about the following units in the SINAMICS equipment range:

- Converter Chassis Units SINAMICS G130 (Catalog D11)
- Converter Cabinet Units SINAMICS G150 (Catalog D11)
- Modular Chassis Unit System SINAMICS S120 (Catalog PM21)
- Modular Cabinet Unit System SINAMICS S120 Cabinet Modules (Catalog D21.3 Cabinet Modules)
- Converter Cabinet Units SINAMICS S150 (Catalog D21.3).

This engineering manual is divided into different chapters.

The first chapter "Fundamental Principles and System Description" focuses on the physical fundamentals of electrical variable-speed drives and provides general system descriptions of products in the SINAMICS range.

The second chapter "EMC Installation Guideline" gives an introduction to the subject of **Electro-magnetic Compatibility (EMC)**, and provides all information required to install drives with the aforementioned SINAMICS devices in an EMC-compliant manner.

The chapters that follow, which describe the configuration of SINAMICS G130, G150, S120 chassis units, S120 Cabinet Modules and S150, focus on specific unit types in more detail than the chapter on fundamental principles.

To provide an easy overview of the system variants and cabinet design, the dimensions are given at the end of the manual.

This engineering manual can and should only be viewed as a supplement to SINAMICS catalogs D11, PM21, D21.3 and D21.3 Cabinet Modules. The document does not, therefore, contain any ordering data. The manual is available as an electronic document in English and German only.

The information of this manual is aimed at technically qualified and trained personnel. The configuring engineer is responsible for assessing whether the information provided is sufficiently comprehensive for the application in question and, therefore, assumes overall responsibility for the whole drive or the whole system.

The information provided in this engineering manual contains descriptions or characteristics of performance which in case of actual use do not always apply as described or which may change as a result of further development of the products.

The desired performance features are only binding if expressly agreed upon in the contract.

Availability and technical specifications are subject to change without prior notice.

EMC warning information

The SINAMICS converter systems G130, G150, S120 chassis units, S120 Cabinet Modules and S150 are not designed to be connected to public networks (first environment). RFI suppression of these converter systems is designed for industrial networks (second environment) in accordance with the EMC product standard EN 61800-3 for variable-speed drives. If the converter systems are connected to public networks (first environment) electro-magnetic interference can occur. With additional measures (e.g. EMC-filters) the converter systems can also be connected to public networks

List of Contents

Fundamental Principles and System Description.....	12
■ Operating principle of SINAMICS converters	12
General operating principle	12
Pulse modulation method	12
Generation of a variable voltage by pulse width modulation.....	13
Maximum attainable output voltage with space vector modulation SVM	15
Maximum attainable output voltage with pulse-edge modulation PEM.....	15
The pulse frequency and its influence on key system properties	17
Output power ratings of SINAMICS converters and inverters / Definition of the output power	19
■ Supply systems and supply system types	21
General.....	21
Connection of converters to grounded systems (TN or TT).....	22
Connection of converters to non-grounded systems (IT).....	22
Connection of converters to supply systems with different short-circuit powers	23
Supply voltage variations and supply voltage dips	25
Behaviour of SINAMICS converters during supply voltage variations and dips.....	26
Permissible harmonics on the supply voltage.....	32
■ Transformers	33
Unit transformers.....	33
Transformer types	34
Features of standard transformers and converter transformers	35
Three-winding transformers.....	36
■ Harmonic effects on the supply system	37
General.....	37
Harmonic currents of 6-pulse rectifier circuits.....	39
Harmonic currents of 6-pulse rectifier circuits with Line Harmonics Filter	42
Harmonic currents of 12-pulse rectifier circuits.....	44
Harmonic currents and harmonic voltages of Active Infeeds (AFE technology)	45
Standards and permissible harmonics	47
■ Line reactors (line commutating reactors)	51
■ Line Harmonics Filter (LHF)	52
■ Line filters (radio frequency interference (RFI) suppression filters or EMC filters).....	54
General information and standards	54
Line filters for the "first" environment (residential) and "second" environment (industrial)	56
Operating principle of line filters	57
Magnitude of leakage or interference currents	57
EMC-compliant installation	58
■ SINAMICS Infeeds and their properties	60
Basic Infeed.....	60
Smart Infeed.....	62
Active Infeed.....	64
Comparison of the properties of the different SINAMICS Infeeds	67
Redundant line supply concepts.....	68
Permissible total cable length for S120 Infeed Modules feeding multi-motor drives	74

List of Contents

Engineering Information

■	Effects of using fast-switching power components (IGBTs)	75
	Increased current load on the inverter output as a result of long motor cables	75
	Increased voltage stress on the motor winding as a result of long motor cables	77
	Bearing currents caused by steep voltage edges on the motor	81
	Measures for reducing bearing currents.....	82
	1. EMC-compliant installation for optimized equipotential bonding in the drive system	83
	2. Insulated bearing at the non-drive end (NDE end) of the motor	86
	3. Other measures	86
	Brief overview of the different types of bearing currents	87
■	Motor reactors	89
	Reduction of the voltage rate of rise dv/dt at the motor terminals	89
	Reduction of additional current peaks when long motor cables are used	89
	Permissible motor cable lengths with motor reactor(s) for single-motor and multi-motor drives	90
	Supplementary conditions which apply when motor reactors are used	93
■	dv/dt filter plus VPL	94
■	Sine-wave filters.....	96
■	Load duty cycles	98
	General	98
	Standard load duty cycles	98
	Free load duty cycles	99
	Thermal monitoring of the power unit during load duty cycles and continuous operation	102
■	Efficiency of SINAMICS converters at full load and at partial load	103
	Converter efficiency at full load	103
	Converter efficiency at partial load	104
■	Parallel connections of converters	110
	General	110
	Parallel connections of SINAMICS converters	110
	Parallel connection of S120 Basic Line Modules	112
	Parallel connection of S120 Smart Line Modules.....	114
	Parallel connection of S120 Active Line Modules	116
	Parallel connection of S120 Motor Modules.....	116
	Admissible and inadmissible winding systems for parallel connections of SINAMICS converters	118
■	SINAMICS S120 Liquid-Cooled units in chassis format	121
	General	121
	Design of the SINAMICS S120 Liquid-Cooled units.....	121
	Requirements concerning coolant and cooling circuit	122
	EMC Installation Guideline	126
■	Introduction	126
	General	126
	EC Directives	126
	CE marking	126
	EMC Directive	127
	EMC product standard EN 61800-3	127
■	Fundamental principles of EMC	129
	Definition of EMC	129
	Interference emissions and interference immunity.....	130
■	The frequency converter and its EMC.....	130
	The frequency converter as a source of interference	130

The frequency converter as a high-frequency source of interference	131
The frequency converter as a low-frequency source of interference	134
The frequency converter as potentially susceptible equipment	135
Methods of influence	135
Conductive coupling	135
Capacitive coupling	136
Inductive coupling	137
Electromagnetic coupling (radiative coupling)	138
■ EMC-compliant installation	138
Zone concept within the converter cabinet	139
Converter cabinet structure	140
Cables inside the converter cabinet	140
Cables outside the converter cabinet	141
Cable shields	141
Equipotential bonding in the converter cabinet, in the drive system, and in the plant	141
Examples for installation	143
EMC - compliant installation of a SINAMICS G150 converter cabinet unit	143
EMC - compliant construction / installation of a cabinet with a SINAMICS G130 chassis unit	144
EMC - compliant cable routing on the plant side on cable racks and in cable routes	145
General Engineering Information for SINAMICS	146
■ Overview of documentation	146
■ Safety-integrated, drive-integrated safety functions	150
Safe Torque Off (previously known as "Safe Standstill") and Safe Stop 1	150
Safe Brake Control	153
■ Precharging intervals of the DC link	155
SINAMICS Booksize units	155
SINAMICS chassis units	155
■ Operator Panel	155
Basic Operator Panel (BOP20)	155
Advanced Operator Panel (AOP30)	155
■ Cabinet construction and air conditioning	157
Directives and standards	157
Cabinet air conditioning	158
Cooling air requirement and sizes of cabinet openings	160
Partitioning	161
■ Changing the power block on chassis power units	162
■ Replacement of SIMOVERT P and SIMOVERT A converter ranges by SINAMICS	163
General	163
Replacement of converters in SIMOVERT P 6SE35/36 and 6SC36/37 ranges by SINAMICS	163
Replacement of converters in SIMOVERT A 6SC23 range by SINAMICS	165
Converter Chassis Units SINAMICS G130	167
■ General information	167
■ Rated data of converters for drives with low demands on control performance	170
■ Incorporating different loads into the 24 V supply	173
■ Factory settings (defaults) of customer interface on SINAMICS G130	174
■ Line-side components	180
Line fuses	180

List of Contents

Engineering Information

Line reactors	180
Line filters.....	181
■ Components at the DC link	182
Braking units	182
■ Load-side components and cables	185
Motor reactor.....	185
dv/dt filter plus VPL	185
Sine-wave filter	185
Maximum connectable motor cable lengths	185
Converter Cabinet Units SINAMICS G150	187
■ General information.....	187
■ Rated data of converters for drives with low demands on control performance	187
■ Factory settings (defaults) of customer interface on SINAMICS G150	191
■ Cable cross-sections and connections on SINAMICS G150 Cabinet Units	193
Recommended and maximum possible cable cross-sections for line and motor connections	193
Required cable cross-sections for line and motor connections	195
Grounding and PE conductor cross-section.....	196
■ Line-side components.....	197
Line fuses.....	197
Line reactors	197
Line filters.....	198
■ Components at the DC link	199
Braking units	199
■ Load-side components and cables	202
Motor reactor.....	202
dv/dt filter plus VPL	202
Sine-wave filter	202
Maximum connectable motor cable lengths	202
■ SINAMICS G150 parallel converters (SINAMICS G150 power extension)	203
6-pulse operation of SINAMICS G150 parallel converters	205
12-pulse operation of SINAMICS G150 parallel converters	207
Operation at motors with electrically isolated winding systems and one common winding system.....	208
Special features to note when precharging SINAMICS G150 parallel converters.....	209
Brief overview of SINAMICS G150 parallel converters with production date up to autumn 2007.....	210
Brief overview of SINAMICS G150 parallel converters with production date from autumn 2007	211
SINAMICS S120, General Information about Built-in and Cabinet Units	212
■ General	212
Assignment table	212
■ Control properties	212
Performance features.....	212
Control properties, definitions	214
Closed-loop control characteristics	214
■ Rating data.....	217
Maximum output frequencies	217
■ DRIVE CLiQ	218
Basic informations.....	218
DRIVE-CLiQ cables supplied with the unit.....	218

Cable installation	220
Specification of the required control performance and selection of the Control Unit	223
Specification of component cabling	225
■ Check of the maximum DC link capacitance	228
Basic informations	228
Capacitance values	229
■ Braking Module / External braking resistor	233
Braking Module for power units in chassis format	233
Braking resistors for power units in chassis format	235
■ Maximum connectable motor cable lengths	237
Booksize units	237
Chassis units	238
■ Checking the total cable length for multi-motor drives	239
Modular Cabinet Unit System SINAMICS S120 Cabinet Modules	240
■ General.....	240
Design	240
General configuring process.....	240
■ Dimensioning and selection information.....	241
Derating data.....	241
Degrees of protection of S120 Cabinet Modules	243
Required cross-sections of DC busbars	243
Required cable cross-sections for line and motor connections.....	244
Cooling air requirements	245
Auxiliary power requirements	247
Line reactors.....	254
Parallel configuration	255
Weights of S120 Cabinet Modules	256
■ Information about equipment handling	259
Customer terminal block -A55	259
Customer terminal block -X55	261
Auxiliary voltage distribution	262
DRIVE-CLiQ wiring.....	263
Erection of cabinets.....	264
Examples of Cabinet Module arrangements.....	264
Door opening angle	265
■ Line Connection Modules	266
Design	266
Planning recommendations, special features	267
Assignment to rectifiers	267
Parallel connections	268
DC busbar	269
Circuit breakers	269
Short-circuit strength	271
■ Basic Line Modules	272
Design	272
DC link fuses	273
Parallel connections of Basic Line Modules	273

List of Contents

Engineering Information

■ Smart Line Modules	274
Design	274
DC link fuses	275
Parallel connections of Smart Line Modules	275
■ Active Line Modules + Active Interface Modules	276
Design	276
DC Link fuses	278
Parallel connections of Active Line Modules + Active Interface Modules	278
■ Motor Modules	280
Design	280
DC link fuses	281
Parallel connections of Motor Modules	281
■ Booksize Base Cabinet / Booksize Cabinet Kits	283
Design	283
Booksize Base Cabinet	283
Booksize Cabinet Kits	283
DC link fuses	284
Planning recommendations, special features	284
■ Central Braking Modules	288
Design	288
Position in the DC link configuration	289
DC Link fuses	290
Parallel configuration of Central Braking Modules	290
Braking resistor	290
■ Options	292
Option G33 (Communication Board CBE20)	292
Option K75 (Second auxiliary busbar)	292
Option K82 (Terminal module for controlling the "Safe Torque Off" and "Safe Stop1" functions)	292
Option K90 / 91 (Control Unit CU320)	296
Option L08 / L09 (Motor reactors)	297
Option L25 (Withdrawable circuit breaker)	297
Option L34 (Circuit breaker on the output side)	298
Option L37 (DC coupling)	299
Option M59 (Cabinet door closed)	299
Option Y11 (Factory assembly of Cabinet Modules into transport units)	300
Converter Cabinet Units SINAMICS S150	302
■ General information	302
■ Rated data and continuous operation of the converters	303
■ Factory settings (defaults) of customer interface on SINAMICS S150	306
■ Cable cross-sections and connections on SINAMICS S150 cabinets	308
Recommended and maximum possible cable cross-sections for line and motor connections	308
Required cable cross-sections for line and motor connections	309
Grounding and PE conductor cross-section	309
■ Load-side components and cables	311
Motor reactor	311
dv/dt filter plus VPL	311
Sine-wave filter	311
Maximum connectable motor cable lengths	311

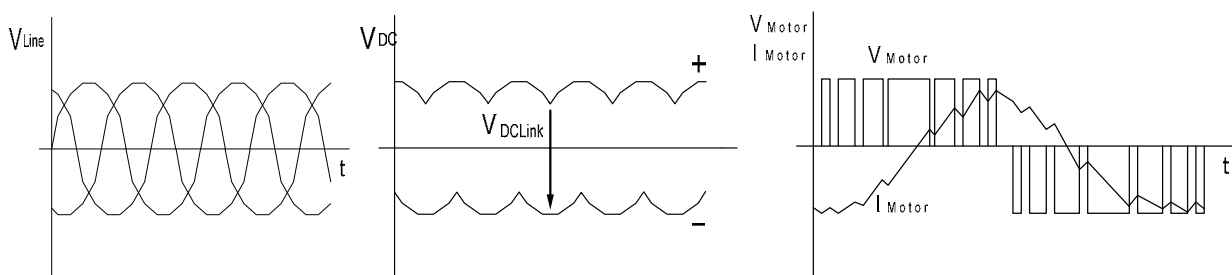
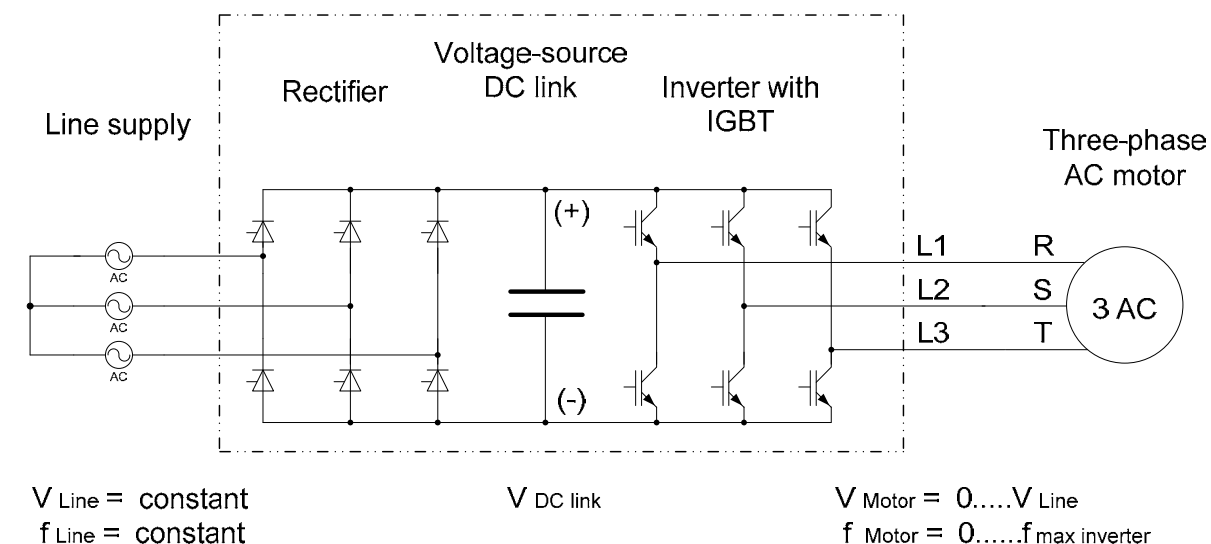
Drive Dimensioning	313
Drives with quadratic load torque	313
Drives with constant load torque	313
Permissible motor-converter combinations.....	314
Drives with permanent-magnet three-phase synchronous motors	314
Motors.....	320
1LG4/1LG6 and 1LA8 self-cooled asynchronous motors	320
1PH7/ 1PL6 compact asynchronous motors	320
1FW3 / 1FW4 three-phase synchronous motors (high-torque motors with permanent magnets).....	320
Special insulation for line supply voltages > 500 V in converter-fed operation	321
Bearing currents	321
Motor protection	322
Operation of explosion proof motors with type of protection "d"	322
Dimension Drawings	323
■ SINAMICS G130	323
■ SINAMICS Line Harmonics Filter	327
■ SINAMICS G150 (type A).....	329
■ SINAMICS G150 (type C).....	345
■ SINAMICS S120 Chassis (Basic Line Modules).....	347
■ SINAMICS S120 Chassis (Smart Line Modules).....	349
■ SINAMICS S120 Chassis (Active Interface Modules)	352
■ SINAMICS S120 Chassis (Active Line Modules).....	356
■ SINAMICS S120 Chassis (Motor Modules)	360
■ SINAMICS S120 Chassis Liquid Cooled (Power Modules)	364
■ SINAMICS S120 Chassis Liquid Cooled (Basic Line Modules).....	366
■ SINAMICS S120 Chassis Liquid Cooled (Motor Modules)	368
■ SINAMICS S120 Cabinet Modules (Line Connection Modules)	371
■ SINAMICS S120 Cabinet Modules (Basic Line Modules).....	373
■ SINAMICS S120 Cabinet Modules (Smart Line Modules).....	374
■ SINAMICS S120 Cabinet Modules (Active Interface Modules + Active Line Modules)	376
■ SINAMICS S120 Cabinet Modules (Motor Modules).....	378
■ SINAMICS S120 Cabinet Modules (Booksize Base Cabinet / Booksize Cabinet Kits)	380
■ SINAMICS S120 Cabinet Modules (Central Braking Modules)	381
■ SINAMICS S120 Cabinet Modules (Auxiliary Power Supply Modules)	382
■ SINAMICS S150.....	383
Notes	393

Fundamental Principles and System Description

Operating principle of SINAMICS converters

General operating principle

The converters in the SINAMICS product range are PWM converters with a voltage-source DC link. At the input side, the converter consists of a rectifier (shown in the schematic sketch as a thyristor rectifier) which is supplied with a constant voltage V_{Line} and a constant frequency f_{Line} from a three-phase supply. The rectifier produces a constant DC voltage V_{DCLink} , i.e. the DC link voltage, which is smoothed by the DC link capacitors. The IGBT inverter on the output side converts the DC link voltage to a three-phase system with a variable voltage V_{Motor} and variable frequency f_{Motor} . This process operates according to the principle of pulse width modulation PWM. By varying the voltage and the frequency, it is possible to vary the speed of the connected three-phase motor continuously and virtually without losses.



Block diagram of a PWM converter with voltage-source DC link

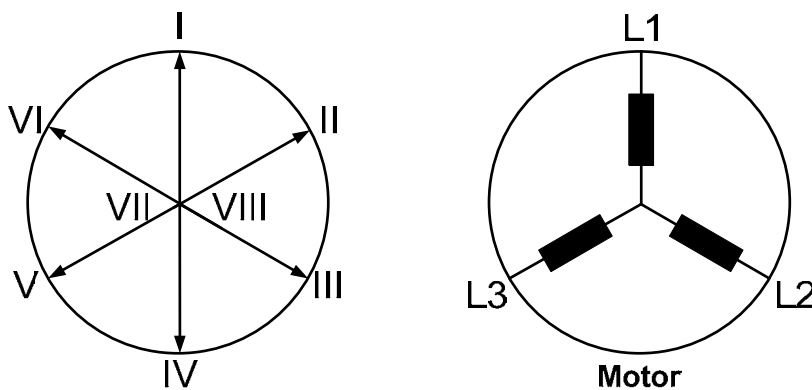
Pulse modulation method

The power semiconductors of the IGBT inverter (IGBT = Insulated Gate Bipolar Transistor) are high-speed, electronic switches which connect the converter outputs to the positive or negative pole of the DC link voltage. The duration of the gating signals in the individual inverter phases and the magnitude of the DC link voltage thus clearly determine the output voltage and therefore also the voltage at the connected motor.

If we consider all three phases, there are a total of $2^3 = 8$ switching states in the inverter, and the effect of these states in the motor can be defined by voltage phasors.

Switching states of the inverter	Phase L1	Phase L2	Phase L3
V_1	+	-	-
V_2	+	+	-
V_3	-	+	-
V_4	-	+	+
V_5	-	-	+
V_6	+	-	+
V_7	+	+	+
V_8	-	-	-

If, for example, phase L1 is connected to the positive DC link voltage, and phases L2 and L3 to the negative voltage so as to produce switching state V_1 , the resultant voltage phasor points in the direction of motor phase L1 and is designated phase I. The length of this phasor is determined by the DC link voltage.



Representation of resultant motor voltages as phasor

If the switching state changes from V_1 to V_2 , then the voltage phasor rotates clockwise by an angle of 60° due to the change in potential at terminal L2. The length of the phasor remains unchanged.

In the same way, the relevant voltage phasors are produced by switching combinations V_3 to V_6 . Switching combinations V_7 and V_8 produce the same potential at all motor terminals. These two combinations therefore produce voltage phasors of "zero" length (zero voltage phasor).

Generation of a variable voltage by pulse width modulation

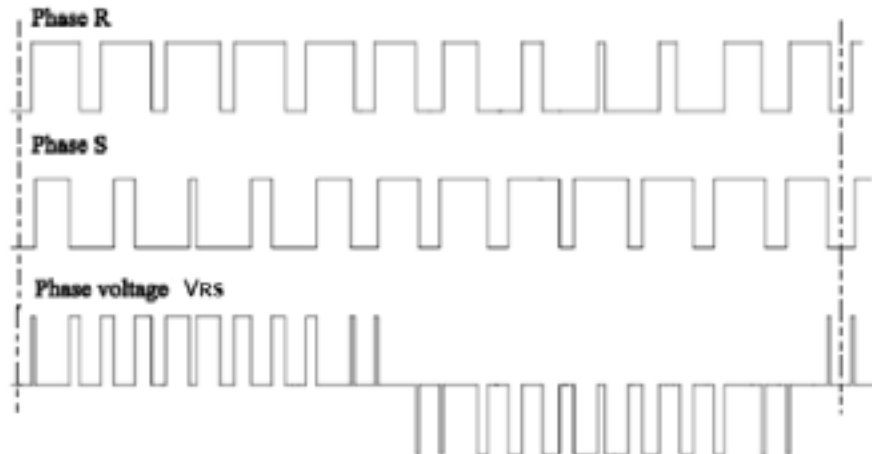
Voltage and frequency must be specified in a suitable way for a certain operating state of the motor, characterized by speed and torque. Ideally, this corresponds to control of the voltage vector $V_{(\omega t)}$ on a circular path with the speed of rotation $\omega t = 2 \cdot \pi \cdot f$ and adjusted absolute value. This is achieved through modulation of the actual settable voltage space vectors (pulse width modulation). In this way, the momentary value $V_{(\omega t)}$ is formed by pulses of the adjacent, actual settable voltage space vectors and the voltage zero.

The solid angle is set directly by varying the ratio of the ON durations (pulse width) of adjacent voltage vectors, the desired absolute value by varying the ON duration of the zero voltage vector. This method of generating gating signals is called space vector modulation SVM. Space vector modulation provides sine-modulated pulse patterns.

Fundamental Principles and System Description

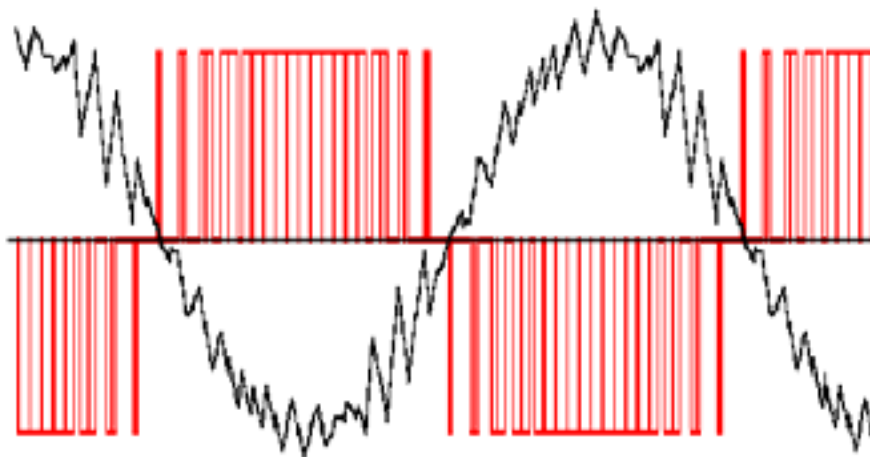
Engineering Information

The following diagram illustrates how the voltages in phases L1 (R) and L2 (S) plus output voltage V_{RS} (phase-to-phase voltage) are produced by the method of pulse width modulation and shows their basic time characteristics. The frequency with which the IGBTs in the inverter phases are switched on and off is referred to as the pulse frequency or clock frequency of the inverter.



Timing of the gating signal sequence for the IGBTs of the two inverter phases L1 (R) and L2 (S) plus the associated output voltage V_{RS} (V- phase-to-phase). The amplitude of the voltage pulses corresponds to the DC link voltage.

The diagram below shows the time characteristic (in red) of the inverter output voltage (phase-to-phase voltage) and the resulting current (in black) generated in the motor when a standard asynchronous motor with a rated frequency of 50 Hz or 60 Hz is used and the inverter is operating with a pulse frequency of 1.25 kHz. The diagram shows that the smoothing effect of the motor inductances causes the motor current to be virtually sinusoidal, despite the fact that the motor is supplied with a square-wave pulse pattern.



Motor voltage (phase-to-phase) and motor current with space vector modulation

Maximum attainable output voltage with space vector modulation SVM

Space vector modulation SVM generates pulse patterns which approximate an ideal sinusoidal motor voltage through voltage pulses with constant amplitude and corresponding pulse-duty factor. The peak value of the maximum (fundamental) voltage that can be attained in this way corresponds to the amplitude of the DC link voltage V_{DCLink} . Thus the theoretical maximum motor voltage with space vector modulation which results is:

$$V_{SVM\ max} = \frac{1}{\sqrt{2}} \cdot V_{DCLink}$$

The true amplitude of the DC link voltage V_{DCLink} is determined by the method of line voltage rectification. In the case of rectifiers of the type used with SINAMICS G130 and G150 and also with S120 Basic Line Modules, it averages $1.41 \cdot V_{Line}$ with no load, $1.35 \cdot V_{Line}$ with partial load and $1.32 \cdot V_{Line}$ with full load. Thus with the true DC link voltage amplitude of $V_{DCLink} \approx 1.32 \cdot V_{Line}$ at full load, the motor voltage theoretically attainable with space vector modulation is:

$$V_{SVM\ max} = 0.935 \cdot V_{Line}$$

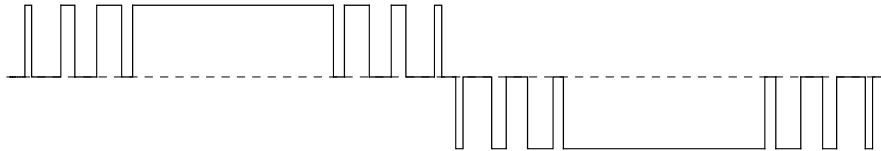
As a result of voltage drops in the converter and minimum pulse times and interlock times in the gating unit responsible for generating the IGBT gating pulse pattern, the values in practice are lower. In practice, the values are:

$$V_{SVM\ max} \approx 0.92 \cdot V_{Line} \quad (\text{with pulse frequency of 2.0 kHz or 1.25 kHz according to the factory setting})$$

For SINAMICS G130 chassis and G150 cabinets that were supplied with firmware versions < V2.3 until the autumn of 2005, this value is the maximum attainable output voltage as devices with this firmware are not capable of utilizing pulse-edge modulation.

Maximum attainable output voltage with pulse-edge modulation PEM

It is possible to increase the inverter output voltage above the values attained with space vector modulation by not pulsing over the entire fundamental-wave period, but only at its edges. This process is referred to as pulse-edge modulation (PEM). The basic waveform of the motor voltage is then as shown below.



Motor voltage with pulse-edge modulation PEM

The maximum possible output voltage is attained when clocking is performed with the fundamental frequency only, i.e. when "pulsing" ceases altogether. The output voltage then consists of 120° rectangular blocks with the amplitude of the DC link voltage. The fundamental frequency RMS value of the output voltage can then be calculated as:

$$V_{rect} = \frac{\sqrt{6}}{\pi} \cdot V_{DCLink} = \frac{\sqrt{6}}{\pi} \cdot 1.32 \cdot V_{Line} = 1.03 \cdot V_{Line}$$

So it is possible with pure rectangular modulation to achieve a motor voltage which is slightly higher than the line voltage. However, the motor voltage then has an unsuitable harmonic spectrum which causes major stray losses in the motor and utilizes the motor inefficiently. It is for this reason that pure square-wave modulation is not utilized on SINAMICS converters.

The pulse-edge modulation method used on SINAMICS converters permits a maximum output voltage which is only slightly lower than the line voltage, even when allowance is made for voltage drops in the converter:

$$V_{PEM\ max} = 0.97 \cdot V_{Line}$$

The pulse-edge modulation process uses optimized pulse patterns which cause only minor harmonic currents and therefore utilize the connected motor efficiently. Commercially available standard motors for 50 Hz or 60 Hz and utilized according to temperature class B in mains operation can be partially utilized according to temperature class F at the nominal working point up to rated torque when operated with pulse-edge modulation.

Fundamental Principles and System Description

Engineering Information

With introduction of firmware version V2.3 and simultaneous modification of the CIB board hardware (interface module between the Control Unit and power unit), pulse-edge modulation has been available as a standard feature on the following SINAMICS units in vector control mode since autumn 2005:

- SINAMICS G130* Chassis
- SINAMICS G150* Cabinets
- SINAMICS S150* Cabinets
- SINAMICS S120* Motor Modules / chassis format
- SINAMICS S120* Motor Modules / Cabinet Modules format

At low output frequencies and low depth of modulation, i.e. at low output voltage, these products utilize the space vector modulation SVM option and switch automatically over to pulse-edge modulation PEM if the depth of modulation required at higher output frequencies is so high that it can no longer be provided by space vector modulation (output voltage > 92 % of input voltage).

In principle it would be possible to reach an output voltage of over 92% through overmodulation of the space vector modulation (SVM). However, through doing this, the harmonics spectrum in the motor current would increase considerably, which would lead to higher torque ripples and noticeably higher motor losses. Therefore, SINAMICS units operating in the vector control mode use pulse-edge modulation with optimised pulse patterns in order to achieve optimum drive behaviour with regard to torque ripples and motor losses.

* Exceptions:

- Parallel converters on which two or more power units operating in parallel are supplying one motor with a common winding system. Under these conditions pulse-edge modulation cannot be selected.

If either a Basic or Smart Infeed is used to supply the inverter, the following formulas apply for the DC link voltage at full load: $V_{DCLink} \approx 1.32 \cdot V_{Line}$ resp. $1.30 \cdot V_{Line}$. Therefore the maximum output voltage without pulse-edge modulation is limited to 92 % of the line input voltage.

If an Active Infeed is used to supply the inverter, the following formula applies to the DC link voltage because the Active Infeed utilizes a step-up converter function: $V_{DCLink} > 1.42 \cdot V_{Line}$ (factory setting: $V_{DCLink} = 1.5 \cdot V_{Line}$). This means that the maximum output voltage even without pulse-edge modulation can correspond to 100 % of the line input voltage or higher if the parameters of ratio V_{DCLink} / V_{Line} are set to sufficiently high values on the Active Infeed. This is described in the section "SINAMICS Infeeds and their properties", subsection "Active Infeed".

- Converters with output-side sine-wave filter. Pulse-edge modulation cannot be selected under these conditions. If either a Basic or Smart Infeed is used to supply the inverter, the following formulas apply for the DC link voltage at full load: $V_{DCLink} \approx 1.32 \cdot V_{Line}$ resp. $V_{DCLink} = 1.30 \cdot V_{Line}$. In this case, the maximum output voltage is limited to 85 % of the line input voltage for units with a supply voltage of 380 V to 480 V 3AC and to 83 % for units with a supply voltage of 500 V to 600 V 3AC.

If an Active Infeed is used to supply the inverter, the following formula applies to the DC link voltage because the Active Infeed utilizes a step-up converter function: $V_{DCLink} > 1.42 \cdot V_{Line}$ (factory setting: $V_{DCLink} = 1.5 \cdot V_{Line}$). This means that the maximum output voltage even without pulse-edge modulation can correspond to 100 % of the line input voltage or higher if the parameters of ratio V_{DCLink} / V_{Line} are set to sufficiently high values on the Active Infeed. This is described in the section "SINAMICS Infeeds and their properties", subsection "Active Infeeds".

Note:

- Pulse-edge modulation PEM is only available in vector control mode. In servo control mode, the converters always operate with space vector modulation (SVM). The reason for this is the slight lower dynamic performance of the drive when it is operating with pulse-edge modulation. This can be accepted in almost all vector control applications, but not in high-dynamic servo control applications.
- With the introduction of Firmware version V2.5 SP1 and the simultaneous changing of the hardware, pulse-edge modulation is available as standard also for Booksize units since autumn 2007.

The pulse frequency and its influence on key system properties

The pulse frequency of the inverter is an important parameter which has a crucial influence on various properties of the drive system. It can be varied within certain given limits. In order to reduce the motor noise, reach very high output frequencies or in the event that sinus filters are to be used at the converter output, it is sensible, or rather necessary, to increase the pulse frequency.

The following aspects of the pulse frequency are described briefly below:

- The pulse frequency factory settings
- The limits within which the pulse frequency can be adjusted
- The effect of the pulse frequency on various properties of the drive system
- When it is advisable or even essential to change the pulse frequency
- What needs to be noted in connection with motor-side options (motor reactor, motor filter).

Factory settings and pulse frequency setting ranges

The pulse frequency of the motor-side inverter on SINAMICS G130, G150, S150, S120 (Chassis and Cabinet Modules) operating in vector control mode is preset at the factory to 2.0 kHz or 1.25 kHz as specified in the table below.

Line supply voltage	Power	Rated output current	Pulse frequency factory setting
380 V to 480 V 3AC	≤ 250 kW ≥ 315 kW	≤ 490 A ≥ 605 A	2.00 kHz 1.25 kHz
500 V to 600 V 3AC	All power ratings	All currents	1.25 kHz
660 V to 690 V 3AC	All power ratings	All currents	1.25 kHz

Converter-dependent factory setting of pulse frequency for SINAMICS G130, G150, S150 and for SINAMICS S120 Motor Modules, Chassis and Cabinet Modules

The pulse frequency can be varied in discrete steps. Possible settings correspond to twice the factory setting value in each case as well as whole multiples thereof. Depending on the unit type, the pulse frequency can therefore be increased to 8 kHz (when factory setting is 2 kHz) or to 7.5 kHz (when factory setting is 1.25 kHz). Switching between integer multiples of the pulse frequency is also possible when the drive is in operation.

With introduction of firmware version V2.4 in the summer of 2006 intermediate values can also be parameterized, allowing the pulse frequency to be set in relatively fine increments. This setting of intermediate values is only possible when the drive is not in operation.

Influence of the pulse frequency on the inverter output current

The pulse frequency factory setting of either 2.0 kHz or 1.25 kHz is relatively low to generate low inverter switching losses. If the pulse frequency would be increased, and this can be done at any time by adjustment of the parameter settings, the switching losses in the inverter and thus the overall losses in the converter would increase accordingly. The result would be overheating of the power unit if the inverter would operate at full capacity. For this reason, the conducting losses must be lowered in order to compensate for the increase of the switching losses. This can be achieved by reducing the permissible output current (current derating). The pulse-frequency-dependent current derating is specific to individual units. This has to be taken into account when dimensioning a converter. The derating factors for integer multiples of factory settings can be found in the chapters on specific unit types. The derating factors for intermediate values can be ascertained through linear interpolation between the corresponding table values.

Influence of the pulse frequency on losses and efficiency of inverter and motor

With the factory set pulse frequency of 2.0 kHz or 1.25 kHz, the motor current is already close to sinusoidal. The stray losses in the motor caused by harmonic currents are low, but not negligible. Commercially available standard motors for 50 Hz or 60 Hz and utilized according to temperature class B in mains operation can be partially utilized according to temperature class F at the nominal working point up to rated torque when operated on a converter. The winding temperature rise is then between 80 and 100 K.

Raising the pulse frequency on standard motors for 50 Hz or 60 Hz reduces the motor stray losses only slightly, but results in a considerable increase in the converter switching losses. The efficiency of the overall system (converter and motor) deteriorates as a result.

Fundamental Principles and System Description

Engineering Information

Influence of the pulse frequency on motor noise

A higher level of magnetic motor noise is excited when three-phase motors are operated on PWM converters. This is caused by the voltage pulsing which results in additional voltage and current harmonics.

According to DIN VDE 0530 or IEC 60034-17 "Rotating electrical machines / Squirrel-cage induction motors fed from converters - Application guide", the A-graded noise pressure level increases in the order of magnitude of between 5 dB and 15 dB when three-phase motors are operated on a PWM converter up to rated frequency as compared to motors of the same type operating on sinusoidal voltage at rated frequency. The actual values depend on the PWM method used, the pulse frequency of the converter and the design and number of poles of the converter-fed motor.

In the case of SINAMICS converters operating at the factory-set pulse frequency, the additional noise pressure level produced by the motor as a result of the converter supply is in the order of magnitude of between 5 dB(A) and maximum 10 dB(A).

A reduction of the additional motor noise caused by the converter supply can generally be achieved by an increase in the pulse frequency. It can therefore be meaningful to raise the pulse frequency in order to attenuate the motor noise. It must be noted that the inverter current may need to be reduced (derated) with an increased pulse frequency and other limitations may apply with respect to motor-side options such as motor reactors, dv/dt filters plus VPL (Voltage Peak Limiter) and sine-wave filters.

Correlation between pulse frequency and converter output frequency (fundamental wave frequency)

With space vector modulation, there is a fixed correlation between the pulse frequency and the maximum attainable converter output frequency (fundamental wave frequency). The pulse frequency must be at least 12.5 times higher than the required converter output frequency on SINAMICS converters. This means that the maximum achievable output frequency at a given pulse frequency is limited according to the formula

$$f_{\text{Converter max}} = f_{\text{pulse}} / 12.5 \quad (\text{but a maximum of 300 Hz on asynchronous machines with vector control mode}).$$

The table below shows the possible pulse frequency settings and the associated maximum achievable output frequencies for converters and inverters with the factory set pulse frequencies $f_{\text{pulse}} = 2.0 \text{ kHz}$ or $f_{\text{pulse}} = 1.25 \text{ kHz}$. The pulse frequency setting scale is expanded with firmware version V2.4 and higher.

Units with factory setting $f_{\text{pulse}} = 2.0 \text{ kHz}$		Units with factory setting $f_{\text{pulse}} = 1.25 \text{ kHz}$	
Pulse frequency	Max. output frequency	Pulse frequency	Max. output frequency
2.0 kHz	160 Hz	1.25 kHz	100 Hz
4.0 kHz	300 Hz	2.50 kHz	200 Hz
8.0 kHz	300 Hz	5.00 kHz	300 Hz
-	-	7.50 kHz	300 Hz

Settable pulse frequencies and associated maximum attainable output frequencies on SINAMICS converters

Correlation between pulse frequency and motor-side options (motor reactor and motor filter)

If motor reactors, dv/dt filters plus VPL or sine-wave filters are installed at the motor output, the maximum permissible pulse frequency and thus also the maximum output frequency are limited by these options. In some cases, a fixed pulse frequency is specified:

- Permissible pulse frequency with motor reactor (SINAMICS):
The maximum pulse frequency is limited to twice the value of the factory setting, i.e. to 4 kHz on units with factory setting 2 kHz and to 2.5 kHz on units with factory setting 1.25 kHz. The maximum output frequency is limited to 150 Hz independent of the selected pulse frequency.
- Permissible pulse frequency with dv/dt filter plus VPL (SINAMICS):
The maximum pulse frequency is limited to twice the value of the factory setting, i.e. to 4 kHz on units with factory setting 2 kHz and to 2.5 kHz on units with factory setting 1.25 kHz. The maximum output frequency is limited to 150 Hz independent of the selected pulse frequency.
- Permissible pulse frequency with sine-wave filter (SINAMICS):
Sine-wave filters are available for voltage levels 380 V to 480 V 3AC and 500 V to 600 V 3AC. The pulse frequency is a mandatory fixed value and equals 4 kHz (380 V to 480 V) or 2.5 kHz (500 V to 600 V). The maximum output frequency is limited to 150 Hz.
- Permissible pulse frequency with sine-wave filter (external supplier):
The pulse frequency and maximum output frequency must be set according to the filter manufacturer's instructions.

Output power ratings of SINAMICS converters and inverters / Definition of the output power

SINAMICS converters produce an electrical three-phase system at their output, the power of which – taking into consideration factor $\sqrt{3}$ – can be calculated from the output voltage and the output current, whereby any phase angle can exist between output voltage and output current, depending on the load characteristics. Therefore electrical output power, for which the converter's output is designed, presents an apparent power as a result of the existing phase angle. This apparent power can be calculated from the obtainable output voltage and the permanent permissible thermal output current, which is the rated output current I_{rated} . When it is taken into consideration that SINAMICS converters in the vector control mode reach at the output almost the value of the incoming supply voltage by using pulse-edge modulation, the apparent output power of the converter can be calculated using the following formula:

$$S_{rated} = \sqrt{3} \cdot V_{line} \cdot I_{rated}$$

This apparent output power of the converter is a physically correct value, but it is not really suitable to allow a simple correlation between the converter output power and the rated motor power as the apparent power of the converter (given in kVA) and the mechanical shaft power (rated power) of the motor (given in kW) do not directly correspond because current, power factor and efficiency of the motor are required.

A much simpler option for the coordination of the output power of the converter and the rated power of the motor is the definition of an active output power for the converter, which is deduced from the mechanical shaft power (rated power) of a typical three-phase asynchronous motor which can be operated by the converter.

Definition of the output power for SINAMICS converters and inverters

The active output power of a SINAMICS converter or inverter is defined as the mechanical shaft power (rated power) of a typical, 6-pole, asynchronous motor, which can be operated by the converter or inverter at its rated point, without overloading the converter or inverter. As 2 and 4-pole motors always have a better power factor and also equal or lower rated currents, all 2, 4 and 6-pole motors are covered by the definition of the output power given above with regard to the coordination of the power between converter and motor.

In the SINAMICS catalogs and operating instructions (equipment manuals), usually several values for the output power of the converters or inverters are given:

- Output power on the basis of the base load current I_L for low overloads
- Output power on the basis of the base load current I_H for high overloads

Each value for the output power of converters and inverters applies to motors with rated voltages of 400 V, 500 V or 690 V as well as a rated frequency of 50 Hz. (The definition of the standard load duty cycles – low overload and high overload – and the definition of the corresponding base load currents I_L and I_H is given in the section "Load duty cycles"). It is particularly important with SINAMICS S120 and S150 units with the wide input voltage range of 500 V - 690 V 3AC that the values for the output power of these units are depending on the voltage. Therefore they are significantly different for 500 V and 690 V.

The following example should clearly illustrate how the output power for a SINAMICS converter is determined:

Converter data:

Line supply voltage	380 V – 480 V
Rated output current	605 A
Base load current I_L for low overload	590 A
Base load current I_H for high overload	460 A

Rated power and rated current for cataloged asynchronous motors in the 1LA8 range, for operation at 400 V / 50 Hz:

Number of poles p	200 kW	250 kW	315 kW	355 kW	400kW
2	-	-	520 A	590 A	660 A
4	-	430 A	540 A	610 A	690 A
6	345 A	430 A	540 A	-	690 A

Fundamental Principles and System Description

Engineering Information

The output power of the above-mentioned converter for low overload, on the basis of the base load current I_L at 400 V 3AC/50 Hz, is defined as the rated power of the largest, 6-pole asynchronous motor for 400V/50 Hz operation, the rated current of which does not exceed the base load current $I_L = 590$ A of the converter. According to this definition the converter has the output power of 315 kW at 400 V on the basis of I_L .

The output power of the converter, which, as the rated power of the motor, is given in kW, offers the possibility of a very simple and safe coordination between the power of the converter and the motor, without having to take into consideration other details such as current, power factor and efficiency. If the output power of the converter is chosen at least as big as the rated power of the motor, it is always safe to operate 2, 4 and 6-pole motors at full load with the selected converter.

It can, however, be noted that, in some cases, motors with a low number of poles (2 or 4), whose rated power is larger than the output power of the converter, can be operated at their rated point without overloading the converter. In the above-mentioned example this is the case for the 2-pole motor with a rated current of 590 A and a rated power of 355 kW.

Therefore on the one hand, the output power of the converter offers an extremely simple and safe way of coordinating the power of a converter and a motor. On the other hand, however, this coordination can lead to an overdimensioning of the converter in combination with motors with a low number of poles. If you want to achieve optimum coordination between the converter and the motor, you must choose the more complicated method involving the currents.

Supply systems and supply system types

General

The low-voltage products in the SINAMICS series with line supply voltages of ≤ 690 V are normally connected to industrial supply systems that are supplied from the medium-voltage distribution system via transformers. In rare cases, however, these devices may be directly connected to the public low-voltage supply systems or to separate supply systems, such as those supplied by diesel-electric generators.

According to IEC 60364-3 supply systems are classified as either TN, TT or IT systems depending on the type of arrangement of the live parts, the exposed-conductive parts and the grounding method. The classifications and letters are explained in brief below.

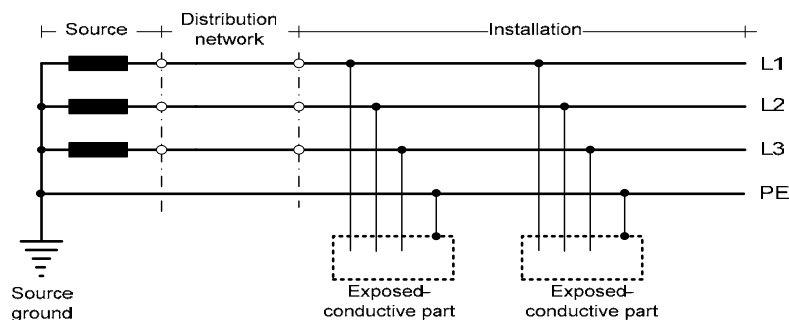
First letter: Relationship of the supply system to ground:

- T = Direct connection of one point to ground.
- I = All live parts isolated from ground, or one point connected to ground through an impedance.

Second letter: Relationship of the exposed-conductive parts (enclosures) of the installation to ground:

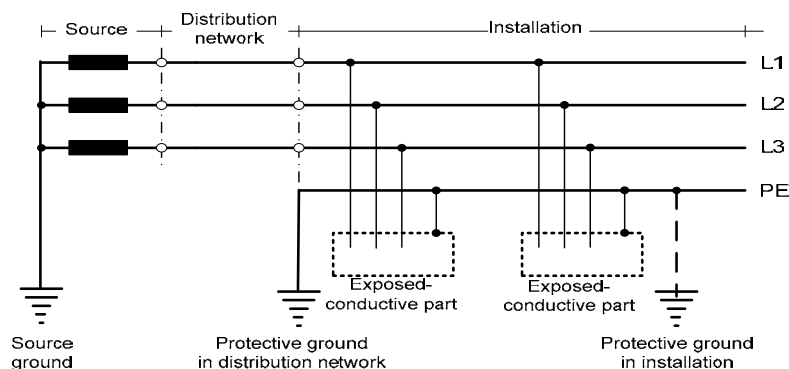
- T = Direct electrical connection of the exposed-conductive parts (enclosures) to ground, independent of whether one point of the supply system is already grounded.
- N = Direct electrical connection of the exposed-conductive parts (enclosures) to the grounded point of the supply system (the grounded point of the supply system is generally the star point in three-phase systems, or one of the three phases if the system has no star point).

In TN systems, one point is directly grounded and the exposed-conductive parts (enclosures) of the electrical installation are connected to the same point via a protective conductor (protective earth PE).



Example of a TN supply system

In TT systems, one point is directly grounded and the exposed-conductive parts (enclosures) of the installation are connected to ground electrodes which are electrically independent of the ground electrodes of the supply system.

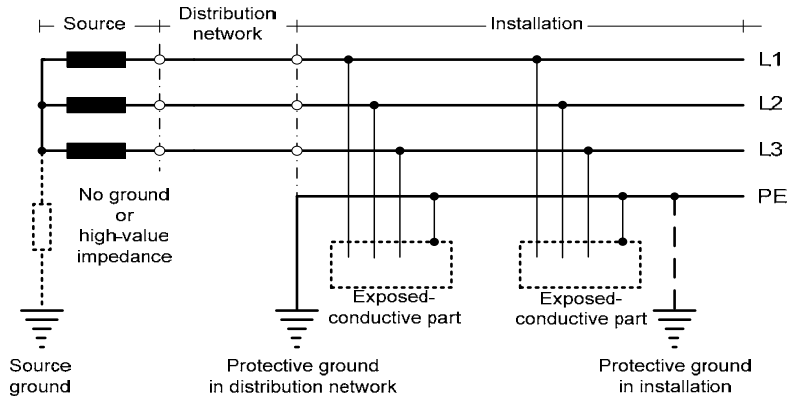


Example of a TT supply system

Fundamental Principles and System Description

Engineering Information

In IT systems, all live parts are isolated from ground, or one point is connected to ground through a high-value impedance. All the exposed-conductive parts (enclosures) in the electrical installation are connected to an independent ground electrode, either separately or in a group.



Example of an IT supply system

Connection of converters to grounded systems (TN or TT)

SINAMICS converters are designed for connection to grounded TN or TT systems, i.e. three-phase supply systems with a grounded star point. The devices are equipped with means of connecting the three phase conductors L1, L2, L3 and the protective conductor (PE) to ground. No connection for a separate neutral conductor (N) is provided, nor is one necessary as the converters place a symmetrical load on the three-phase system and the star point is not therefore loaded.

If a single-phase AC voltage, e.g. 230 V, is required to supply auxiliaries or the fan, this is supplied internally via single-phase control-power transformers that are connected between two phase conductors. Alternatively, it can be supplied from an external source.

It is not essential to install an earth-leakage monitor at the converter input. However, suitable precautions must be taken to ensure that the substantial ground-fault current caused by ground faults in the device is promptly interrupted. On SINAMICS G150 and S150 cabinets and S120 Cabinet Modules, this protection can be provided by optional line fuses or, at higher current ratings, by optional circuit breakers in the converters themselves. The type 3NE1 fuses recommended for this purpose are dual-function fuses which provide both line protection as well as semiconductor protection for the thyristors and diodes in the rectifiers of G150 and S120 Basic Infeeds. In systems using S120 Smart Infeeds and S120 Active Infeeds and in S150 cabinets containing IGBT rectifiers, semiconductor protection cannot be provided by fuses of any type due to the extremely low I^2t values of the IGBT chips. Type 3NE1 fuses, however, considerably restrict the extent of damage if a rectifier has a serious fault.

Ground faults in the motor cable at the output side or in the motor itself can be detected by the electronic ground fault monitor implemented in the inverter. The response threshold of this monitor can be parameterized to values higher than about 10 % of the rated output current.

SINAMICS units for operation in grounded TN and TT systems are equipped as standard with RFI suppression filters for the "second environment" (category C3 according to the EMC product standard EN 61800-3). This applies to SINAMICS G150 and S150 cabinets, to SINAMICS G130 Chassis and to the Infeeds (Basic Infeeds, Smart Infeeds and Active Infeeds) of the S120 modular system (Chassis and Cabinet Modules). For more information about RFI suppression, please refer to the section "Line filters" or to the chapter "EMC Installation Guideline".

Connection of converters to non-grounded systems (IT)

SINAMICS converters can also be connected to and operated on non-grounded IT supply systems. The advantage of IT systems as compared to grounded supply systems is that no ground-fault current can flow when a ground fault occurs and operation can therefore be maintained. The system does not shut down on faults until a second ground fault occurs. This advantage means that IT supply systems are widely used in areas where fault tripping needs to be reduced to a minimum due to the processes being carried out (e.g. in the chemical, steel, and paper industry).

An initial ground fault, however, must be detected and eliminated promptly for two reasons. First, a second ground fault occurring will lead to a short circuit current and therefore to a fault tripping and, in turn, to an interruption in operation. Second, a phase conductor or pole of the DC link in the converter is grounded when a ground fault occurs, which leads to a 1.73 to 2.0 times higher operational voltage load on the converter and motor insulation at the conductors that are not affected. In the short term, this increased voltage load does not have a critical effect on the converter and motor but, over extended periods of operation (more than 24 hours), it can reduce the lifetime of the motor winding. As a result, ground fault detection by means of an insulation monitor is crucial.

Ground faults can be detected at a central location in the IT supply system or in the SINAMICS converter itself. Insulation monitors such as those supplied by Bender have proven to be suitable and successful. Insulation monitors are available as option L87 for G150 and S150 cabinets and for S120 Line Connection Modules.

A common drive configuration that is operated as a non-grounded IT supply system is a 12-pulse drive, which is supplied by a three-winding transformer. This transformer has one secondary winding with a star connection and another with a delta connection. Since the delta-connected winding does not have a star point that can be properly grounded, 12-pulse drives are operated with two non-grounded secondary windings i.e. as an IT supply system. For this reason, 12-pulse-operated converters such as 12-pulse-operated SINAMICS G150 parallel converters must be equipped with option L87/insulation monitor.

When installing or commissioning SINAMICS devices in an IT supply system, the grounding connection for the RFI suppression filters found as standard in SINAMICS devices and designed for the "second environment" (category C3 in accordance with the EMC product standard EN 61800-3) must be opened. This can be done simply by removing a metal clip on the filter as described in the operating instructions. If this is not done, the capacitors of the suppression filters will be overloaded and possibly destroyed by a ground fault at the motor side. When the grounding connection for the standard RFI suppression filter has been removed, the devices meet category C4 in accordance with the EMC product standard EN 61800-3. For more information, refer to the chapter "EMC Installation Guideline".

The lack of ground connection in IT supply systems means that the line voltage can theoretically drift by any amount from ground potential, so that surge voltages to ground of infinite magnitude would be possible. This is fortunately not the case in practice as the line voltage is coupled capacitively to ground by the capacitance of the transformer winding and line feeder cables. This capacitive ground connection ensures that the neutral of the non-grounded system is practically at ground potential in normal, symmetrical three-phase operation and that voltages to ground are very similar to those in TN systems.

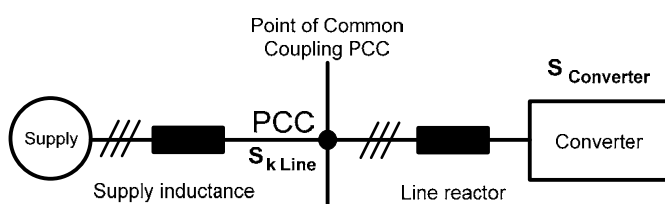
In the event of a ground fault (in particular, when a ground fault occurs at the converter DC link or motor), however, an operational voltage with respect to ground that is 1.73 to 2.0 times higher than in the TN system develops in the IT system. Under these conditions, therefore, the drive system will no longer have any large reserves with respect to insulation. For this reason, transient overvoltages injected into the system from an external source (e.g. due to switching operations in the medium-voltage power supply or by lightning strikes) are deemed to be more critical in this situation than during normal operation. Even in large-scale systems equipped with several converters in the medium to high output power range, a risk of transient overvoltages with respect to ground exists, which can damage the devices.

For this reason, we strongly recommend the installation of surge arresters to ground in IT supply systems. A surge arrester must be connected between each phase and ground and located, where possible, directly at the Infeed transformer. Suitable surge arresters are available from suppliers such as Dehn.

Connection of converters to supply systems with different short-circuit powers

Definition of relative short-circuit power RSC

The relative short-circuit power RSC (**R**elative **S**hort-Circuit power) at the point of common coupling (**P**oint of **C**ommon **C**oupling) is defined as the ratio between the short-circuit power $S_{K \text{ line}}$ at the PCC and the apparent power $S_{\text{Converter}}$ of the connected converter(s).



Fundamental Principles and System Description

Engineering Information

Supply systems with high relative short-circuit power $RSC > 50$ (strong systems)

Relative short-circuit powers of $RSC > 50$ always require the installation of line reactors for 6-pulse rectifier circuits (G130, G150, S120 Basic Line Modules and S120 Smart Line Modules). These limit the line-side current harmonics and protect the converter (rectifier and DC link capacitors) against thermal overloading. In the case of 6-pulse rectifier circuits equipped with Line Harmonics Filters LHF and Active Infeeds (S150, S120 Active Line Modules), no special conditions need to be observed.

Supply systems with medium relative short-circuit power $15 \leq RSC \leq 50$

Supply systems with medium-level, relative short-circuit power in the $15 \leq RSC \leq 50$ range do not generally necessitate any special measures. Depending on the converter output rating, it might be necessary to install line reactors where 6-pulse rectifier circuits are used. In the case of 6-pulse rectifier circuits equipped with Line Harmonics Filters LHF and Active Infeeds (S150, S120 Active Line Modules), no special conditions need to be observed.

Supply systems with low relative short-circuit power $RSC < 15$ (weak systems)

If SINAMICS converters are connected to supply systems with a low, relative short circuit power $RSC < 15$, it must be noted that not only the supply system perturbation, i.e. the voltage harmonics in the line voltage, is increasing but also other undesirable side-effects may occur.

If the RSC value drops to below 10 with a 6-pulse rectifier circuit, the voltage harmonics can reach critical levels. The permissible harmonic limits specified in the standards are exceeded and reliable operation of the converter and other equipment connected at the PCC can no longer be guaranteed. For additional information, please refer to "Standards and permissible harmonics" in the section "Harmonic effects on supply system".

If the RSC value drops to below 10 with a 6-pulse rectifier circuit including a Line Harmonics Filter, the detuning of the Line Harmonics Filter caused by the high impedance of the supply system will lead to a considerable increase of the fundamental wave of the line voltage. This can reach values beyond the permissible line voltage tolerance of the converter, which means that the system can no longer function properly.

Restrictions also apply in the case of Active Infeeds. With RSC values of < 15 , the dynamic control response is impaired and the voltage harmonics at pulse frequency in the line voltage start to rise significantly. With RSC values of < 10 , there is the same risk as with 6-pulse rectifier circuits that the converter and other equipment connected at the PCC will no longer operate reliably.

Relative short-circuit power values of $RSC < 10$ can be encountered, for example, when converters are supplied by transformers of the correct rating that have high relative short-circuit voltages of $u_k > 10\%$. RSC values of < 10 are generally also encountered when converters are operated on separate supply systems which are supplied by diesel-electric generators of the correct rating. In such cases, the power supply conditions must be analyzed precisely. It is often necessary to consider overdimensioning the transformers or generators in order to reduce voltage harmonics. When Infeeds with regenerative capability (Smart Infeeds or Active Infeeds) are supplied by diesel-electric generators, the appropriate parameters should be set to prevent the system from operating in generator mode.

An extremely weak supply system would be, for example a very low-output laboratory or test bay supply on which a high-powered, variable-speed drive needs to be tested.

If the drive were operated under no load, there could be no objection to this type of constellation. Very little active power is required under no load condition and the supply system would not be overloaded in terms of power drawn.

If a converter comprises a 6-pulse rectifier without Line Harmonics Filter on the line side (SINAMICS G130, G150 and S120 Basic Line Modules or S120 Smart Line Modules), the supply system perturbation is on an acceptable level due to the low line current, which makes this configuration suitable for testing purposes. Although 6-pulse drives with Line Harmonics Filters have no problems regarding harmonics, there is still a risk as described above that the fundamental wave of the line voltage will increase due to the detuning of the filter, which means that the system can no longer function properly.

If powerful drives with Active Infeeds are to be tested (SINAMICS S150 or drives with S120 Active Line Modules), an arrangement of this type is critical with respect to voltage harmonics. The harmonics at the line side which are normally kept very low by the Clean Power Filter can cause such distortions in the line voltage, even under no load conditions, due to the high impedance of the weak supply system that the closed-loop control of the Active Infeed can start to malfunction. In such cases, the system cannot operate properly, even if the Active Infeed closed-loop control has been optimally parameterized.

Supply voltage variations and supply voltage dips

General

The voltage of the power supply systems is usually not constant but rather susceptible to noticeable changes, as a result of load variations, switching operations and individual occurrences, such as short circuits. The connected SINAMICS units are inevitably affected by these changes and show different reactions to them, depending on the magnitude and duration as well as on the operating conditions of the drive. These reactions range from entirely unaffected operation over operation with certain restrictions to the complete drive shut-down.

The following paragraphs deal with the most important types of supply voltage changes, their causes, magnitude and duration. Afterwards the behaviour of SINAMICS units during supply voltage variations and supply voltage dips will be explained.

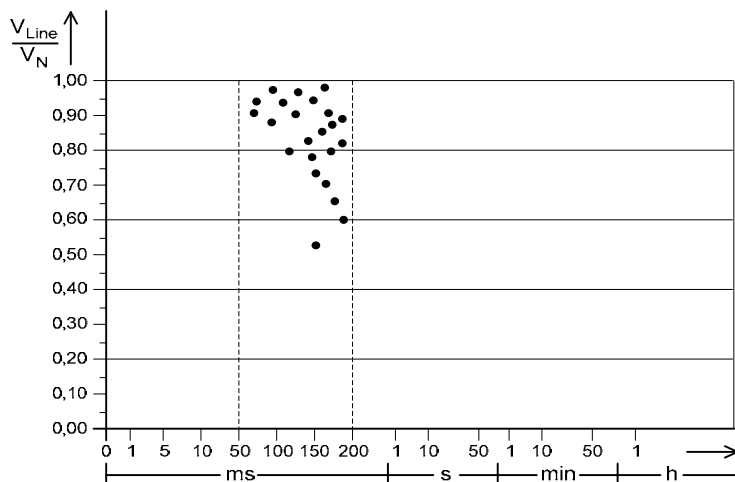
Supply voltage variations are relatively slow, long-term increases or decreases of the RMS value (root mean square value) of the supply voltage, which usually occur as a result of load variations in the power supply system, the switching of the transformer tap changers and other operational adjustments in the power supply system. According to EN 61000-2-4, it is possible, in European interconnected supply systems, to assume the following typical variations in the nominal supply voltage V_N :

- $0.9 \cdot V_N \leq V_{Line} \leq 1.1 \cdot V_N$ (permanent)
- $0.85 \cdot V_N \leq V_{Line} \leq 0.9 \cdot V_N$ (short-term, i.e. < 1 min)

Supply voltage dips are characterized by a sudden decrease in the supply voltage, followed by a restoration shortly afterward. Supply voltage dips are usually associated with the emergence and disappearance of short-circuits or other very large current increases in the supply (e.g. the starting of relatively large motors directly at the supply with correspondingly high starting currents). Supply voltage dips vary quite a lot with regard to their depth and duration. The depth of a supply voltage dip depends on the location of the short circuit and the current increase. If this occurs close to the unit's connection point, the dip will be large, if it occurs far away from the connection point, it will be small. The duration of the dip depends, when short circuits occur in the supply system, how quickly the protection device, such as fuses or circuit breakers, respond and clear the short circuit. In European interconnected supply systems, it is possible, according to EN 50160, to assume the following approximate values for supply voltage dips:

$$0.01 \cdot V_N \leq V_{Line} \leq V_N \text{ (very short-term, i.e. 10 ms to approx. 1 s)}$$

The following diagram shows supply voltage dips in a typical, European interconnected supply system over a time period of two months. The supply voltage dips are in the range of $0.5 \cdot V_N \leq V_{Line} \leq V_N$ with a duration of between 50 ms and 200 ms, whereby very large dips occur very seldom.



Supply voltage dips in a typical European interconnected supply system

Outside Europe, larger and longer supply voltage dips can occur more frequently, particularly in states with fewer closely connected power supply systems, such as those in the USA, Russia, China or Australia. Here supply voltage dips which last a second or longer must be expected.

Fundamental Principles and System Description

Engineering Information

Behaviour of SINAMICS converters during supply voltage variations and dips

Supply voltage ranges

SINAMICS units are dimensioned for relatively wide supply voltage ranges, whereby each range covers several of the worldwide nominal supply voltages V_N .

The converter chassis units SINAMICS G130 and the converter cabinet units SINAMICS G150 are available in three supply voltage ranges. The components of the modular system SINAMICS S120 (Chassis and Cabinet Modules) as well as converter cabinet units SINAMICS S150 are available in two supply voltage ranges. The supply voltage range of the units has to be selected so that the on-site nominal supply voltage V_N is within the permissible supply voltage range.

SINAMICS unit	Permissible nominal supply voltage range V_N	
SINAMICS G: G130 / G150	$380 \text{ V} \leq V_N \leq 480 \text{ V}$	3AC
	$500 \text{ V} \leq V_N \leq 600 \text{ V}$	3AC
	$660 \text{ V} \leq V_N \leq 690 \text{ V}$	3AC
SINAMICS S: S120 (Chassis and Cabinet Modules) and S150	$380 \text{ V} \leq V_N \leq 480 \text{ V}$	3AC
	$500 \text{ V} \leq V_N \leq 690 \text{ V}$	3AC

Supply voltage ranges for SINAMICS G130, G150, S120 (Chassis and Cabinet Modules) and S150

During commissioning, the units must be set up to the on-site available nominal supply voltage V_N :

- Hardware set-up: Adaptation of the line-side transformer tap for the internal supply of auxiliaries with 230 V and adaptation of the line-side transformer tap for the supply of the fans with 230 V.
- Firmware set-up: Adaptation of parameter P0210 / Supply voltage

These settings are absolutely essential, in order that the units behave optimally during supply voltage variations. On the one hand, they ensure that the units are as insusceptible as possible to supply voltage variations and that unnecessary fault trips are avoided. On the other hand, they also ensure that the units react to unacceptably large supply voltage changes with prompt fault trips, thus avoiding any damage being incurred to the units.

The hardware settings also guarantee a sufficient level for the 230 V produced by the transformers for the auxiliaries and the fans at lower supply voltage and prevent the overloading of the 230 V auxiliaries when the supply voltage is increased.

The firmware settings ensure an optimal adaptation of the under and over-voltage trip levels of the DC link voltage. For all further considerations, it is assumed that the units are set-up correctly in terms of hardware and firmware, according to the on-site available nominal supply voltage V_N .

Permanent permissible supply voltage variations

Continuous operation of SINAMICS units is permissible in the following range of the nominal supply voltage:

$$0.9 \cdot V_N \leq V_{\text{Line}} \leq 1.1 \cdot V_N$$

In this supply voltage range, all the auxiliaries supplied with 230 V by the internal transformer operate within their permissible limits and also the fans supplied with 230 V by an internal transformer are able to fully provide the cooling air flow required by the power components within the limits of the permissible frequency tolerances. The DC link voltage has a wide safety margin to the under and over-voltage trip level regardless of whether a regulated rectifier (Active Infeed) or unregulated rectifier (Basic Infeed or Smart Infeed) is used.

At higher supply voltage of $V_N \leq V_{Line} \leq 1.1 \cdot V_N$ no restrictions in the operational behaviour of the drive need to be taken into consideration.

At lower supply voltage of $0.9 \cdot V_N \leq V_{Line} \leq V_N$ it must be taken into consideration that the drive power decreases in proportion to the supply voltage. If a power reduction cannot be tolerated, converter and motor must have current reserves, in order to compensate for the lower supply voltage with an increased current input. This may make the over-dimensioning of the drive necessary.

Short-term permissible supply voltage variations (< 1 min)

Short-term operation (i.e. up to 1 min) of SINAMICS units is permissible within the following range of the nominal supply voltage:

$$0.85 \cdot V_N \leq V_{Line} \leq 0.9 \cdot V_N$$

In this range all the auxiliaries supplied with 230 V by the internal transformer still operate within their permissible limits, but the fans also supplied with 230 V by an internal transformer can no longer, within the range of permissible frequency tolerances, fully provide the cooling air flow required by the power components. As a result of this reduced cooling capacity, operation must be limited to a time period of < 1 min. The DC link voltage still has a wide safety margin to the under and over-voltage trip level regardless of whether a regulated rectifier (Active Infeed) or unregulated rectifier (Basic Infeed or Smart Infeed) is used.

In this short-term, permissible supply voltage range, it must also be taken into consideration that the drive power decreases in proportion to the supply voltage. If a power reduction cannot be tolerated, the converter and motor must have current reserves in order to compensate for the reduced supply voltage with a higher current input. This may mean that the drive has to be over-dimensioned.

Permissible supply voltage dips

On the following pages, dips which do not cause fault tripping of the drive will be termed permissible supply voltage dips. So that no fault trip occurs, two conditions must be fulfilled:

- All auxiliaries in the converter, which are supplied with 230 V – with the exception of the fans – and also the electronics supplied with 24 V DC, must remain in operation, and
- The DC link voltage must not reach the under-voltage trip level.

Whether these conditions can be fulfilled during supply voltage dips depends on a lot of factors. These factors are:

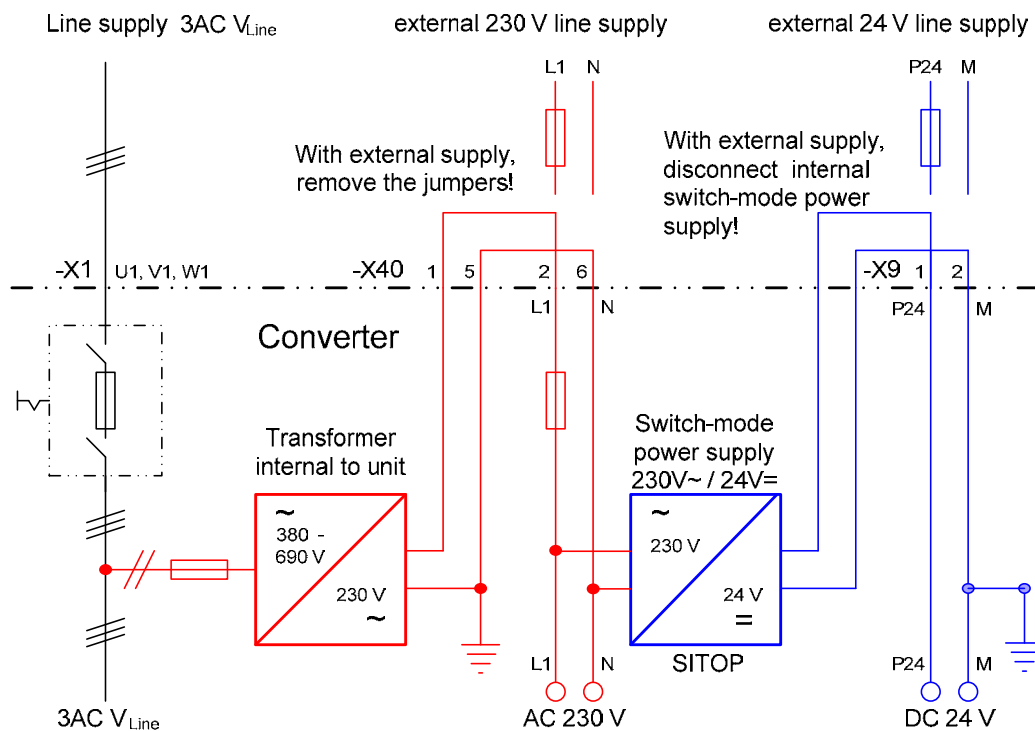
- The supply of auxiliaries with 230 V and the supply of the electronics with 24 V DC (directly from the power supply, via the internal transformer or from a secure, external supply e.g. an uninterruptible power supply)
- The type of the SINAMICS Infeed (regulated or unregulated)
- The load condition of the drive (full load, partial load or no-load)
- The depth of the supply voltage dip
- The duration of the supply voltage dip

The supply for the auxiliaries with 230 V AC and for the electronics with 24 V DC is produced in the cabinet units SINAMICS G150, S120 Cabinet Modules and S150 as a standard via built-in transformers internal to the units, which are supplied directly by the power supply voltage. Consequently, the supply voltage dips have an effect directly on the auxiliaries supplied with 230 V. If the supply voltage dips too much and over a too long time period, the auxiliaries (including the internal switch-mode power supply for the 24 V supply for the electronics) will fail. This leads to a fault trip.

If the voltage of the auxiliaries (230 V) and the electronics (24 V) should remain in operation even during large and long supply voltage dips, the voltage of 230 V must be supplied from a secure, external supply, such as an uninterruptible power supply (UPS). For that two jumpers must be removed inside the cabinet unit and the external 230 V supply must be connected as shown in the following diagram with the example of a G150 cabinet unit. Also the voltage of 24 V can be supplied from a secure, external supply by disconnecting the internal switch-mode power supply and replacing it by a secure, external supply.

Fundamental Principles and System Description

Engineering Information



Supply of the auxiliaries with 230 V AC and of the electronics with 24 V. Example with a SINAMICS G150 cabinet unit.

The type of the SINAMICS Infeed (rectifier) determines the relationship between the supply voltage and the DC link voltage. Further information on this can be found in the section "SINAMICS Infeeds (rectifiers) and their properties".

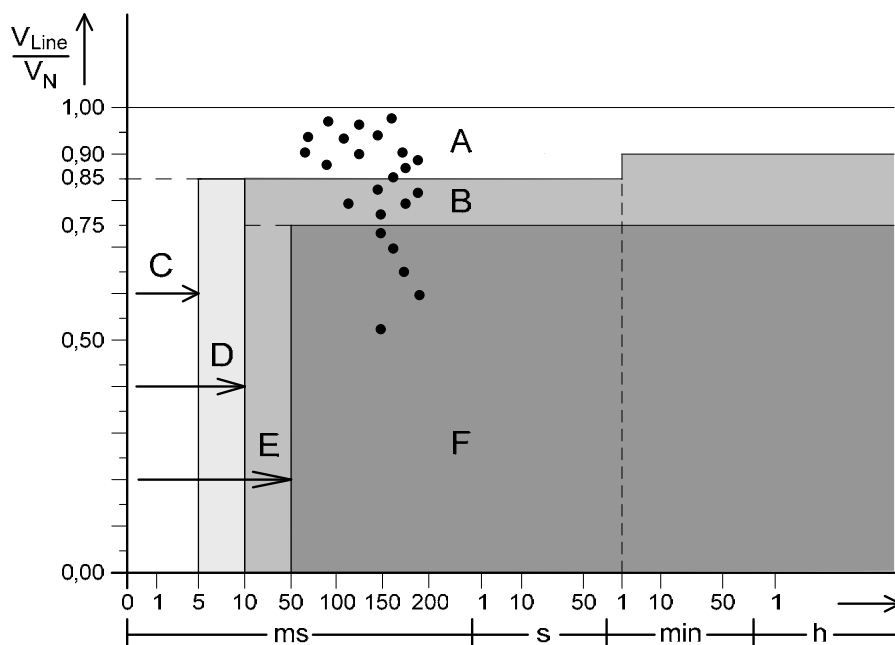
The line-commutated, unregulated Infeeds SINAMICS Basic Infeed and SINAMICS Smart Infeed generate a DC link voltage, which is at stationary operation in proportion to the supply voltage. If the supply voltage dips, the energy flow from the supply to the DC link is interrupted until the DC link voltage has, as a result of the load current, fallen to a voltage level which corresponds to the supply voltage which has dipped. If this voltage level is below the under-voltage trip level of the DC link, the energy flow from the supply to the DC link is completely interrupted. In this case the drive can only use the electrical energy stored in the DC link capacitors and can only continue to operate until the DC link voltage has dropped to the value of the under-voltage trip level by means of the load current on the motor side. This time span is in the range of a few milliseconds and depends on the load conditions of the drive. It decreases as the load increases so that at full load, only small supply voltage dips of a few milliseconds can be overcome without fault tripping.

The self-commutated, regulated Infeed, SINAMICS Active Infeed, operates as a step-up converter and can regulate the DC link voltage, almost independently of the supply voltage, to a constant value. As a result, the energy flow from the supply to the DC link can also be maintained during serious supply voltage dips. As long as the reduced power, as a result of the lower supply voltage, can be compensated for by a higher input current, the drive is able to overcome large and long supply voltage dips, without a fault trip.

The following pages will deal with the behaviour of the unregulated and regulated SINAMICS Infeeds in view of the above-mentioned considerations.

Permissible supply voltage dips with the unregulated SINAMICS Infeeds, Basic Infeed and Smart Infeed

In order to explain the behaviour of SINAMICS drives with line-commutated, unregulated Infeeds, all theoretically possible supply voltage dips with regard to magnitude and duration are divided into six different ranges, named A to F. In the following diagram, these ranges are shown for unregulated SINAMICS Infeeds, whereby each range corresponds to different boundary conditions and, therefore, to a different behaviour of the drive.



Division of all supply voltage dips according to magnitude and duration in the ranges A - F for the description of the behaviour of SINAMICS drives with unregulated Infeeds

Range A

Range A comprises supply voltage dips, the magnitude of which is in the long and short-term ranges of permissible supply voltage variations.

Dips in range A are, therefore, permissible, with the restriction that the DC link voltage and the drive power decrease in proportion to the magnitude of the supply voltage dips.

Range B

Range B comprises supply voltage dips, the magnitude of which reaches values of $V_{Line}/V_N \approx 0.75$. The DC link voltage which is in proportion to the supply voltage is still over the under-voltage trip level in the DC link but the auxiliaries which are supplied with 230 V by the internal transformer do not function any more after a few milliseconds.

Dips in range B are, therefore, only permissible when the supply of the auxiliaries with 230 V is done via a secure, external source. It must also be taken into consideration that the DC link voltage and the drive power decrease in proportion to the magnitude of the supply voltage dip.

Range C

Range C comprises very short supply voltage dips of any magnitude, the duration of which is up to 5 ms. During this time, the current required by the load is delivered entirely by the DC link capacitors, thus causing the DC link voltage to decrease. As a result of the extremely short duration of the dip, the DC link voltage still does not reach the under-voltage trip level, even at 100 % load. The auxiliaries supplied with 230 V also remain in operation.

Dips in range C are, therefore, as a result of the extremely short duration, permissible without restrictions.

Range D

Range D comprises very short supply voltage dips of any magnitude, the duration of which is up to 10 ms. During this time, the current required by the load is delivered entirely by the DC link capacitors, thus causing the DC link voltage to decrease. The DC link voltage then only does not reach the under-voltage trip level, if the DC link is discharged more slowly than in range C. Therefore, the drive can be operated with a maximum load of approx. 50 %. Due to the still relatively short duration, it can be assumed that the auxiliaries which are supplied with 230 V will remain in operation.

Dips in range D are, therefore, as a result of the very short duration, permissible, as long as the drive is operating at partial load with a maximum of 50 %.

Fundamental Principles and System Description

Engineering Information

Range E

Range E comprises short supply voltage dips of any magnitude, the duration of which is up to 50 ms. During this time, the current required by the load is delivered entirely by the DC link capacitors, whereby the DC link voltage decreases. The DC link voltage then only does not reach the under-voltage trip level, if the DC link is discharged more slowly than in range D. Therefore, the drive can only be operated with no load. The auxiliaries, which are supplied with 230 V directly from the supply via the internal transformer, do not remain in operation.

Dips in Range E are, therefore, only permissible if the auxiliaries are supplied from a secure, external supply and the drive is in no-load operation.

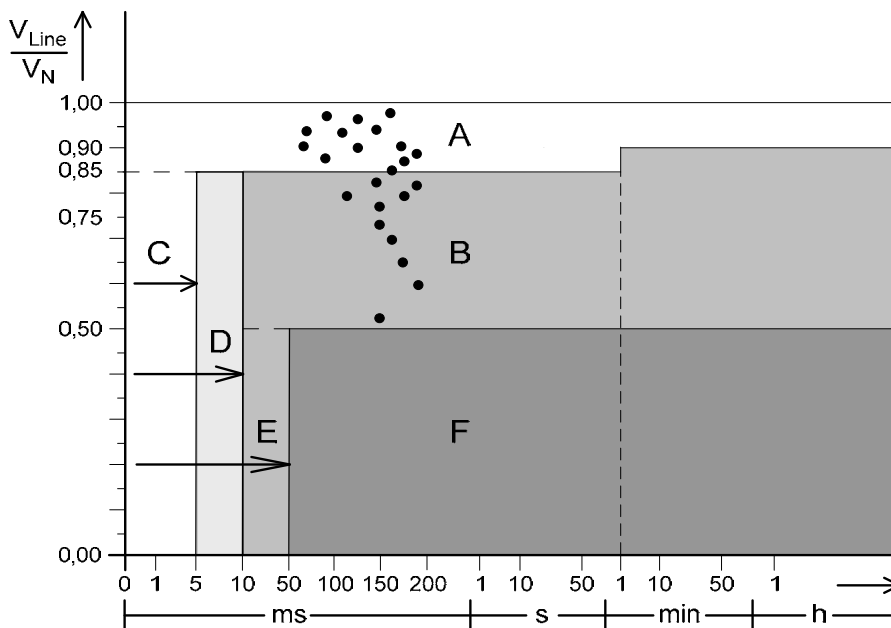
Range F

Range F comprises supply voltage dips, the magnitude and duration of which is so large, that, independently of the load, a fault trip due to under-voltage in the DC link cannot be avoided.

Dips in range F are, therefore, not permissible.

Permissible supply voltage dips with the regulated SINAMICS Active Infeed

In order to explain the behaviour of SINAMICS drives with self-commutated, regulated Infeeds, all theoretically possible supply voltage dips with regard to magnitude and duration are divided into six, different ranges, named A to F. In the following diagram, these ranges are shown for regulated SINAMICS Infeeds, whereby each range corresponds to different boundary conditions and, therefore, to a different behaviour of the drive.



Division of all supply voltage dips according to magnitude and duration in the ranges A to F for the description of the behaviour of SINAMICS drives with regulated Infeeds

Range A

Range A comprises supply voltage dips, the magnitude of which is in the long and short-term ranges of permissible supply voltage variations.

Dips in range A are, therefore, permissible, with the restriction that the DC link voltage and the drive power decrease in proportion to the magnitude of the supply voltage dips.

Range B

Range B comprises supply voltage dips, the magnitude of which reaches values of $V_{\text{Line}}/V_N \approx 0.5$. As a result of the regulated operation, the DC link voltage can be maintained at its pre-set value, as long as the reduced supply voltage can be compensated for with an increased input current. The auxiliaries supplied with 230 V via the internal transformer, do not, however, remain in operation.

Dips in range B are, therefore, only permissible when the supply of the auxiliaries with 230 V is done via a secure, external source. It must also be taken into consideration that the DC link voltage and the drive power decrease in proportion to the magnitude of the supply voltage dip.

Range C

Range C comprises very short supply voltage dips of any magnitude, the duration of which is up to 5 ms. During this time, the current required by the load is mainly delivered by the DC link capacitors, thus causing the DC link voltage to decrease. Due to the extremely short duration, the DC link voltage does not reach the under-voltage trip level, even at 100 % load. The auxiliaries supplied with 230 V also remain in operation.

Dips in range C are, therefore, as a result of the extremely short duration, permissible without restrictions.

Range D

Range D comprises very short supply voltage dips of any magnitude, the duration of which is up to 10 ms. During this time, the current required by the load is mainly delivered by the DC link capacitors, thus causing the DC link voltage to decrease. The DC link voltage then only does not reach the under-voltage trip level, if the DC link is discharged more slowly than in range C. Therefore, the drive can be operated with a maximum load of 50 %. Due to the relatively short duration, it can be assumed that the auxiliaries supplied with 230 V will remain in operation.

Dips in range D are, therefore, as a result of the very short duration, permissible, as long as the drive is operating at partial load with a maximum of 50 % load.

Range E

Range E comprises short supply voltage dips of any magnitude, the duration of which is up to 50 ms. During this time, the current required by the load is mainly delivered by the DC link capacitors, whereby the DC link voltage decreases. The DC link voltage then only does not reach the under-voltage trip level, if the DC link is discharged more slowly than in range D. Therefore, the drive can only be operated with no load. The auxiliaries, which are supplied with 230 V directly from the supply via the internal transformer, do not remain in operation.

Dips in Range E are, therefore, only permissible if the auxiliaries are supplied from a secure, external supply and the drive is in no-load operation.

Range F

Range F comprises supply voltage dips, the magnitude and duration of which is so large, that, independently of the load, a fault trip due to under-voltage in the DC link cannot be avoided.

Dips in range F are, therefore, not permissible.

Summary of the drive behaviour during supply voltage dips

If one considers the behaviour of the unregulated and regulated SINAMICS Infeeds and also reflects upon the typical distribution of supply voltage dips as shown in the diagram in the section "Supply voltage variations and supply voltage dips", the following conclusions can be drawn.

Extremely large dips as those in the ranges C to E, during which the supply voltage dips to almost zero and the energy flow from the supply to the DC link is essentially interrupted, can only be tolerated, independently from the kind of Infeed, for a time period of approximately 5 ms to a maximum of 50 ms, depending on the load condition, because the energy stored in the DC link capacitors is very low. However, dips of such magnitude and duration very rarely occur in practice.

Longer dips of more than 50 ms can only be tolerated if the energy flow from the supply to the DC link is maintained.

With the line-commutated, unregulated Infeeds, Basic Infeed and Smart Infeed, this is only the case if the supply voltage dips not lower than on values of approx. 75 % of the nominal supply voltage V_N (ranges A and B). Without an external auxiliary supply, 50 % of all typical supply voltage dips can be dealt with (range A), with an external auxiliary supply, this increases to 70 % (ranges A and B).

With the self-commutated, regulated Infeed, SINAMICS Active Infeed, the energy flow from the supply to the DC link is maintained even if the supply voltage dips to around 50 % of the nominal supply voltage (ranges A and B). Without an external auxiliary supply, 50 % of all typical supply voltage dips can be dealt with as in the case with unregulated Infeeds (range A). With an external auxiliary supply, however, this increases to almost 100 % (ranges A and B). Thus the regulated SINAMICS Active Infeed offers clear advantages in comparison with the unregulated Basic and Smart Infeed for supplies which often experience relatively large voltage dips.

Fundamental Principles and System Description

Engineering Information

Measures for the reduction of the effects of large and long supply voltage dips

Kinetic Buffering

Longer supply voltage dips of more than 50 ms and larger than 50 % of the nominal supply voltage V_N corresponding to range F can, due to the more or less interrupted energy flow from the supply to the DC link, be bridged without a fault trip only if the motor can provide energy to buffer the DC link. This is the case at drives with sufficiently large rotating masses. In such cases, the kinetic buffering function can be used. This function is included as a standard in the firmware of SINAMICS converters and inverters and can be activated by parametrization when required. During a supply voltage dip, the kinetic buffering function takes energy from the rotating masses for the buffering of the DC link and thus prevents a fault trip. After the supply voltage dip the rotating masses are accelerated again. This procedure can be used if sufficiently large rotating masses are available in order to buffer the supply voltage dip for a long enough time period and if the driven process can tolerate a reversal in the direction of energy flow during the supply voltage dip. With sufficiently large rotating masses, very large supply voltage dips and even supply voltage failures which last for several seconds can be bridged without a fault trip of the drive.

Automatic Re-Start in combination with Flying-Restart

At large and very long supply voltage dips in the range F, or at longer supply voltage failures, a fault trip is unavoidable. This trip can be accepted in many applications, as long as the drive is able to re-start again by its own after the voltage dip or voltage failure and as long as the drive is able to accelerate again to the original operating condition. For this, the automatic re-start function can be used. If a re-start after a supply voltage dip is expected with a rotating motor, the automatic re-start function must be combined with the flying re-start function. The flying re-start function recognizes direction and speed of the rotating motor even without speed encoder at the motor and starts the acceleration process beginning from the actual speed. The automatic re-start function and flying re-start function are included as a standard in the firmware of SINAMICS converters and inverters and can be activated by parametrization when required.

Permissible harmonics on the supply voltage

SINAMICS converters and the corresponding line-side system components (line reactors, Line Harmonics Filter and line filters) are designed for being connected to supplies with a permanent level of voltage harmonics, according to EN 61000-2-4, Class 3. In the short-term (< 15 s within a time period of 2.5 min) a level of 1.5 times the permanent level is permissible.

Harmonic Number h	Class 1 V_h %	Class 2 V_h %	Class 3 V_h %
5	3	6	8
7	3	5	7
11	3	3,5	5
13	3	3	4,5
17	2	2	4
$17 < h \leq 49$	$2.27 \times (17/h) - 0.27$	$2.27 \times (17/h) - 0.27$	$4.5 \times (17/h) - 0.5$

Compatibility level for harmonics, according to EN 61000-2-4
– harmonic contents of the voltage V, odd harmonics, no multiples of 3

	Class 1	Class 2	Class 3
Total Harmonic Distortion factor THD(V)	5 %	8 %	10 %

Compatibility levels for the Total Harmonic Distortion factor of the Voltage (THD)(V) according to EN 61000-2-4

That means that no voltage harmonics higher than those given in the table under Class 3 may appear at the connection point for SINAMICS units. This includes harmonics produced by the units themselves. This must be guaranteed by means of correct engineering. If necessary, Line Harmonics Filters, 12-pulse solutions or Active Infeeds may be used to stay within the limits of Class 3.

Otherwise, components in the converter itself or the corresponding line-side components may be thermally overloaded or error functions may occur in the converter.

Further information can be found in the section "Harmonic effects on the supply system", under the subsection "Standards and permissible harmonics".

Transformers

Unit transformers

Unit transformers supply only a single converter unit and are rated specifically for the power of the specific converter unit.

If a converter is supplied by a unit transformer, a line reactor does not generally need to be installed provided that the relative short circuit voltage u_k of the transformer is $\geq 4\%$

Exceptions:

- With S120 Smart Infeeds a line reactor is not required, only if the relative short circuit voltage u_k of the transformer is $\geq 8\%$.
- If converters with rectifiers connected in parallel are being used (high power output G150 with 2 power units connected in parallel or S120 Basic Infeeds / S120 Smart Infeeds with power units connected in parallel), line reactors are required to provide balanced current distribution in 6-pulse operation.

Calculation of apparent power S_T of a unit transformer

The required rated apparent power S_T can be calculated from the power balance of the drive:

$$S_T > k * \frac{P_W}{\lambda * \eta_{\text{Converter}} * \eta_{\text{Motor}}}$$

Key to equation:

- P_W Shaft output (continuous output) of the motor or rated output of the converter
- $\eta_{\text{Converter}}$ Efficiency of converter
- η_{Motor} Efficiency of motor
- λ Line power factor
- kFactor which allows for transformer stray losses as a result of line-side harmonic currents

The line power factor λ is obtained as follows:

$$\lambda = g_1 * \cos \varphi_1 = \frac{I_{(1)}}{I_{\text{eff}}} * \cos \varphi_1$$

Key to equation:

- g_1 Fundamental factor of current
- $\cos \varphi_1$ Line-side power factor of fundamental current

For outputs of > approx. 50 kW, i.e. the lowest converter rating for which unit transformers can be used, the following values are accurate approximations:

- $\eta_{\text{Converter}} \approx 0.98$ For G130, G150 converters and units with S120 Basic Infeeds or S120 Smart Infeeds
- $\eta_{\text{Converter}} \approx 0.96$ For S150 converters and units with S120 Active Infeeds
- $\eta_{\text{Motor}} = 0.93$ to 0.97 $\eta \approx 0.93$ for motor output of 50 kW rising to $\eta \approx 0.97$ for a motor output of 1MW
- $\lambda \approx 0.95$ For G130, G150 converters and S120 Basic Infeeds and S120 Smart Infeeds
- $\lambda = 1$ or $\lambda = \cos \varphi_{\text{AI}}$ For S150 converters and converters with Active Infeed:
 $\lambda = 1$ if $\cos \varphi_{\text{AI}} = 1$ is parameterized for the Active Infeed (factory setting),
 $\lambda = \cos \varphi_{\text{AI}}$ if $\cos \varphi_{\text{AI}} \neq 1$ is parameterized for the Active Infeed
- $k = 1.20$ For systems configured with a standard distribution transformer and G130 without LHF, G150 without LHF, S120 Basic Infeeds and S120 Smart Infeeds
- $k = 1.15$ For systems configured with a standard distribution transformer and G130 or G150 with Line Harmonics Filter LHF
- $k = 1.10$ For systems configured with a standard distribution transformer and S150 and S120 Active Infeeds
- $k = 1$ When a converter transformer is used irrespective of the converter type

Fundamental Principles and System Description

Engineering Information

On the basis of the formulas specified on the previous page and assuming that $\eta_{\text{Motor}} \approx 0.95$ is the typical mean value for the motor efficiency, the required rated apparent power S_T for the unit transformer is calculated as follows:

a) When a standard distribution transformer is used

$S_T > 1.40 \cdot P_W$	For G130 converters without LHF, G150 without LHF and for units with S120 Basic Infeeds and S120 Smart Infeeds
$S_T > 1.30 \cdot P_W$	For G130 or G150 converters with Line Harmonics Filters LHF
$S_T > 1.20 \cdot P_W / \cos \varphi_{AI}$	For S150 converters and units with S120 Active Infeeds

b) When a converter transformer is used:

$S_T > 1.15 \cdot P_W$	For G130 converters with/without LHF, G150 with/without LHF and for converters with S120 Basic Infeeds and S120 Smart Infeeds
$S_T > 1.1 \cdot P_W / \cos \varphi_{AI}$	For S150 converters and units with S120 Active Infeeds

The following output ratings are standardized for unit transformers:

100 160 250 315 400 500 630 800 1000 1250 1600 2000 2500 [kVA]

The no-load ratio must be specified on the transformer order. The no-load voltage on the low-voltage side is generally 5 % higher than the voltage under full load. If, for example, a transformer for 10 kV in the primary circuit and 690 V in the secondary circuit is required, then it must be ordered for a no-load ratio of 10 kV / 725 V.

The purpose of taps is to allow adjustment of the ratio to the actual line voltage. With a standard transformer, the high-voltage winding has tap points equaling ± 2.5 %. These HV-taps can be adjusted by means of reconnectable jumpers when the transformer is de-energized. Additional taps are available at extra cost on request.

Circuits and vector groups

The high-voltage and low-voltage windings of three-phase transformers can be star- or delta-connected. These connection types are identified by the letters specified below (capital letters: high-voltage side, small letters: low-voltage side):

- Y, y for star-connected windings
- D, d for delta-connected windings

In the vector group code for each transformer, these letters are followed by a digit. This states (in units of 30 degrees) the phase angle φ by which the voltages on the high-voltage side lead those on the low-voltage side. For example:

$$\varphi = n \cdot 30^\circ \quad \text{where } n = 1, 2, 3, \dots, 11.$$

The vector groups of standard distribution transformers are normally Dy5 or Yy0 on which the neutrals are not brought out.

Transformer types

Oil-immersed transformers or dry-type transformers (GEAFOL) are suitable to feed drive converters.

The oil-immersed transformer is generally cheaper to buy. However, in most cases, the transformer needs to be installed outdoors. This transformer type can be installed indoors only if it can be directly accessed from outside. Precautions must be taken to protect against fire and groundwater pollution. Although the transformer should ideally be sited at the central power distribution point, this is often not possible.

The procurement costs for a GEAFOL transformer are higher. Due to its design, i.e. without fluid or combustible insulating agents, it can be installed indoors and thus at the central power distribution point. It is often the most cost-effective transformer type in installations with a relatively high energy density owing to its low losses and the fact that no groundwater protection measures need be taken.

Transformers must be selected with a view to achieving the optimum cost effective solution for the entire plant, i.e. to reduce investment and operating costs to a minimum. The following factors need to be considered:

- Procurement costs of transformers
- Required measures at installation site
- Operating costs incurred by losses, particularly in the distribution system

Features of standard transformers and converter transformers

Converter transformers are specially designed for use with converters. They are specially built to withstand the increased stresses associated with converter operation.

Differences between converter transformers and standard distribution transformers

- The windings of converter transformers are designed with increased insulation strength. This makes them capable of withstanding the extreme voltage surges which can occur during converter commutation.
- The laminated core and winding are specially constructed, e.g. with small radial conductor depth on GEAFOL transformers, so as to minimize stray losses caused by current harmonics.
- The transformers are mechanically designed to achieve low short-circuit forces on the one hand, and high short-circuit strength on the other. The high thermal capacity of the transformers means that they are easily capable of withstanding frequent surge loads up to 2.5 times rated output, such as those typical of main drives in rolling mill applications.
- A pulse imbalance in the converter (e.g. caused by an interrupted firing pulse to a thyristor in the rectifier under full power draw and the ensuing DC components in the line current) can cause damage to the core and laminated moldings on GEAFOL transformers as a result of overheating. Monitoring the temperature of the tie-rod inside the core is an effective method of eliminating this problem and does not damage the transformer.

It is evident from this description of the features of converter transformers that they are designed for relatively extreme operating conditions of a kind not generally encountered with SINAMICS drives. For standard applications where the transformer power is adjusted to suit the converter rated output, it is therefore permissible, even in the case of unit transformers, to use normal distribution transformers instead of converter transformers.

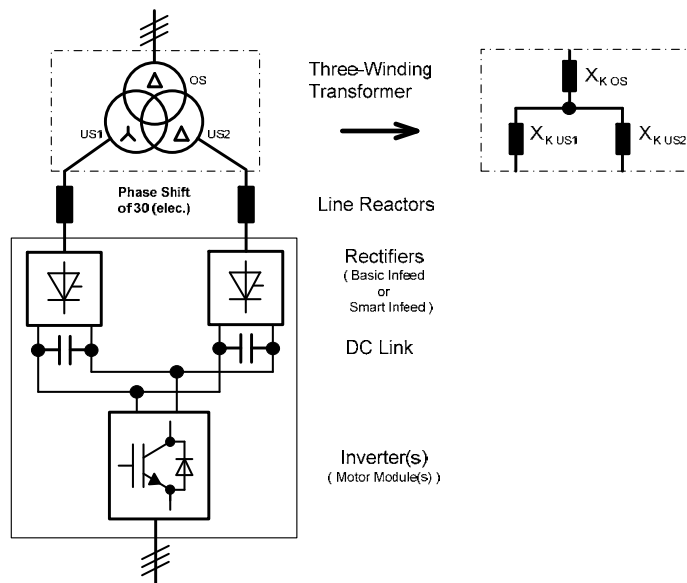
Fundamental Principles and System Description

Engineering Information

Three-winding transformers

Minimization of harmonic effects on the supply system is a frequent requirement associated with the operation of high-power-output, variable-speed three-phase drive systems. This requirement can be met at relatively low cost through a 12-pulse supply Infeed, particularly in cases where a new Infeed transformer needs to be installed anyway. In such cases, a three-winding transformer must be selected. Three-winding transformers are basically designed as converter transformers.

The basic operating principle of the 12-pulse Infeed is explained in section "Harmonic currents of 12-pulse rectifier circuits". The following description therefore focuses solely on the requisite properties of three-winding transformers used in conjunction with 12-pulse Infeeds, or on the standards to be satisfied by these transformers where they are used to supply SINAMICS converters.



Principle of the 12-pulse supply

Requirements of three-winding transformers for 12-pulse operation with SINAMICS

To achieve an optimum 12-pulse effect, i.e. the most effective possible elimination of current harmonics of the orders $h = 5, 7, 17, 19, 29, 31, \dots$ on the high-voltage side of the transformer, the three-winding transformer design must be as symmetrical as possible and suitable measures must also be taken to ensure that both of the low-voltage windings are evenly loaded by the two 6-pulse rectifiers. Even current distribution is achieved by voltage drops (predominantly resistive) at:

- the secondary windings of the transformer
- the feeder cables between the transformer and rectifiers,
- the rectifier line reactors.

The requirements of the three-winding transformer, the feeder cable and the rectifier line reactors are therefore as follows:

- Three-winding transformer must be symmetrical, recommended vector groups Dy5d0 or Dy11d0.
- Relative short-circuit voltage of three-winding transformer $u_k \geq 4\%$.
- Difference between relative short-circuit voltages of secondary windings $\Delta u_k \leq 5\%$.
- Difference between no-load voltages of secondary windings $\Delta V \leq 0.5\%$.
- Identical feeder cables, i.e. same type, same cross-section and same length.
- Use of line (commutating) reactors to improve current symmetry if applicable.

Generally speaking, double-tier transformers are the only transformer type capable of fully satisfying the requirements specified above of three-winding transformers for 12-pulse operation with SINAMICS.

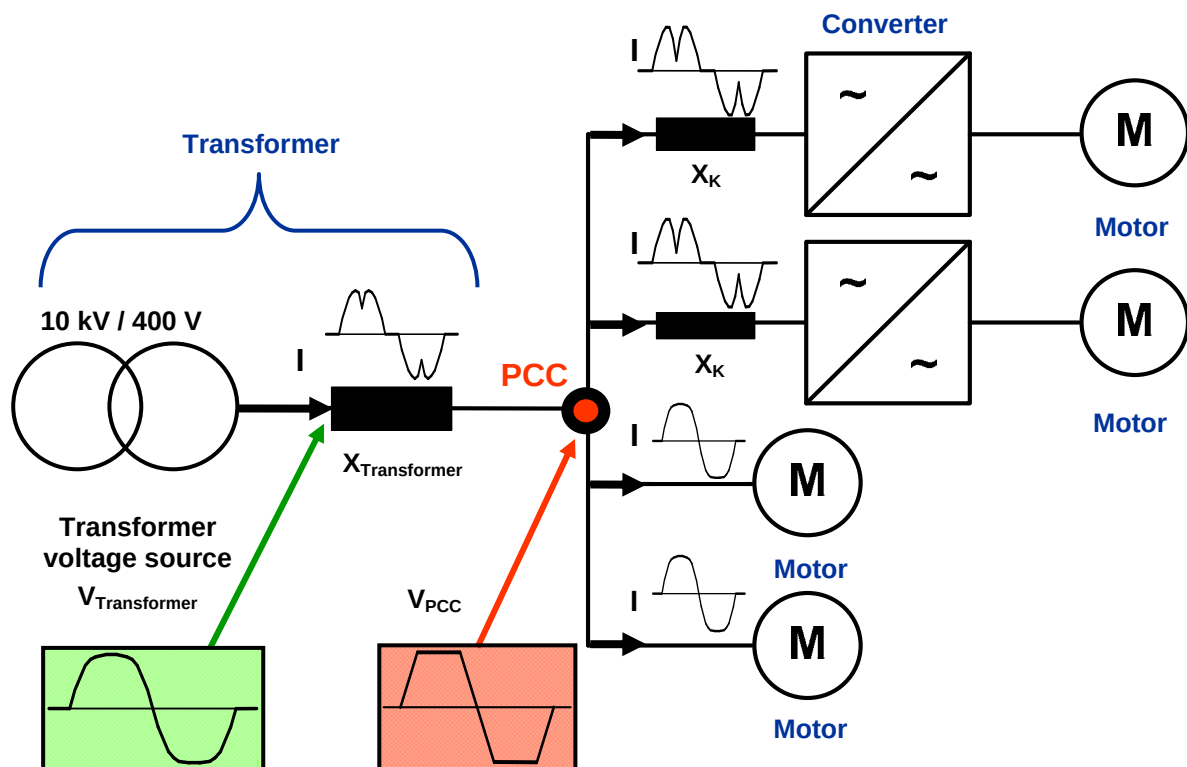
Harmonic effects on the supply system

General

The analysis presented in this section refers exclusively to low-frequency harmonic effects in the frequency range up to 9 kHz. It does not take into account high-frequency harmonic effects as they relate to EMC (Electro-magnetic Compatibility) or radio frequency interference suppression. These high-frequency harmonic effects in the frequency range from 150 kHz to 30 MHz are dealt with in the section "Line filters".

If electrical loads with non-linear characteristics are connected to a supply system with a sinusoidal voltage source (generator, transformer), non-sinusoidal currents flow, which distort the voltage at the PCC (point of common coupling). This influence on the line voltage caused by connecting non-linear loads is referred to as "harmonic effects on the supply system" or "supply system perturbation".

The following diagram illustrates the relationships using the example of a low-voltage system which is supplied via a transformer representing a sinusoidal voltage source and the internal resistance X_{Trans} . Loads with various characteristics are connected at the PCC. The motors display a linear current-voltage characteristic and when fed with sinusoidal voltage draw pure sinusoidal currents from the supply system. Because of the non-linear components in the rectifier circuits (thyristors, diodes), the converters have a non-linear current-voltage characteristic and therefore load the supply system with non-sinusoidal currents despite the supply with sinusoidal voltage. These non-sinusoidal currents, which come from the loads with non-linear characteristic, cause non-sinusoidal voltage drops across the internal resistance of the transformer X_{Trans} and therefore distort the voltage at the PCC.



A low-voltage system supplied via a transformer representing a sinusoidal voltage source

The non-sinusoidal variables at the PCC (voltages and currents) can be divided into sinusoidal components, the fundamental frequency component and the harmonic components. The higher the harmonic components of a variable are, the larger are the distortions of this variable, i.e. the larger the deviations of this variable are from the desired sinusoidal form of the fundamental frequency.

Fundamental Principles and System Description

Engineering Information

A useful factor for the resulting distortion of a variable is the total harmonic distortion THD. It is defined as the ratio between the rms value of the sum of all harmonic components and the rms value of the fundamental component.

$$THD[\%] = \sqrt{\sum_{h=2}^{h=\infty} \left(\frac{Q_h}{Q_1} \right)^2} * 100\%$$

Whereby:

- Q is the considered electrical variable (voltage V or current I)
- h is the order of the harmonic (harmonic frequency referred to line frequency)
- Q_h is the rms value of the harmonic component with harmonic number h
- Q₁ is the rms value of the fundamental component (harmonic number 1)

As the individual devices and loads in a power supply system, such as generators, transformers, compensation systems, converters, motors etc. are generally designed for operation on sinusoidal voltages and their function is negatively influenced or, in exceptional cases, can even be destroyed by harmonic components that are too high, the distortions of the voltages and currents by loads with non-linear characteristics must be limited.

For this purpose, limits are defined in the appropriate standards not only for the individual harmonics, but also for the total harmonic distortion THD. Some standards specify limits for the voltage only (e.g. EN 61000-2-2 and EN 61000-2-4), others for voltage and current (e.g. IEEE 519). These standards are discussed in more detail at the end of section "Harmonic effects on supply system".

Because of the constantly increasing use of variable-speed drives, the evaluation of harmonic effects on the supply is gaining in importance. The operators of supply systems as well as variable-speed drive users are demanding ever more data about the harmonic response of the drives so that they can already check in the planning and configuration phase whether the limits required by the standards are met.

This requires calculation of the harmonic load which results from the interaction between the connected loads on the one hand and the transformer including its supply system on the other. The following data are therefore required to calculate the harmonic currents and voltages exactly:

- Number of variable-speed drives on the supply system
- Shaft output at the operating point of the variable-speed drives
- Rectifier circuit type of the variable-speed drives (e.g.: 6-pulse, 6-pulse with Line Harmonics Filter, 12-pulse)
- Data of the line (commutating) reactors of the variable-speed drives (relative short-circuit voltage u_k)
- Transformer data (rated power, relative short-circuit voltage u_k, rated voltages on the high-voltage and low-voltage sides)
- Data of the supply system which supplies the transformer (short-circuit power)

For most of the drives in the SINAMICS range, these calculations can be performed easily and exactly with the SIZER configuration tool.

Note:

The calculated value for the total harmonic distortion of voltage THD(V) takes into account only the harmonics caused by the relevant drives. Harmonics caused by other unknown electrical drives which are also connected to the supply system or transformer in question are not included in the calculation. Consequently, the value calculated for THD(V) should not be regarded as absolute, but as the value by which the total harmonic distortion factor THD(V) at the PCC increases when the relevant drives are connected.

For many practical problems, an exact determination of all harmonic components of current and voltage is not required and often an approximation of the expected harmonic currents is sufficient. These calculations are easy to provide when the following generally valid relationships are clear:

- The harmonic currents (harmonic numbers which occur and their amplitudes) are mainly determined by the rectifier circuit type of the converter and are therefore device-specific. The transformer and the supply system for the transformer have a relatively small effect on the harmonic currents. This means that when the rectifier circuit type is known, the approximate magnitude of the harmonic currents is also defined and detailed information about the transformer and the supply system are not required.
- The harmonic voltages (harmonic numbers which occur and amplitudes) are determined by the interaction between the rectifier circuit of the converter and the transformer including the supply system. As they require knowledge of the supply system and transformer data, these are system-specific and it is not therefore easy to make general statements about their possible impact.

The following sections provide detailed information about the various types of rectifier circuits used with SINAMICS and their harmonics currents.

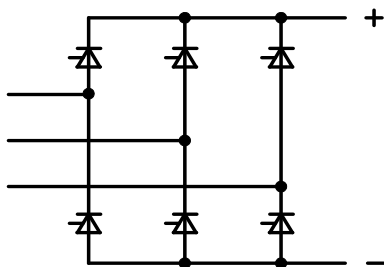
It is assumed that there are no non-reactor-protected compensation systems in the line supply to which the variable-speed drives are connected. When a supply system includes capacitors without reactor protection for reactive power compensation, it is highly probable that resonances excited by the harmonics of the converters will occur at relatively low frequencies. Therefore, it is strongly recommended that capacitors without reactor protection are not used in supply systems loaded by converters and that all capacitors used in such constellations must have reactor protection.

Harmonic currents of 6-pulse rectifier circuits

1. SINAMICS G130, G150, S120 Basic Infeed and S120 Smart Infeed in motor operation of the drive

6-pulse rectifier circuits are line-commutated three-phase bridge circuits, which usually are equipped with thyristors or diodes. They are used with SINAMICS G130 (thyristors), G150 (thyristors) and S120 Basic Line Modules (thyristors for low power outputs and diodes for larger outputs). A line reactor with a relative short-circuit voltage of 2 % is usually connected in series with these rectifiers.

With the rectifier / regenerative feedback units SINAMICS S120 Smart Line Modules which are equipped with IGBT modules, the rectifier bridge for motor operation consists of the diodes integrated into the IGBT modules, so that a 6-pulse diode bridge circuit is present during rectifier operation (motor operation). A line reactor with a relative short-circuit voltage of 4 % is normally connected in series with the Smart Line Modules.



6-pulse three-phase bridge circuit with thyristors

With 6-pulse rectifier circuits, only odd harmonic currents and odd harmonic voltages that cannot be divided by 3 occur, with the following harmonic numbers h :

$$h = n \cdot 6 \pm 1 \quad \text{where } n = 1, 2, 3, \dots$$

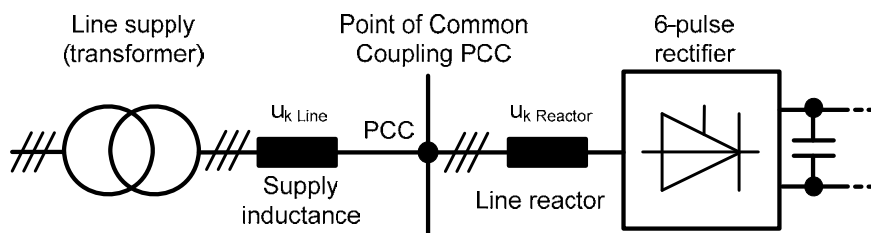
i.e.

$$h = 5, 7, 11, 13, 17, 19, 23, 25, 29, 31, 35, 37, 41, 43, 47, 49, \dots$$

The order of magnitude of the individual harmonic currents with the above harmonic numbers is mainly determined by the 6-pulse rectifier circuit. However, the power supply inductance, which mainly consists of the inductance of the supply transformer, and the inductance of the line reactor also have a certain effect. The larger these inductances are, the better the line current is smoothed and the lower the harmonic currents are, especially the harmonic currents with numbers 5 and 7.

Fundamental Principles and System Description

Engineering Information



6-pulse rectifier with line reactor on a three-phase supply

Typical harmonic currents of a 6-pulse rectifier with an line reactor are specified in the following (relative short-circuit voltage of the line reactor = 2 %).

These data are based on three different supply system constellations with differences in supply system inductance or relative short-circuit power RSC (RSC = Ratio of the short-circuit power $S_{k \text{ Line}}$ at the PCC to the fundamental frequency apparent power $S_{\text{Converter}}$ of the connected converters).

a) Supply system with low supply system inductance or high relative short-circuit power (RSC >> 50)

The short-circuit power $S_{k \text{ Line}}$ at the PCC is significantly higher than the apparent power of the connected converters, i.e. only a relatively small percentage of the transformer load is attributable to the converter. This is the case, for example, when a converter with an apparent power of a few 100 kW is connected to a supply system which is supplied via a transformer with an apparent power of several MVA.

b) Supply system with average supply system inductance or average relative short-circuit power (RSC = 50)

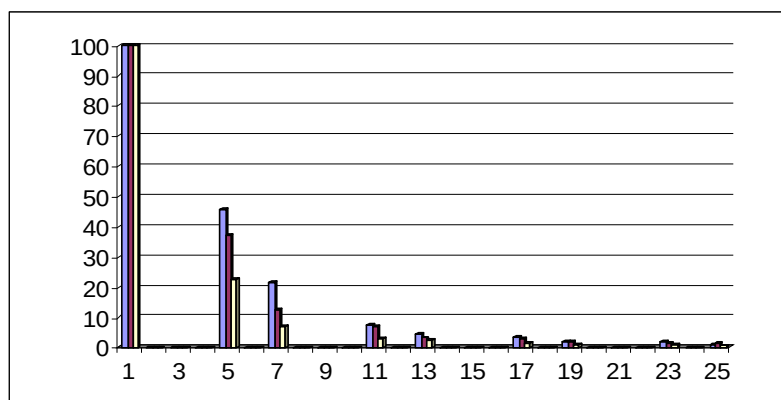
This applies, for example, when approximately 30 % to 50 % of the transformer load is attributable to the converter.

c) Supply system with high supply system inductance or low relative short-circuit power (RSC < 15)

This is the case when 100 % converter load is connected to a transformer with a high short-circuit voltage, i.e. only one converter whose apparent power approximately corresponds to the apparent power of the transformer.

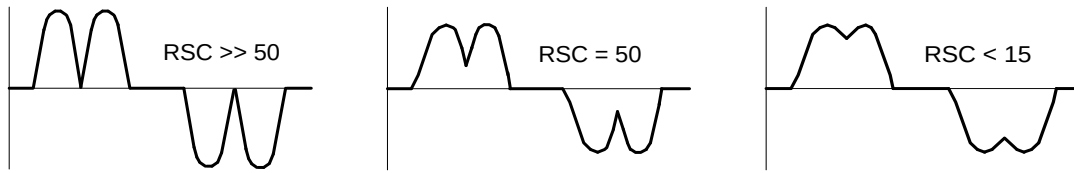
Supply system with high relative short-circuit power (RSC >> 50): "Strong supply system"										
h	1	5	7	11	13	17	19	23	25	THD(I)
I_h	100 %	45.8 %	21.7 %	7.6 %	4.6 %	3.4 %	1.9 %	1.9 %	1.1 %	51.7 %
Supply system with average relative short-circuit power (RSC = 50)										
h	1	5	7	11	13	17	19	23	25	THD(I)
I_h	100 %	37.1 %	12.4 %	6.9 %	3.2 %	2.8 %	1.9 %	1.4 %	1.3 %	40.0 %
Supply system with low relative short-circuit power (RSC < 15) "Weak supply system"										
h	1	5	7	11	13	17	19	23	25	THD(I)
I_h	100 %	22.4 %	7.0 %	3.1 %	2.5 %	1.3 %	1.0 %	0.8 %	0.7 %	23.8 %

Typical harmonic currents of 6-pulse rectifier with line reactors $u_k = 2 \%$



Spectral representation of the harmonic currents of a 6-pulse rectifier with line reactor $u_k = 2 \%$ (specified in %)

- Bars on left: RSC >> 50
- Bars in center: RSC = 50
- Bars on right: RSC < 15



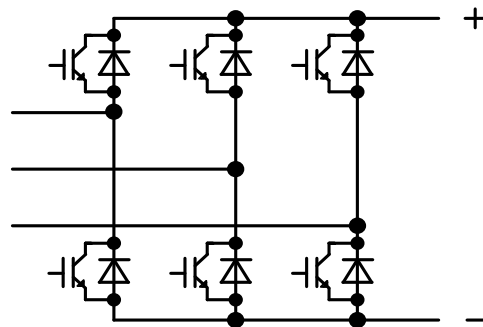
Typical line currents of a 6-pulse rectifier with line reactor $u_k = 2\%$ as a function of the relative short-circuit power RSC

2. SINAMICS S120 Smart Infeed in regenerative operation

The SINAMICS S120 Smart Infeed is a rectifier / regenerative unit for four-quadrant operation and is equipped with IGBT modules. On the line side a line reactor with a relative short-circuit voltage of 4 % is necessary. More detailed information on the Smart Infeed can be found in the section "SINAMICS Infeeds and their properties" in the subsection "Smart Infeed". The following pages only deal with the harmonic effects of the Smart Infeed.

The rectifier bridge for rectifier operation (motor operation) consists of the diodes integrated into the IGBT modules so that a 6-pulse diode bridge circuit is present in motor operation. All the information given in preceeding pages apply here.

The bridge circuit for regenerative operation consists of the IGBTs which are connected anti-parallel to the diodes. So this is also a 6-pulse bridge circuit, but the line currents in regenerative operation are slightly different from those in motor operation and show slightly different harmonics.



Smart Line Module with diodes for motor operation and IGBTs for regenerative operation

In both, motor and regenerative operation, only odd harmonic currents and harmonic voltages that cannot be divided by 3 occur, with the following harmonic order numbers h :

$$h = n \cdot 6 \pm 1 \quad \text{with} \quad n = 1, 2, 3, \dots$$

i.e.

$$h = 5, 7, 11, 13, 17, 19, 23, 25, 29, 31, 35, 37, 41, 43, 47, 49, \dots$$

The following table shows the typical current harmonics in motor and regenerative operation with a reactor on the line side (relative short-circuit voltage of the line reactor = 4 %)

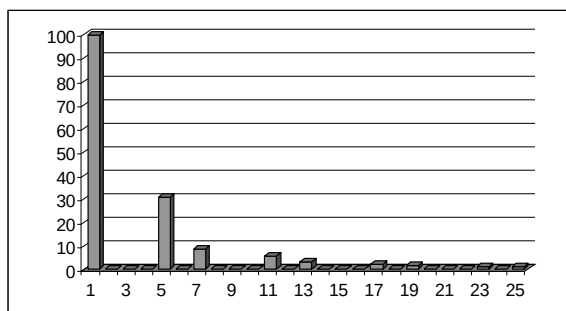
For this a supply system constellation with an average supply inductance and an average relative short-circuit power of RSC = 50 has been taken as a basis for the calculations.

Current harmonics in rectifier operation (motor operation)										
h	1	5	7	11	13	17	19	23	25	THD(I)
I_h	100 %	30.6 %	8.6 %	5.7 %	3.1 %	2.1 %	1.6 %	1.2 %	1.1 %	32.6 %
Current harmonics in regenerative operation										
h	1	5	7	11	13	17	19	23	25	THD(I)
I_h	100 %	20 %	16 %	11 %	8 %	7 %	6 %	5 %	4 %	32 %

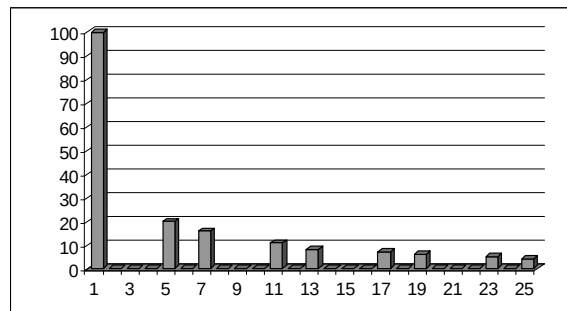
Typical current harmonic values for the SINAMICS Smart Infeed in rectifier (motor) operation and regenerative operation with a line reactor of 4 %

Fundamental Principles and System Description

Engineering Information



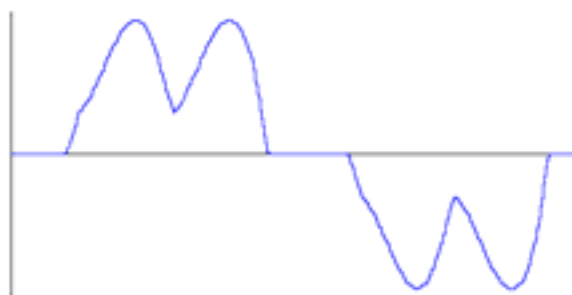
Typical current harmonic spectrum with Smart Infeed in rectifier (motor) operation with a line reactor of 4 % (specified in %)



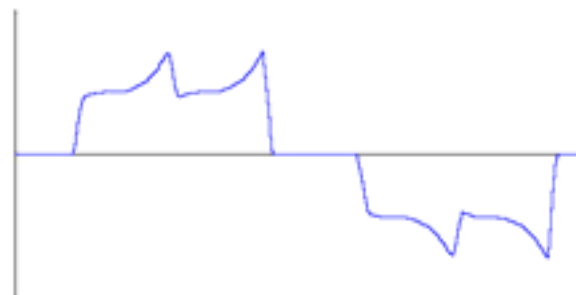
Typical current harmonic spectrum with Smart Infeed in regenerative operation with a line reactor of 4 % (specified in %)

The 5th current harmonic, which is very strong in rectifier (motor) operation, is reduced considerably during regenerative operation. Therefore all remaining harmonics increase slightly. Due to the considerable decrease in the 5th current harmonic, there is a slightly lower Total Harmonic Distortion factor THD(I) in regenerative operation. So it is sufficient for harmonics calculations with the SINAMICS Smart Infeed to consider only the worse rectifier (motor) operation.

The following diagrams show the typical line side currents with SINAMICS Smart Infeed in rectifier (motor) operation and regenerative operation.



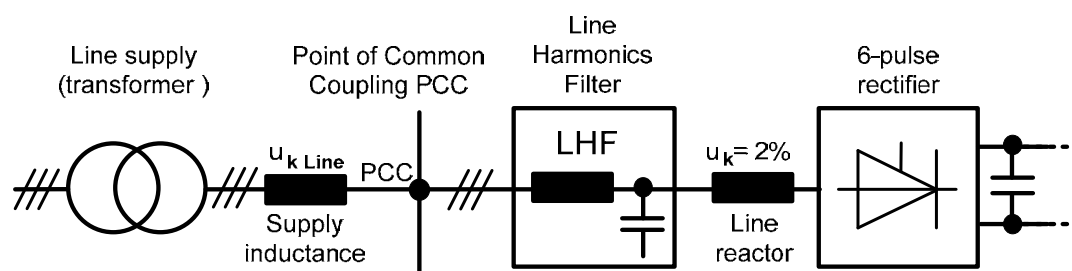
Typical line current with Smart Infeed in rectifier operation



Typical line current with Smart Infeed in regenerative operation

Harmonic currents of 6-pulse rectifier circuits with Line Harmonics Filter

A Line Harmonics Filter LHF is a passive filter that mainly absorbs the 5th and the 7th harmonic in the line current of 6-pulse rectifiers and in this way significantly reduces the harmonic effects on the supply. It is installed between the line supply connection and converter and can be used on SINAMICS G130 and G150. Line Harmonics Filter LHF require a line reactor with a relative short-circuit voltage of $u_k = 2\%$ to be installed in the converter. Further information about the operating principles and usage limitations of the Line Harmonics Filter can be found in the section "Line Harmonics Filter LHF". Here only the harmonic effects on the supply system with Line Harmonics Filters are discussed in detail.



Fundamental Principles and System Description

Engineering Information

6-pulse rectifier with line reactor and Line Harmonics Filter LHF on a three-phase supply

Line Harmonics Filter LHF influence only the magnitude of the harmonic currents, but not their spectrum. As a consequence, therefore, the 6-pulse rectifier causes odd harmonic currents and voltages that cannot be divided by 3 despite the use of a Line Harmonics Filter. The harmonic numbers h are as follows:

$$h = n \cdot 6 \pm 1 \quad \text{where} \quad n = 1, 2, 3, \dots$$

i.e.

$$h = 5, 7, 11, 13, 17, 19, 23, 25, 29, 31, 35, 37, 41, 43, 47, 49, \dots$$

Even when Line Harmonics Filters are used, the supply system inductance has a certain effect on the magnitude of the harmonic currents, but this is, however, far less than with 6-pulse rectifiers without Line Harmonics Filters.

The typical harmonic currents of 6-pulse rectifiers with Line Harmonics Filters LHF are specified below.

These data again are based on three different supply system constellations with differences in supply system inductance or relative short-circuit power RSC.

a) Supply system with low supply system inductance or high relative short-circuit power ($RSC \gg 50$)

The short-circuit power $S_{k \text{ Line}}$ at the PCC is significantly higher than the apparent power of the connected converters, i.e. only a relatively small percentage of the transformer load is attributable to the converter.

b) Supply system with average supply system inductance or average relative short-circuit power ($RSC = 50$)

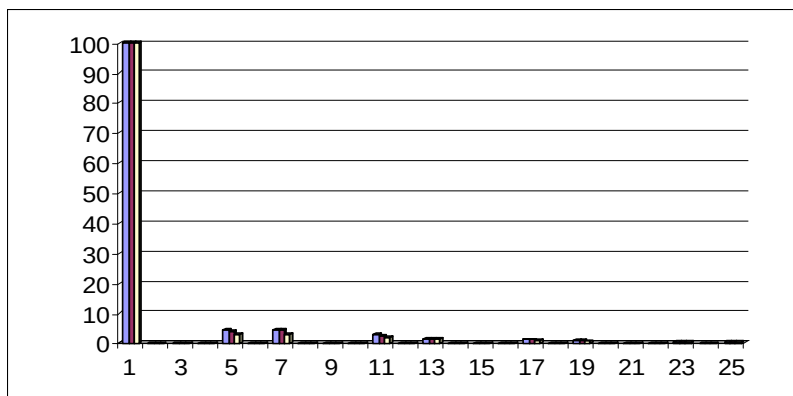
This applies, for example, when approximately 30 % to 50 % of the transformer load is attributable to the converter.

c) Supply system with high supply system inductance or low relative short-circuit power ($RSC < 15$)

This is the case when 100 % converter load is connected to a transformer with a high short-circuit voltage, i.e. only one converter whose apparent power approximately corresponds to the apparent power of the transformer.

Supply system with high relative short-circuit power ($RSC \gg 50$): "Strong supply system"										
h	1	5	7	11	13	17	19	23	25	THD(I)
I_h	100 %	4.5 %	4.7 %	2.8 %	1.6 %	1.2 %	0.9 %	0.6 %	0.5 %	7.5 %
Supply system with average relative short-circuit power ($RSC = 50$)										
h	1	5	7	11	13	17	19	23	25	THD(I)
I_h	100 %	4.2 %	4.4 %	2.6 %	1.4 %	1.2 %	0.8 %	0.6 %	0.5 %	7.0 %
Supply system with low relative short-circuit power ($RSC < 15$): "Weak supply system"										
h	1	5	7	11	13	17	19	23	25	THD(I)
I_h	100 %	2.9 %	3.1 %	1.8 %	1.3 %	1.1 %	0.7 %	0.6 %	0.5 %	5.0 %

Typical harmonic currents of 6-pulse rectifiers with Line Harmonics Filters LHF

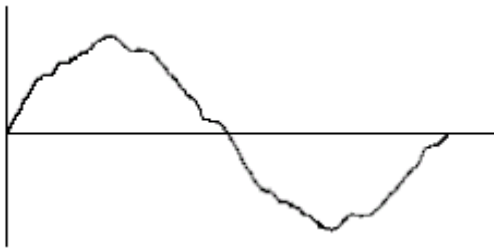


Spectral representation of the harmonic currents of 6-pulse rectifiers with Line Harmonics Filters (specified in %)

- Bars on left: $RSC \gg 50$
- Bars in center: $RSC = 50$
- Bars on right: $RSC < 15$

Fundamental Principles and System Description

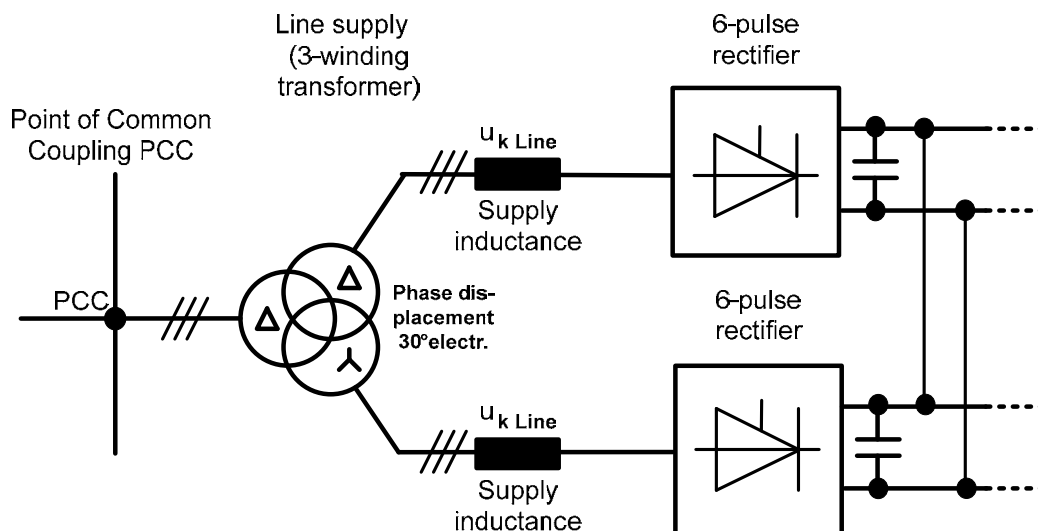
Engineering Information



Typical line current of 6-pulse rectifiers with Line Harmonics Filters (LHF)

Harmonic currents of 12-pulse rectifier circuits

A 12-pulse rectifier circuit is created when two identical 6-pulse rectifiers are supplied from two different supply systems, whose voltages are out of phase by 30°. This is achieved with the use of a three-winding transformer, whose one low-voltage winding is star-connected and the other delta-connected. The harmonic effects can be significantly reduced with 12-pulse circuits as compared to 6-pulse circuits. 12-pulse rectifier circuits can be implemented for SINAMICS G150 in the higher power range, which consists of the parallel connection of two individual G150 devices and therefore two 6-pulse rectifiers. 12-pulse rectifier circuits can also be implemented by using two S120 Basic Line Modules or S120 Smart Line Modules.



12-pulse rectifier with separate three-winding transformer

Due to the phase shifting of 30° between the two secondary voltages, the harmonic currents with harmonic numbers $h = 5, 7, 17, 19, 29, 31, 41, 43, \dots$, which are still present in the input currents of the 6-pulse rectifiers, compensate one another so that theoretically only odd harmonic currents and voltages that cannot be divided by 3 with the following numbers h occur at the PCC on the primary side of the three-winding transformer:

$$h = n \cdot 12 \pm 1 \quad \text{where } n = 1, 2, 3, \dots$$

i.e.

$$h = 11, 13, 23, 25, 35, 37, 47, 49, \dots$$

Fundamental Principles and System Description

Engineering Information

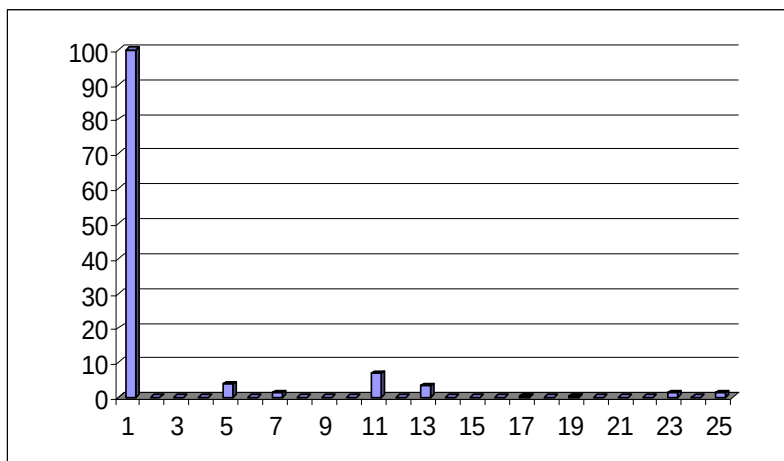
However, as in practice there is never a perfectly symmetrical load distribution between the two rectifiers, it must be assumed that harmonic currents with harmonic numbers $h = 5, 7, 17, 19, 29, 31, 41, 43, \dots$ are also present with 12-pulse circuits, but with amplitudes that are maximum 10 % of the corresponding values of 6-pulse circuits.

The typical harmonic currents of 12-pulse rectifier circuits are specified below:

As these are generally only used with high-power ratings, it can be assumed that converters with a 12-pulse rectifier circuit are operated on a separate three-winding transformer and line reactors are dispensed with. This constellation corresponds to a supply system with a low to medium relative short-circuit power $RSC = 15$ to 25 .

Supply system with low to medium relative short-circuit power ($RSC = 15 \dots 25$): "Weak supply system"										
h	1	5	7	11	13	17	19	23	25	THD(I)
I_h	100 %	3.7 %	1.2 %	6.9 %	3.2 %	0.3 %	0.2 %	1.4 %	1.3 %	8.8 %

Harmonic currents of 12-pulse rectifier circuits with separate three-winding transformer without line reactor

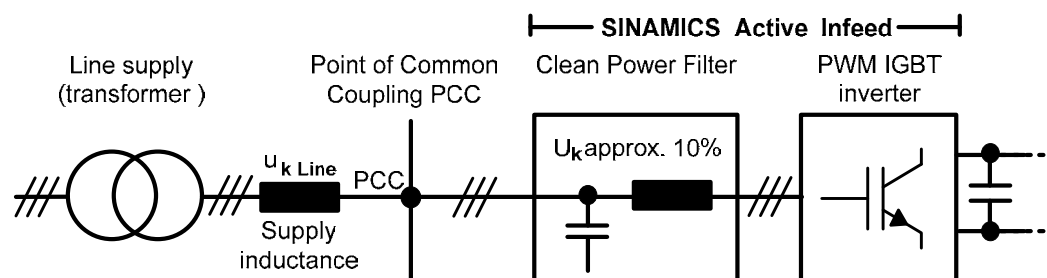


Spectral representation of the harmonic currents of 12-pulse rectifier circuits without line reactor (specified in %)

Harmonic currents and harmonic voltages of Active Infeeds (AFE technology)

The SINAMICS Active Infeed is a self-commutated, PWM IGBT inverter (Active Line Module ALM) which produces a constant, stabilized DC link voltage from the three-phase line voltage. Thanks to the Clean Power Filter (Active Interface Module AIM) installed between the power supply and IGBT inverter, the power drawn from the supply is near-to-perfect sinusoidal. The Active Infeed is ideally suited for 4Q operation, i.e. it has both Infeed and regenerative feedback capability.

The Active Infeed is the highest grade Infeed variant for SINAMICS. It is used in SINAMICS S150 cabinets and as S120 Active Infeed.



Active Infeed (PWM IGBT inverter with Clean Power Filter) on a three-phase supply system

Fundamental Principles and System Description

Engineering Information

The harmonic effects on the supply system associated with the Active Infeed are very low due to the combination of Clean Power Filter and the IGBT inverter which is clocked with a pulse frequency of a few kHz.

In contrast to 6-pulse and 12-pulse rectifier circuits, the harmonics associated with the Active Infeed are both even and odd. Each individual harmonic current and voltage is less than 1 % of the rated current and rated voltage respectively with an Active Infeed.

The total distortion factors of current THD(I) and voltage THD(V) are given in the following table and indicate – in exactly the same way as the individual harmonics – only a very minor dependence on the supply system conditions.

	Total distortion factor current THD(I)	Total distortion factor voltage THD(V)
Supply system with high relative short-circuit power ($RSC \gg 50$): "Strong supply system"	< 4.1 %	< 1.8 %
Supply system with average relative short-circuit power ($RSC = 50$)	< 3.0 %	< 2.1 %
Supply system with low relative short-circuit power ($RSC = 15$): "Weak supply system"	< 2.6 %	< 2.3 %

Total distortion factors THD(I) and THD(V) with Active Infeed as a function of the system short-circuit power

Standards and permissible harmonics

A number of key standards which define the permissible limit values for harmonics are listed below.

EN 61000-2-2

Compatibility Levels for Low-Frequency Conducted Disturbances and Signaling in Public Low-Voltage Power Supply Systems

This European standard deals with conducted disturbance variables in the frequency range from 0 Hz to 9 kHz. It specifies the compatibility levels for low-voltage AC supply systems with a rated voltage of up to 420 V 1-phase, or 690 V 3-phase and a rated frequency of 50 Hz or 60 Hz.

The compatibility levels specified in this standard are valid for the PCC (Point of Common Coupling) with the public supply system.

Limits for harmonic currents are not defined. Limits are specified only for harmonic voltages and the total harmonic distortion of the voltage THD(V).

The limits for the PCC with the public supply system are identical to the limits of Class 2 according to EN 61000-2-4 (see below).

The corresponding compatibility level for the total harmonic distortion THD(V) is 8 %.

EN 61000-2-4

Compatibility Levels for Low-Frequency Conducted Disturbances in Industrial Plants

This European standard deals with conducted disturbance variables in the frequency range from 0 Hz to 9 kHz. It specifies compatibility levels in numbers for industrial and private supply systems with rated voltages up to 35 kV and a rated frequency of 50 Hz or 60 Hz.

Supply systems on ships, aircraft, offshore platforms and railways are not in the field of application of this standard.

EN 61000-2-4 defines three electromagnetic environmental classes:

Class 1	This class applies to protected supplies and has compatibility levels that are lower than the level of the public supply system. It refers to equipment that is very sensitive to disturbance variables in the power supply, e.g. electrical equipment of technical laboratories, certain automation and protection equipment, certain data processing equipment etc.
Class 2	This class generally applies to PCCs (Points of Common Coupling) with the public supply system and to IPCs (Internal Points of Coupling) with industrial or other private supply systems. The compatibility levels for this class are generally identical to those for public supply systems. Therefore components that have been developed for operation on public supply systems can be used in this industrial environment class.
Class 3	This class applies only to IPCs (Internal Points of Coupling) in industrial environments. It has higher compatibility levels for some disturbance variables than Class 2. For example, this class should be considered when one of the following conditions applies: • The main part of the load is supplied via converters; • Welding machines are used; • Large motors are started frequently; • Loads vary quickly.

The class that is to be used for new plants or expansions to existing plants cannot be defined in advance, but depends on the intended type of installation (of equipment, device) and the process.

Fundamental Principles and System Description

Engineering Information

EN 61000-2-4 does not define limits for harmonic currents. Limits are specified only for harmonic voltages and the total harmonic distortion of the voltage THD(V).

Harmonic number h	Class 1 V _h %	Class 2 V _h %	Class 3 V _h %
5	3	6	8
7	3	5	7
11	3	3.5	5
13	3	3	4.5
17	2	2	4
17 < h ≤ 49	2.27 x (17/h) – 0.27	2.27 x (17/h) – 0.27	4.5 x (17/h) – 0.5

Compatibility levels for harmonics

– harmonic contents of the voltage V, odd harmonics, no multiples of 3

	Class 1	Class 2	Class 3
Total Harmonic Distortion factor THD(V)	5 %	8 %	10 %

Compatibility levels for the Total Harmonic Distortion factor of the voltage THD(V)

The following is a rough guide to the supplementary conditions under which the limits can be maintained in accordance with EN 61000-2-4:

- When using 6-pulse rectifier circuits (G130, G150, S120 Basic Line Modules and S120 Smart Line Modules), the limits of Class 2 can generally be maintained when 30 % to maximum 50 % of the total transformer load is made up of converter load. The limits of Class 3 are generally also maintained even with almost 100 % converter load.
- When using 6-pulse rectifier circuits (G130, G150) with Line Harmonics Filters, the limits of Class 2 can generally be maintained independent from what percentage of the transformer load is attributable to the converter.
- When using 12-pulse rectifier circuits (G150 in the higher power range with two parallel connected converters or S120 Basic Line Modules or S120 Smart Line Modules supplied by a three-winding transformer), the limits of Class 2 can also be maintained.
- When self-commutated IGBT infeeds (S150, S120 Active Line Modules) are used, the limit values of class 2 can always be maintained. Under normal supply system conditions, the limit values of class 1 can also generally be maintained.

If a large number of 6-pulse rectifier circuits are used, an exact calculation of the harmonic effects on the supply should always be performed with the supplementary conditions of the individual plant constellation.

SINAMICS converters and the corresponding line-side system components (line reactors, Line Harmonics Filter and line filters) are designed for being connected to supplies with a permanent level of voltage harmonics, according to EN 61000-2-4, Class 3. In the short-term (< 15 s within a time period of 2.5 min) a level of 1.5 times the permanent level is permissible.

That means that no voltage harmonics higher than those given in the table under Class 3 may appear at the connection point for SINAMICS units. This includes harmonics produced by the units themselves. This must be guaranteed by means of correct engineering. If necessary, Line Harmonics Filters, 12-pulse solutions or Active Infeeds may be used to stay within the limits of Class 3.

The values according to EN 61000-2-4, Class 3, must be observed not only for the protection of other equipment connected to the PCC, but also for the protection of the SINAMICS units themselves. Otherwise, components in the converter itself or the corresponding line-side components may be thermally overloaded or error functions may occur in the converter.

Fundamental Principles and System Description

Engineering Information

IEEE 519

IEEE Recommended Practices and Requirements for Harmonic Control in Electrical Power Systems

This standard is used in the USA, Canada and many countries in Asia. It specifies limits for harmonic voltages and currents for both individual loads and also for the sum of all loads at the PCC (Point of Common Coupling).

Permissible harmonic voltages and permissible total harmonic distortion THD(V):

The permissible harmonic voltage levels, which may be produced by each individual load at the PCC, are governed by the type of application or the ratio between the supply short-circuit current and the maximum current consumption of the individual load (averaged over 15 or 30 min) in accordance with the following table:

Ratio of short-circuit current/ max. current consumption	Permissible values for each individual harmonic voltage	Typical users
10	2.5 – 3 %	Special customers with special agreements
20	2.0 – 2.5 %	1 – 2 large loads
50	1.0 – 1.5 %	A few high-output loads
100	0.5 – 1 %	5 – 20 medium-output loads
1000	0.05 – 0.1 %	A large number of low-output loads

Permissible voltage levels at the PCC for each individual load

The following limits apply to the sum of all loads connected to the PCC:

Voltage at the PCC	Permissible value for each individual harmonic voltage	Permissible value for the total harmonic distortion THD(V)
$V_{Line} \leq 69 \text{ kV}$	3 %	5 %

Permissible voltage levels at the PCC for the sum of all loads

Permissible harmonic currents and permissible total harmonic distortion THD(I):

In addition to the mandatory voltage harmonics limits, the harmonic currents also have to be limited to permissible values. The limits depend on the ratio between the supply short-circuit current and the maximum current consumption at the PCC (averaged over 15 or 30 min) in accordance with the following table:

Ratio of short-circuit current/ max. current consumption	$h < 11$	$11 \leq h < 17$	$17 \leq h < 23$	$23 \leq h < 35$	$35 \leq h$	Total Harmonic Distortion THD(I)
< 20	4 %	2.0 %	1.5 %	0.6 %	0.3 %	5 %
$20 < 50$	7 %	3.5 %	2.5 %	1.0 %	0.5 %	8 %
$50 < 100$	10 %	4.5 %	4.0 %	1.5 %	0.7 %	12 %
$100 < 1000$	12 %	5.5 %	5.0 %	2.0 %	1.0 %	15 %
> 1000	15 %	7.0 %	6.0 %	2.5 %	1.4 %	20 %

Permissible harmonic currents at the PCC in relation to the maximum current drawn at the PCC

The limits of IEEE519 are in some cases significantly lower than the limits of EN 61000-2-4, especially for the harmonics with low harmonic numbers. The following is a rough guide to the supplementary conditions under which the limits can be maintained in accordance with IEEE 519:

Fundamental Principles and System Description

Engineering Information

- When using 6-pulse rectifier circuits (G130, G150, S120 Basic Line Modules and S120 Smart Line Modules), the limits can generally be maintained only if a very low percentage of the total transformer load is made up of converter load. Typical constellations with 6-pulse rectifiers cannot maintain the limits due to excessive harmonic currents with harmonic numbers 5, 7, 11 and 13.
- When using 6-pulse rectifier circuits (G130, G150) with Line Harmonics Filters, the limits can always be maintained.
- When using 12-pulse rectifier circuits (G150 in the higher power range with two parallel connected converters, S120 Basic Line Modules or S120 Smart Line Modules supplied by a three-winding transformer) the limits can only be maintained with a relatively strong supply and, correspondingly, a large relative short-circuit power. Configurations with 12-pulse rectifier circuits connected to weak supplies with small relative short-circuit power do not maintain the limits due to high harmonic currents with the harmonic numbers 11 and 13.
- When self-commutated IGBT rectifiers / regenerative units (S150, S120 Active Line Modules) are used, the limits can always be maintained.

If 6-pulse rectifier circuits without Line Harmonics Filters or 12-pulse rectifier circuits are used, an exact calculation of the harmonic effects on the supply should always be with the supplementary conditions of the individual plant constellation.

■ Line reactors (line commutating reactors)

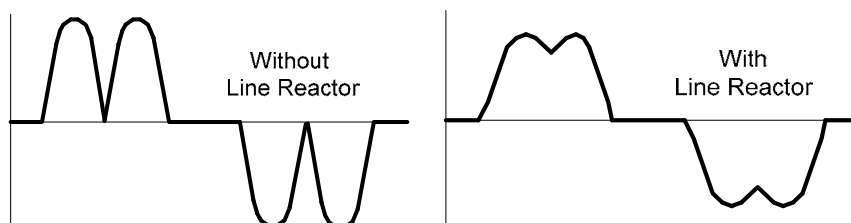
Converters with 6-pulse or 12-pulse rectifier circuits (G130, G150, S120 Basic Line Modules and S120 Smart Line Modules) always require line reactors if

- they are connected to a supply system with high short-circuit power, i.e. with low impedance,
- more than one converter is connected to the same point of common coupling (PCC),
- converters are equipped with line filters for RFI suppression,
- G130/G150 units are equipped with Line Harmonics Filters for reducing harmonic effects on the supply,
- converters are operating in parallel as to increase the output power (G150 parallel converters and converters with a parallel connection of S120 Basic Line Modules or S120 Smart Line Modules).

For the converters G130 and G150 as well as for S120 Basic Line Modules line reactors with a relative short-circuit voltage of $u_K = 2\%$ are available. The S120 Smart Line Modules require line reactors with a relative short-circuit voltage of $u_K = 4\%$.

Supply systems with high short-circuit power

The line reactor smoothes the current drawn by the converter and thus reduces harmonic components in the line current. The use of a line reactor in conjunction with the SINAMICS devices described in this engineering manual can reduce the 5th harmonic by approximately 5 to 10 %, and the 7th by approximately 2 to 4 %. The harmonics with higher harmonic numbers are not significantly affected by a line reactor. As a result of the reduced harmonic currents the thermal loading on the power components in the rectifier and the DC link capacitors is reduced. The harmonic effects on the supply are also reduced, i.e. both, the harmonic currents and harmonic voltages in the line supply are attenuated.



Typical line current of a 6-pulse rectifier circuit without and with use of a line reactor

The installation of line reactors can be dispensed with only if the line inductance is sufficiently high resp. the relative short-circuit power RSC at the point of common coupling PCC is sufficiently low. The relevant applicable values are unit-specific and therefore given in the chapters on specific unit types. A definition and explanation of the term "relative short-circuit power" can be found in the section "Supply systems and supply system types".

More than one converter connected to the same point of common coupling

Line reactors must always be provided if more than one converter is connected to the same point of common coupling. In this instance, the reactors perform two functions, i.e. they smooth the line current and decouple the rectifiers at the line side. This decoupling is an essential prerequisite for correct operation of the rectifier circuit, particularly in the case of SINAMICS G130 and G150. For this reason, each converter must be provided with its own line reactor, i.e. it is not permissible for a single line reactor to be shared among converters.

Converters with line filters or Line Harmonics Filters LHF

A line reactor must also be installed for any converter that is to be equipped with a line filter for RFI suppression or with a Line Harmonics Filter LHF for reducing harmonic effects on the supply. This is because filters of this type cannot be 100% effective without a line reactor.

Fundamental Principles and System Description

Engineering Information

Converters connected in parallel

Another constellation which requires the use of line reactors is the parallel connection of converters where the paralleled rectifiers are directly connected at both the line side and the DC link sides. This applies to both G150 paralleled units and to parallel connections of S120 Basic Line Modules and S120 Smart Line Modules if these involve a 6-pulse connection. The line reactors provide for balanced current distribution and ensure that no individual rectifier is overloaded by excessive current imbalances.

Line Harmonics Filter (LHF)

Line Harmonics Filters LHF are passive filters that mainly absorb the 5th and the 7th harmonic in the line currents of 6-pulse rectifiers and in this way significantly reduce the harmonic effects on the supply system to the significantly lower level associated with 12-pulse rectifier circuits.

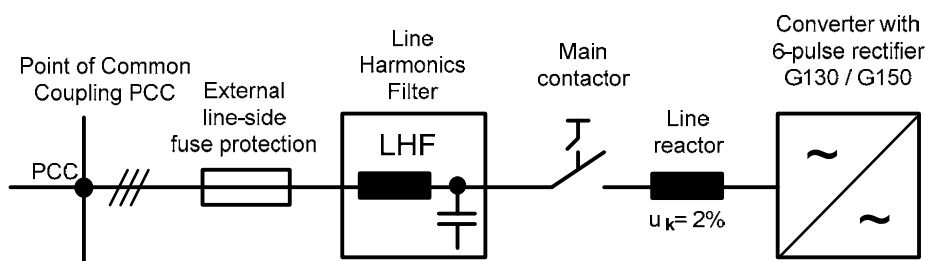
They can be used on SINAMICS G130 and G150 units and are installed between the mains supply connection and the converter.

Line Harmonics Filters produce losses, which slightly reduce the efficiency of the converter. The converter efficiency drops by approximately 0.3 % from typically 98.0 % to 97.7 % when a Line Harmonics Filter is used with either SINAMICS G130 or G150 converters. The relatively large reduction in the harmonics compared to 6-pulse converters without LHF is associated with a relatively small reduction of the efficiency.

In order to reduce the harmonics on the supply, SINAMICS S150 converters with a pulsed Active Infeed can also be used, as an alternative to SINAMICS G130 / G150 with Line Harmonics Filters. This would produce slightly lower harmonics on the line side but the efficiency of the converter is quite noticeably reduced to approximately 96%. Thus, from a purely energy-related point of view, this alternative solution cannot be recommended.

Line Harmonics Filters LHF require the following additional components:

- Line-side fuse protection of the Line Harmonics Filter,
- A main contactor or a circuit breaker on the converter side
- A converter-side line reactor with a relative short-circuit voltage of 2 %



Additional components required in conjunction with Line Harmonics Filters LHF

The following points must also be noted:

Each converter must have its own Line Harmonics Filter LHF. It is not permitted to operate more than one low power converter on a single high output Line Harmonics Filter LHF.

The power rating of the converter must not be less than two grades lower than that of the Line Harmonics Filter LHF, otherwise the mismatching of the line reactors will influence the resonance frequency on the converter side too much, thereby reducing the effectiveness of the filter. With this in mind, Line Harmonics Filters are available for the following converter output power ratings:

Supply voltage	Rated converter power
3AC 380 V – 480 V	≥ 160 kW
3AC 500 V – 600 V	≥ 110 kW
3AC 660 V – 690 V	≥ 160 kW

Fundamental Principles and System Description

Engineering Information

The relative short circuit power RSC of the supply system must have a value of at least 10. If the short circuit power is any smaller, the line-side resonance frequency will be affected too much and the fundamental wave of the line voltage may increase considerably until it reaches values beyond the permissible line voltage tolerance of the converter.

Line-side fuse protection for the Line Harmonics Filters should be implemented using the same fuse types as those recommended in catalog D11 as line-side power components for protecting the corresponding converters.

If line-side switches or contactors are used for switching on/off a Line Harmonics Filter, these must be dimensioned for the making current involved, which is in the same order of magnitude as the rated current. For this reason, AC-3 category contactors must be used.

The converter-side main contactor or the converter-side circuit breaker must not connect the converter to the filter, before the filter is connected to the supply. When shutting down the system, the converter must always be disconnected from the filter by means of the main contactor or the circuit breaker, before the filter is disconnected from the supply.

Line Harmonics Filters can be connected in parallel in order to increase the power. A current derating of 7.5 % must be taken into consideration.

Line Harmonics Filters LHF can also be used with G150 parallel converters (G150 power extension), if a 6-pulse power supply is given and both partial converters are fed from the same supply resp. the same transformer winding. In this case, each partial converter must be connected to a Line Harmonics Filter on the line side, which is adapted to the power of the partial converter.

With a 12-pulse line connection, the use of a Line Harmonics Filter does not make technical sense because no additional improvement of the harmonic effects will be achieved.

Line Harmonics Filter LHF can be operated on both 50 Hz and 60 Hz supply systems. The supply frequency is selected through reconnection of jumper links in the filter at the commissioning stage. The supply frequency is set for 50 Hz in the delivery state (factory setting).

Line Harmonics Filters LHF can be used in grounded (TN/TT) and non-grounded (IT) supply systems.

Line Harmonics Filter LHF must be sited close to the converter. The length of cable between the Line Harmonics Filter LHF and the converter input should not exceed 10 m.

Fundamental Principles and System Description

Engineering Information

Line filters (radio frequency interference (RFI) suppression filters or EMC filters)

General information and standards

Line filters limit the high-frequency, conducted interference emitted by variable-speed drive systems in the frequency range from 150 kHz to 30 MHz and therefore contribute to improving the **E**lectro-**M**agnetic **C**ompatibility (EMC) of the overall system.

The electromagnetic compatibility describes - according to the definition of the EMC directive - the "capability of a device to work satisfactorily in the electromagnetic environment without itself causing electromagnetic interference which is unacceptable for other devices present in this environment".

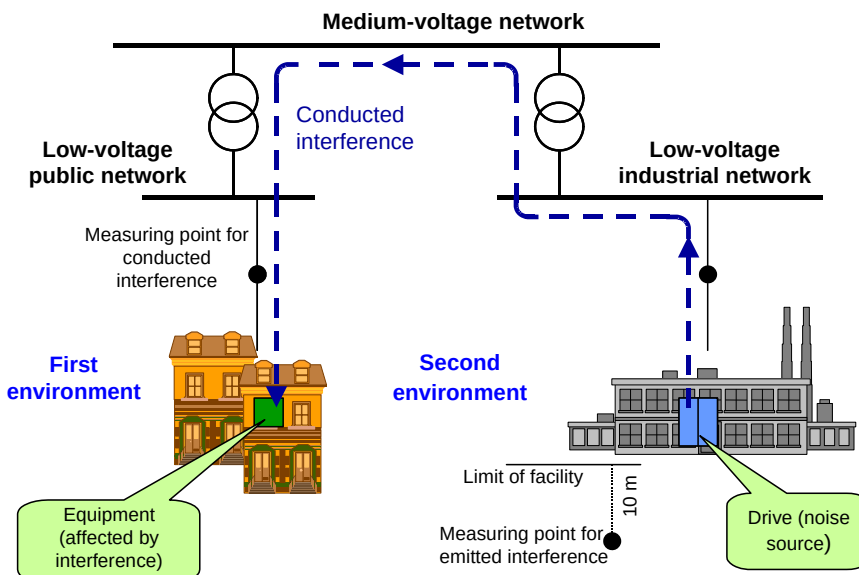
To guarantee that the appropriate EMC directives are observed, the devices must demonstrate a sufficiently high noise immunity, and also the emitted interference must be limited to acceptable values.

The EMC requirements for "Adjustable speed electrical power drive systems" are defined in the EMC product standard EN 61800-3. A variable-speed drive system (or **P**ower **D**rive **S**ystem PDS) in the context of this standard comprises the drive converter and the electric motor including cables. The driven machine is not part of the drive system.

EMC product standard EN 61800-3 defines different limits depending on the location of the drive system and refers to installation sites as "first" and "second" environments.

Definition of "first" and "second" environment

- "First" environment:
Residential buildings or locations at which the drive system is directly connected to a public low-voltage supply without intermediate transformer.
- "Second" environment:
Locations outside residential areas or industrial sites which are supplied from the medium-voltage network via a separate transformer.



"First" and "second" environment as defined by EMC product standard EN 61800-3

Four different categories are defined in EN 61800-3 depending on the location and the output of the variable-speed drive.

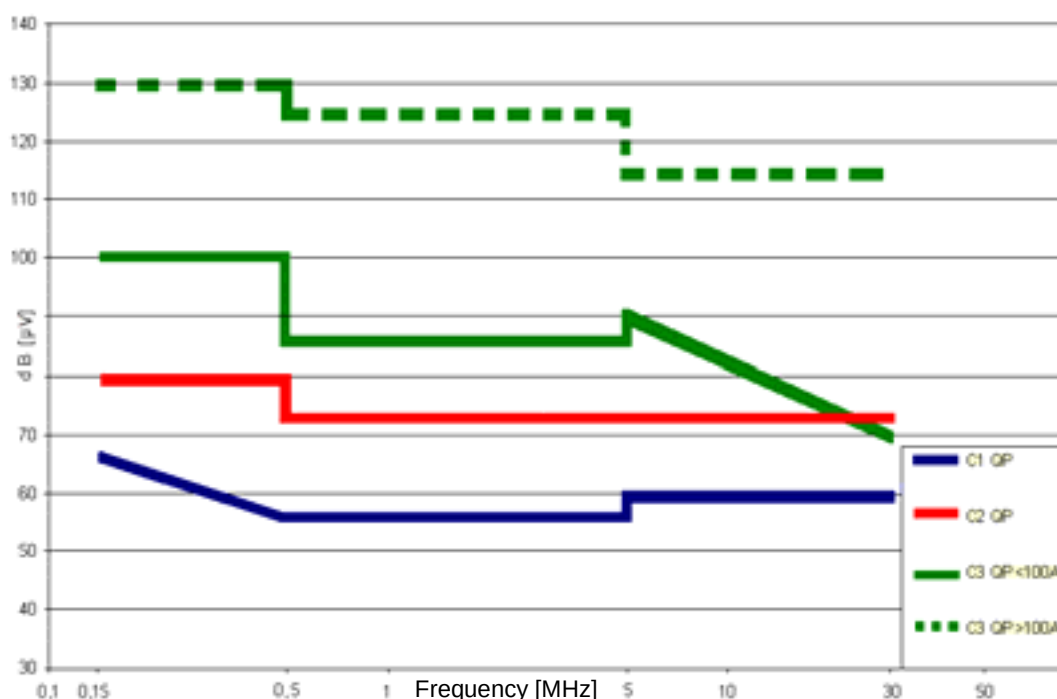
Fundamental Principles and System Description

Engineering Information

Definition of categories C1 to C4 and associated permissible limits of interference voltage levels

- Category C1:
Drive systems with rated voltages of < 1000 V for unlimited use in the "first" environment
- Category C2:
Fixed-location drive systems with rated voltages of <1000 V for use in the "second" environment. Use in the "first" environment is possible if the drive system is installed and used by qualified personnel. The warning and installation information supplied by the manufacturer must be observed.
- Category C3:
Drive systems with rated voltages of < 1000 V for unlimited use in the "second" environment.
- Category C4:
Drive systems with rated voltages of ≥ 1000 V or for rated currents of ≥ 400 A for use in complex systems in the "second" environment.

The diagram below shows the permissible interference voltage levels for categories C1, C2 and C3. Category C3 is subdivided again into currents of < 100 A and > 100 A. The higher the category, the higher the permitted limit values for conducted interference emissions. The requirements of category C1 can be met only through heavy filtering (blue limit curve below), while category C4 demands only minimal filtering and is therefore not included in the diagram.



Permissible interference voltage levels in dB[μV] for categories C1, C2 and C3 (QP = quasi-peak values)

SINAMICS equipment is almost exclusively used in the "second" environment as defined by categories C3 and C4. It is therefore equipped as standard with RFI suppression filters for the "second" environment, category C3. This applies to SINAMICS G150 and S150 cabinets, to SINAMICS G130 Chassis and to the Infeeds of the modular system S120 (Basic Infeeds, Smart Infeeds and Active Infeeds).

Optional RFI suppression filters are available for use in the "first" environment according to category C2 for SINAMICS G130 / G150 as well as for SINAMICS S120 Basic Infeeds.

Standards

EN 61800-3

Adjustable speed electrical power drive systems, part 3: EMC requirements and specific test methods

Variable-speed electrical drives fall into the scope of EMC product standard EN 61800-3 with regard to interference emissions. This standard has been discussed in detail above.

Fundamental Principles and System Description

Engineering Information

EN 55011

Industrial, scientific and medical (ISM) radio-frequency equipment - Radio disturbance characteristics - Limits and methods of measurement

Before the EMC product standard was introduced, variable-speed electrical drives were covered by the scope of standard EN 55011 which defines limit values for the interference emissions of industrial, scientific and medical radio-frequency equipment. EN 55011 defines two classes of limit value:

- Class A:
Equipment in class A is suitable for use in all locations except residential areas and other areas connected directly to a low-voltage distribution system which (also) supplies residential buildings. Equipment in class A must remain within the limits defined for class A.
→ Class A therefore corresponds to the "second" environment defined by EN 61800-3.
- Class B:
Equipment in class B is suitable for use in residential areas and other areas connected directly to a low-voltage distribution system which (also) supplies residential buildings. Equipment in class B must remain within the limits defined for class B.
→ Class B therefore corresponds to the "first" environment defined by EN 61800-3.

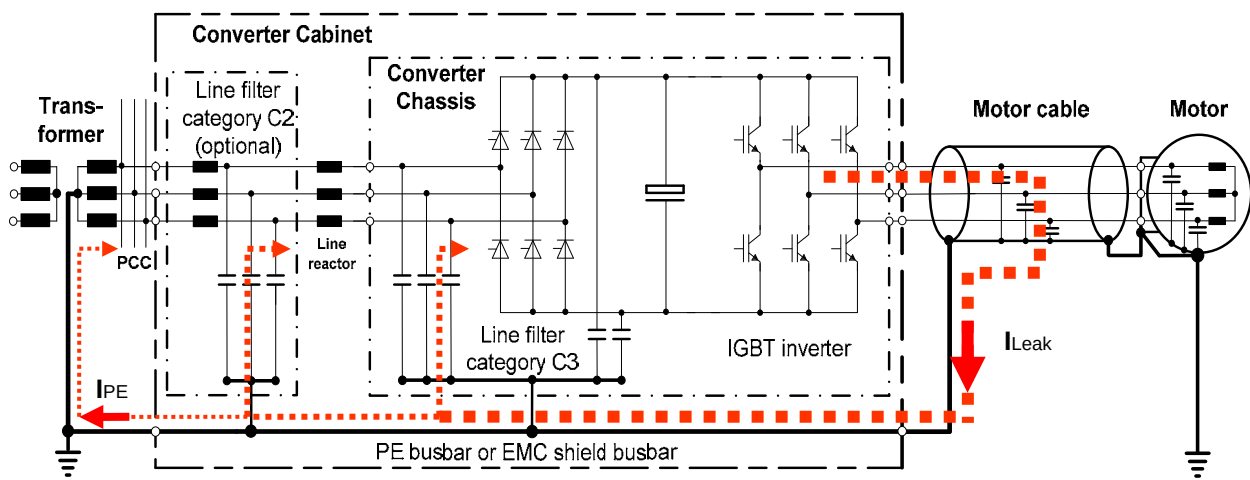
These classifications are therefore used to define the limit values for conducted interference emissions, corresponding exactly to categories C1 to C3 as defined in EN 61800-3.

- Class B1:
→ This class corresponds to category C1 of EN 61800-3
- Class A1:
→ This class corresponds to category C2 of EN 61800-3
- Class A2:
→ This class corresponds to category C3 of EN 61800-3

Line filters for the "first" environment (residential) and "second" environment (industrial)

Line filters or RFI suppression filters limit the high-frequency harmonic effects on the supply systems of the drive by reducing the conducted emissions in the frequency range between 150 kHz and 30 MHz. They ensure that the disturbances produced by the variable-speed drive are mainly kept inside the drive system itself and that only a small percentage (within the permissible tolerance range) can spread into the supply system.

The following diagram shows a variable-speed drive system which comprises a cabinet-mounted SINAMICS G130 Chassis which is supplying a motor via a shielded motor cable. This example will be used to illustrate the operating principle of standard and optional line filters.



Variable-speed drive system PDS comprising a cabinet with a SINAMICS G130 Chassis and a motor

Operating principle of line filters

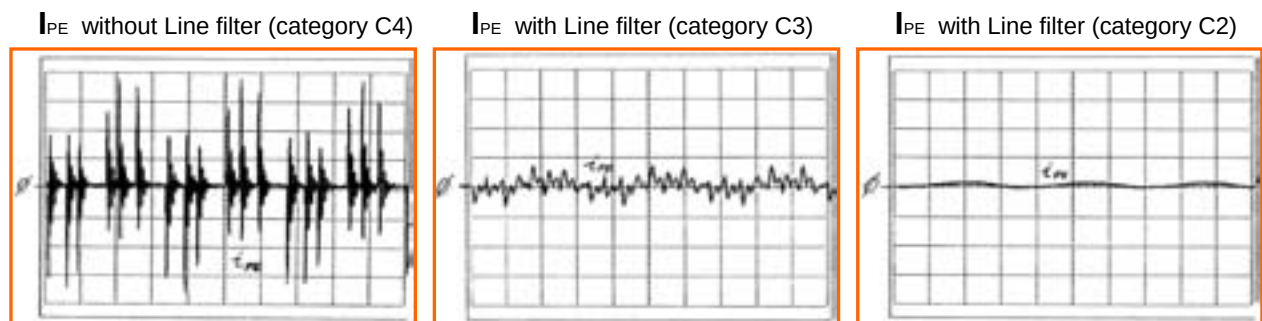
High-frequency interference in the variable-speed drive system is caused by the IGBTs (Insulated Gate Bipolar Transistors) switching at high speed in the motor-side inverter of the converter unit. These switching operations produce very high rates of voltage rise dv/dt . For further information about this phenomenon, please refer to the section "Effects of using fast-switching power components".

The high rates of voltage rise at the inverter output generate large, high-frequency leakage currents which flow to ground across the capacitance of the motor cable and motor winding. These must return via a suitable path to their source, i.e. the inverter. When shielded motor cables are used, the high-frequency leakage or interference currents I_{Leak} pass via the shield to the PE busbar or the EMC shield busbar in the cabinet.

If the cabinet or the chassis unit would not contain filters of any type which could offer this high-frequency interference current a low-resistance return path to the inverter, then all the interference current would flow via the line-side PE connection of the cabinet to the transformer neutral ($I_{PE} = I_{Leak}$) and from there back to the converter (rectifier) via the three phases of the three-phase supply. If this were the case, the interference current would superimpose high-frequency interference voltages on the line voltage and thus influence or even destroy other loads connected to the same point of common coupling as the cabinet itself. The interference at the connection point would match the level defined by category C4.

Due to the line filter which is a standard feature of SINAMICS Chassis the high-frequency interference current gets a low-resistance return path to its source so that a high percentage of the interference current I_{Leak} can flow via the filter inside the chassis unit. As a result, the supply system is loaded with lower interference currents $I_{PE} < I_{Leak}$ and the interference level at the point of common coupling drops to the level of category C3.

If the optional line filter is installed in the cabinet in addition to the standard line filter fitted to SINAMICS Chassis, almost all the interference current I_{Leak} is diverted before it can exit the drive system and the load on the power supply is reduced still further ($I_{PE} \ll I_{Leak}$), i.e. the interference level drops to the value defined for category C2.



High-frequency interference current at the line-side PE connection as a function of line filters

Magnitude of leakage or interference currents

The magnitude of the high-frequency leakage currents depends on a large number of drive parameters. The most important influencing factors are:

- Level of the line voltage V_{Line} or the DC link voltage V_{DCLink} of the converter,
- Rate of voltage rise dv/dt produced by fast-switching IGBTs in the inverter,
- Pulse frequency f_P of the inverter,
- Converter output with or without motor reactor or motor filter,
- Impedance Z_W or capacitance C of motor cable,
- Inductance of grounding system and all ground and shield connections.

The inductance values of the grounding system and the exact grounding conditions are normally not known so it is very difficult in practice to precisely calculate the leakage currents that are likely to occur. It is however possible to work out the theoretical maximum values of the leakage current I_{Leak} carried by the motor cable shield if we assume that the grounding system inductance is negligible and the line filter action is ideal. In this case, the peak value of leakage current $\hat{I}_{Leak}$ can be calculated as follows from the DC link voltage V_{DCLink} and the impedance Z_W of the motor cable:

$$\hat{I}_{Leak} = \frac{V_{DCLink}}{Z_W}.$$

Fundamental Principles and System Description

Engineering Information

If we apply this formula to the converters and inverters in the SINAMICS range and assume the Infeed to be 400 V 3AC plus the maximum number of parallel motor cables $n_{\max}$ and the maximum cross-sections of shielded motor cables $A_{\max}$, then the magnitudes of the theoretical peak values $\hat{I}_{\text{Leak}}$ of the leakage currents carried by the motor cable shields are calculated to be:

- Booksize format 1.5 kW - 100 kW $\hat{I}_{\text{Leak}} = 10 \text{ A} - 30 \text{ A}$
- Chassis format 100 kW - 250 kW $\hat{I}_{\text{Leak}} = 30 \text{ A} - 100 \text{ A}$
- Chassis format 250 kW - 800 kW $\hat{I}_{\text{Leak}} = 100 \text{ A} - 300 \text{ A}$

The associated rms values I_{Leak} are approximately 10 times lower when the following supplementary conditions apply:

- Pulse frequency f_p matches factory setting
- 300 m shielded motor cable (with $n_{\max}$ and $A_{\max}$)

Both the peak values and rms values increase in proportion to the line voltage or DC link voltage. Peak values are not influenced by pulse frequency or cable length while rms values increase in proportion to pulse frequency and cable length.

Since the above analysis does not take the grounding system inductance into account, the real values are generally lower. If motor reactors or motor filters are installed, the leakage currents are reduced even further.

What proportion of the high-frequency leakage current I_{Leak} carried by the motor cable shield reaches the line-side PE connection depends on the line filters in the converter chassis unit or converter cabinet, as described on the previous page. The oscillograms shown in the previous page provide a rough guide as to the reduction in leakage currents at the PE connection that can be achieved depending on the line filters used. Even when line filters in accordance with category C2 are installed, leakage current peak values of 300 mA may possibly occur at the PE connection with converters in Booksize format and 10 A with the largest chassis units.

As the analysis above makes clear, high-frequency leakage currents at the line-side PE connection are not negligible, even when relatively extensive RFI suppression measures are implemented. For this reason, it is not generally possible to use residual-current circuit breakers (RCCBs) on SINAMICS drive systems. This applies to both RCCBs with an operating threshold of 30 mA for personnel protection as well as to RCCBs with higher operating thresholds.

EMC-compliant installation

To ensure that the line filters can achieve the intended filtering effect, it is essential to install the entire drive system correctly. The installation must be such that interference current can find a continuous, low-inductance path without interruptions or weak points from the shield of the motor cable to the PE or EMC shield busbar and the line filter back to the inverter.

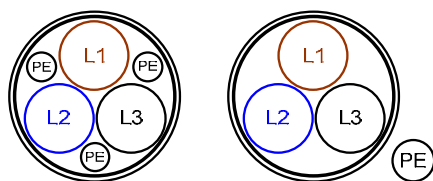
For this reason, the lead used to link the converter and motor always has to be shielded and should be a symmetrical, 3-wire, three-phase cable.

Shielded cables with symmetrically arranged three-phase conductors L1, L2 and L3 and an integrated, 3-wire, symmetrically arranged PE conductor, such as the PROTOFLEX EMV cable, type 2YSLCY-J supplied by Prysmian, are ideal.



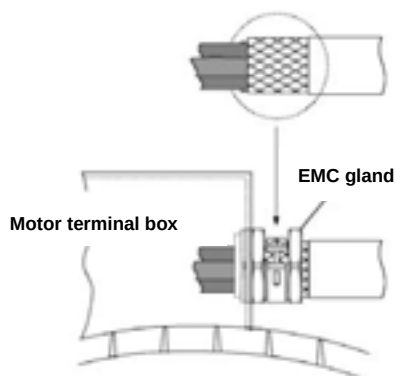
Shielded, symmetrically arranged three-phase cable with 3-core PE conductor

Alternatively, it is also possible to use a shielded cable containing only three-phase conductors L1, L2 and L3 in a symmetrical arrangement. In this case, the PE conductor must be installed separately.

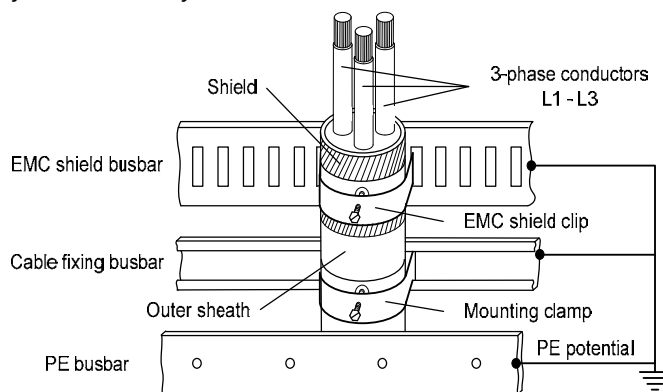


Symmetrical 3-wire three-phase cables with concentric copper or aluminum shield

Effective shield bonding is achieved if EMC cable glands are used to create a solid 360° contact between the shield and motor terminal box and, at the other side in the converter cabinet, a solid 360° contact with the EMC shield busbar using EMC shield clips. An alternative shield connection to the PE busbar in the converter using only long, braided "pigtailes" is less suitable, particularly if the pigtailes are very long, as this type of shield bond represents a relatively high impedance for high-frequency currents. Further additional shield bonds between the converter and motor, e.g. in intermediate terminal boxes, must never be created as the shield will then become far less effective in preventing interference currents from spreading beyond the drive system.



Shield bonding to motor terminal box using an EMC gland



Shield bonding to the EMC shield busbar in the converter using an EMC shield clip

The cable symmetry combined with the concentric shield with good bonding connections at both sides ensures the interference currents can flow easily back to the cabinet.

The housing of the SINAMICS Chassis containing the standard, category C3 line filter must be connected inside the cabinet to the PE busbar and the EMC shield busbar with a low-inductance contact. The connection can be made over a large area using metal construction components of the cabinet. In this case, the contact surfaces must be bare metal and each contact point must have a minimum cross-section of several cm^2 . Alternatively, this connection can be made with short ground conductors with a large cross-section ($\geq 95 \text{ mm}^2$). These must be designed to have a low impedance over a wide frequency range, e.g. made of finely stranded, braided round copper wires or finely stranded, braided flat copper strips.

The same rules apply to the connection of the optional category C2 line filter to the PE busbar and the EMC shield busbar.

The optional line filter must always be combined with a line reactor, otherwise it cannot achieve its full filtering effect.

If the motor cable used were unshielded rather than shielded, the high-frequency leakage currents would be able to return to the cabinet via an indirect path, i.e. across the motor cable capacitance. They would inevitably flow to the cable rack and thus to system ground. From here they would continue to the transformer neutral point along undefined paths and finally via the three phases of the supply system back to the converter. They would bypass the line filter, rendering it largely ineffective.

It is basically also possible to reduce conducted interference emissions to low values with unshielded motor cables. However, this would require very sophisticated filtering measures at the inverter output, i.e. filters which would achieve a major reduction in voltage rates of rise and thus the interference current. The only filter suitable for this purpose is the sine-wave filter and this would be effective only if the permissible motor cable lengths were not fully utilized.

Line filters and IT systems

The standard line filters for category C3 and the optional line filters for category C2 are suitable for use only in grounded supply systems (TN and TT supply systems). Where SINAMICS equipment is to be operated on an ungrounded (IT) supply system, the following must be noted:

- In the case of standard line filters, the connection between the filter and ground must be interrupted when the equipment is installed or commissioned. This can be done simply by removing a metal clip as described in the operating instructions.
- Optional line filters for category C2 must not be used at all.

If these rules are not followed, the line filters will be overloaded and irreparably damaged in the event of a ground fault at the motor side. Once the ground connection for the standard RFI suppression filter has been removed, the devices meet the criteria of category C4 in accordance with the EMC product standard EN 61800-3. For more information, refer to the chapter "EMC Installation Guideline".

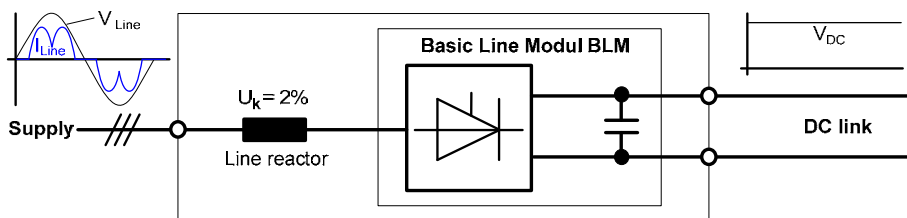
SINAMICS Infeeds and their properties

Basic Infeed

The Basic Infeed is a robust, unregulated infeed for two-quadrant operation (i.e. the energy always flows from the supply system to the DC link). This Infeed is not designed to regenerate energy from the DC link back to the supply system. If regenerative energy is produced for brief periods by the drive, e.g. during braking, it must be converted to heat by a Braking Module connected to the DC link combined with a braking resistor.

The Basic Infeed consists of a line-commutated, 6-pulse, three-phase rectifier equipped with thyristors or diodes. A line reactor with a relative short-circuit voltage of 2 % is generally connected on the line side. Further details can be found in the section "Line reactors" and in the chapters on specific unit types.

The Basic Infeed is an integral component of SINAMICS G130 chassis units and SINAMICS G150 cabinet units (with thyristors in each case). It is also available as a stand-alone infeed in the SINAMICS S120 modular system, in Chassis and Cabinet Modules format (with thyristors for the lower power ratings and with diodes for the higher power ratings 900 kW/400 V and 1,500 kW/500 V-690 V).



SINAMICS S120 Basic Infeed comprising a Basic Line Module with thyristors and a line reactor with $u_k = 2\%$

The Basic Infeed is a line-commutated rectifier which, from the three-phase line voltage V_{Line} , produces an unregulated, load-dependent DC link voltage V_{DCLink} . Under no-load conditions, the DC link is charged to the peak line voltage value, i.e. $V_{DCLink} = 1.41 \cdot V_{Line}$. When loaded the DC link voltage decreases. When partially loaded the DC link voltage will be $V_{DCLink} \approx 1.35 \cdot V_{Line}$ and at full load,

$$V_{DCLink} = 1.32 \cdot V_{Line}.$$

As the DC link voltage is unregulated, line voltage fluctuations cause the DC link voltage to fluctuate correspondingly.

The processes for precharging the connected DC link are very different depending on the device variant used:

In the case of SINAMICS G130 and G150 converters in which the Basic Infeed is an integral component of their power units, a small precharging rectifier equipped with diodes is connected in parallel with the main rectifier equipped with thyristors. If this arrangement is applied to the voltage at the line side, the DC link is charged by means of the precharging rectifier and the associated precharging resistors.

The principle of precharging involves the use of ohmic resistors and is, therefore, subject to losses. This means that the precharging resistors must be thermally dimensioned to support precharging of the DC link for their G130 or G150 converter without becoming overloaded. Additional DC link capacitances cannot be precharged. For this reason, other S120 Motor Modules, for example, must not be connected to the DC link of a SINAMICS G130 or G150 converter.

In the case of Basic Line Modules for the SINAMICS S120 modular system equipped with thyristors, the DC link is charged via the rectifier thyristors by changing the firing angle (phase angle control). During this process, the firing angle is increased continuously for 1 second until it reaches the full firing angle setting. This precharging principle results in hardly any losses, which means that an extremely high DC link capacitance could be precharged. The permissible DC link capacitance for the connected inverters (S120 Motor Modules), however, must be limited to protect the thyristors against an excessive recharge current entering the DC link capacitance when the voltage is restored following a line voltage dip. Despite this, the limit for the permissible DC link capacitance is relatively high due to the robust line-frequency thyristors.

The maximum permissible DC link capacitance for the different S120 Basic Line Modules can be found in the section "Checking the maximum DC link capacitance" of the chapter "SINAMICS S120, General Information about Built-in and Cabinet Units".

Fundamental Principles and System Description

Engineering Information

In the case of Basic Line Modules for the SINAMICS S120 modular system equipped with diodes, precharging is carried out via resistors, which create losses. Due to the power loss that occurs in the resistors during precharging, the permissible DC link capacitance of the connected inverters (S120 Motor Modules) is limited to a lower value than with Basic Line Modules equipped with thyristors.

The maximum permissible DC link capacitance for the different S120 Basic Line Modules can be found in the section "Checking the maximum DC link capacitance" of the chapter "SINAMICS S120, General Information about Built-in and Cabinet Units".

To achieve an increased output power rating, it is possible to connect up to four S120 Basic Line Modules in parallel (including 6-pulse and 12-pulse configurations). Further details can be found in the section "Parallel connections of converters".

Due to the operating principle of the 6-pulse three-phase bridge circuit, the Basic Infeed causes relatively high harmonic effects on the supply system. The line current contains a high harmonic content with harmonic numbers $h = n \cdot 6 \pm 1$, where n assumes integers 1, 2, 3, etc. The Total Harmonic Distortion factor of current THD(I) is typically in the range from about 30 % to 45 %. For further information about harmonic characteristics, please refer to the section "Harmonic effects on the supply system". Line Harmonics Filters LHF can be installed on the line side of G130 chassis units and G150 cabinet units in order to reduce the effects of harmonics on the supply. These reduce the total harmonic distortion factor THD(I) to below 7.5%. A similar reduction can also be achieved with 12-pulse circuits, i.e. by supplying two Basic Line Modules from a three-winding transformer with a 30 ° phase displacement between its voltages.

The criteria for defining of the required transformer power rating, taking into account the harmonic load as well as the characteristics of three-winding transformers in 12-pulse operation, are described in the section "Transformers".

Fundamental Principles and System Description

Engineering Information

Smart Infeed

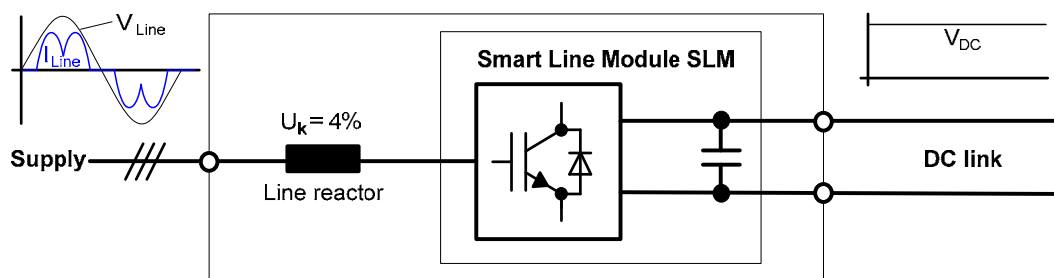
The Smart Infeed is a simple, unregulated rectifier / regenerative unit for four-quadrant operation (i.e. the energy flows from the supply system to the DC link and vice versa).

The Smart Infeed consists of an IGBT inverter, which operates at the line supply as a line commutated 6-pulse bridge rectifier / regenerative unit. In contrast to the Active Infeed, the IGBTs are not active pulsed using the pulse width modulation method. In rectifier operation (motor operation) the current flows via the diodes integrated into the IGBT modules from the line supply to the DC link, so that a line-commutated, 6-pulse diode bridge circuit is present in motor operation. In regenerative operation the current flows via the IGBTs, which are synchronised at the line frequency. Thus, a line-commutated, 6-pulse IGBT bridge circuit is present at regenerative operation.

As IGBTs, in contrast to thyristors, can be switched off at any time, inverter shoot-through during regenerative operation caused by supply system failures cannot occur in contrast to rectifier / regenerative units equipped with thyristors.

On the line side, the Smart Infeed is normally equipped with a line reactor having a relative short circuit voltage of $u_k = 4\%$.

The Smart Infeed is available as a stand-alone infeed of the SINAMICS S120 modular system in Chassis and Cabinet Modules format.



SINAMICS S120 Smart Infeed comprising a Smart Line Module and a line reactor with $u_k = 4\%$

The IGBTs for regenerative operation of the Smart Infeed are always switched on at the natural firing point and switched off after 120° (electr.) independently from the direction of the energy flow. As a result of this, a current resp. energy flow from the supply to the DC link or vice-versa is possible at any time. This control principle offers the advantage that the Smart Infeed can react relatively fast to load variations and can also change the direction of the current resp. energy flow at any time.

However, the control principle described creates a capacitive reactive current at no-load operation, which flows on the line side and cannot be neglected. This leads to a capacitive reactive current on the line side, which decreases with increasing load of the Smart Infeed and it is no longer present when the rated load is reached.

The magnitude of the capacitive reactive current at no-load condition is depending on the DC link capacitance connected to the Smart Infeed. At the maximum permissible DC link capacitance of the connected Motor Modules, the no-load reactive current reaches a magnitude of approx. 15 % to 20 % of the rated current of the Smart Infeed.

The no-load reactive current can, in principle, be prevented by blocking the regenerative operation via corresponding parametrization of the firmware.

The Smart Infeed is a line-commutated rectifier / regenerative unit and produces an unregulated, load-dependent DC link voltage V_{DCLink} from the three-phase line voltage V_{Line} . Under no-load conditions, the DC link is charged to the peak line voltage value, i.e. $V_{DCLink} = 1.41 \cdot V_{Line}$. When the DC link is loaded, its voltage drops more than with the Basic Infeed, as the voltage drop at the 4 % reactor of the Smart Infeed is bigger than at the 2 % reactor of the Basic Infeed. At partial-load the DC link voltage will be $V_{DCLink} \approx 1.32 \cdot V_{Line}$ and at full load,

$$V_{DCLink} \approx 1.30 \cdot V_{Line}$$

Fundamental Principles and System Description

Engineering Information

As the DC link voltage is unregulated, line voltage fluctuations cause the DC link voltage to fluctuate correspondingly.

With S120 Smart Line Modules, the connected DC link is precharged via resistors, which create losses. Due to the power loss that occurs in the resistors during precharging, the permissible DC link capacitance of the connected inverters (S120 Motor Modules) is limited to relatively low values. This restriction is not only required due to the power losses, however, but also to protect the diodes in the IGBT modules against an excessive recharge current from entering the DC link capacitors when the voltage is restored following voltage dips.

The maximum permissible DC link capacitance for the different S120 Smart Line Modules can be found in the section "Checking the maximum DC link capacitance" of the chapter "SINAMICS S120, General Information about Built-in and Cabinet Units".

To achieve an increased output power rating, it is possible to connect up to four S120 Smart Line Modules in parallel (including 6-pulse and 12-pulse configurations). Further details can be found in the section "Parallel connections of converters".

Due to the operating principle of the 6-pulse three-phase bridge circuit, the Smart Infeed causes relatively high harmonic effects on the supply system. The line current contains a high harmonic content with harmonic numbers $h = n \cdot 6 \pm 1$, where n assumes integers 1, 2, 3, etc. The harmonic currents produced in rectifier operation (motor operation) are identical as those of the Basic Infeed and have the same spectral distribution. The Total Harmonic Distortion factor of the current THD(I) is typically in the range from about 30 % to 45 %. In regenerative operation, the 5th harmonic decreases significantly but all the others increase slightly so that the Total Harmonic Distortion factor THD(I) only decreases by a few percent. The use of Line Harmonics Filters for the reduction of harmonic effects is not permissible with Smart Infeeds due to the different spectrums of the current harmonics in rectifier operation (motor operation) and in regenerative operation. A reduction of the Total Harmonic Distortion factor (THD)(I) to a value of approx. 10% can only be achieved with 12-pulse circuits, i.e. by supplying two Smart Line Modules from a three-winding transformer with a 30° phase displacement between its secondary voltages.

The criteria for defining of the required transformer power rating, taking into account the harmonic load as well as the characteristics of three-winding transformers in 12-pulse operation, are described in the section "Transformers".

Fundamental Principles and System Description

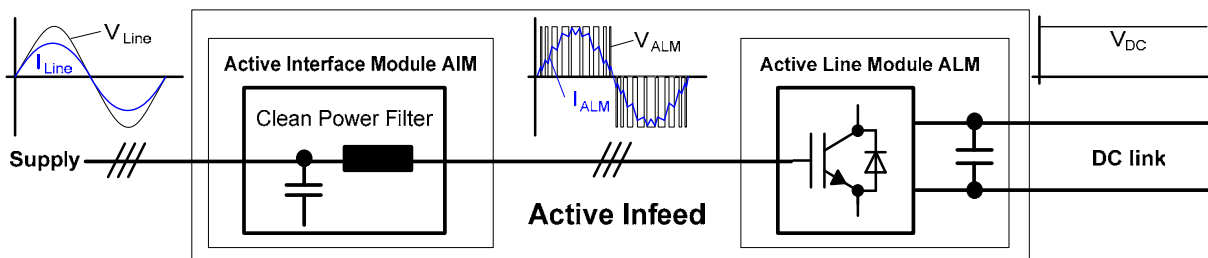
Engineering Information

Active Infeed

The Active Infeed is an actively pulsed, regulated rectifier / regenerative unit for four-quadrant operation (i.e. energy flows from the supply system to the DC link and vice versa).

The Active Infeed comprises a self-commutated IGBT inverter (Active Line Module ALM), which operates on the supply system via the Clean Power Filter (Active Interface Module). The Active Line Module operates according to the method of pulse-width modulation and generates a constant, regulated DC link voltage V_{DC} from the three-phase line voltage V_{Line} . The Clean Power Filter, which is installed between the Active Line Module and the supply system, filters out, as far as possible, the harmonics from the Active Line Module's pulse-width-modulated voltage V_{ALM} , thereby ensuring a virtually sinusoidal input current on the line side and, therefore, minimal harmonic effects on the supply system.

The Active Infeed is the highest grade SINAMICS infeed variant. It is a component of SINAMICS S150 cabinet units and is available as a stand-alone infeed of the SINAMICS S120 modular system, in Chassis and Cabinet Modules format.



SINAMICS S120 Active Infeed comprising an Active Interface Module and an Active Line Module

The Active Infeed is a self-commutated rectifier / regenerative unit and produces from the three-phase line voltage V_{Line} a regulated DC link voltage V_{DCLink} , which remains constant independently from line voltage variations and supply voltage dips. It operates as a step-up converter, i.e. the DC link voltage is always higher than the peak value of the line voltage ($V_{DCLink} > 1.41 \cdot V_{Line}$). The value can be parameterized. The factory setting is

$$V_{DCLink} = 1.50 \cdot V_{Line}$$

This setting should not be changed without a valid reason. Reducing the factory-set value tends to impair the control quality while increasing it unnecessarily increases the voltage on the inverter and the motor winding. If the permissible voltage of the motor winding is sufficiently high (see section "Increased voltage stress on the motor winding as a result of long cables"), the DC link voltage can be increased from the factory setting to the values V_{DCmax} specified in the table. This method allows a voltage higher than the line voltage to be obtained at the output of the inverter or Motor Module connected to the Active Infeed. The table shows the maximum achievable inverter output voltage as a function of the DC link voltage and the modulation system used for vector control (space vector modulation SVM or pulse-edge modulation PEM).

Supply voltage V_{Line}	Maximum permissible DC link voltage in steady-state operation $V_{DC \text{ max.}}$	Maximum attainable output voltage with space vector modulation $V_{out \text{ max SVM}}$	Maximum attainable output voltage with pulse-edge modulation $V_{out \text{ max. PEM}}$
Units with 380 V – 480 V 3AC	720 V	503 V	538 V
Units with 500 V – 690 V 3AC in operation with supply voltages 500 V – 600 V 3AC 660 V – 690 V 3AC	910 V 1100 V	636 V 770 V	680 V 822 V

SINAMICS Active Infeed: Maximum, continuously permissible DC link voltages and attainable output voltages

As the magnitude of the DC link voltage can be parameterized and the DC link current depends on this parameter setting, the DC current is not suitable as a criterion for dimensioning the Active Infeed required. For this reason, the power balance of the drive should always be used as a basis for dimensioning the Active Infeed.

Fundamental Principles and System Description

Engineering Information

The first important quantity to know is the mechanical power P_{mech} to be produced on the motor shaft. Starting with this shaft power value, it is possible to work out the electrical active power P_{Line} to be drawn from the supply system by adding the power loss of the motor $P_{\text{L Mot}}$, the power loss of the Motor Module $P_{\text{L MoMo}}$ and the power loss of the Active Infeed $P_{\text{L AI}}$ to the mechanical power value P_{mech} .

$$P_{\text{Line}} = P_{\text{mech}} + P_{\text{L Mot}} + P_{\text{L MoMo}} + P_{\text{L AI}}.$$

It is also possible to use the efficiency factors of the motor (η_{Mot}), Motor Module (η_{MoMo}) and Active Infeed (η_{AI}) instead of the power loss values

$$P_{\text{Line}} = P_{\text{mech}} / (\eta_{\text{Mot}} \cdot \eta_{\text{MoMo}} \cdot \eta_{\text{AI}}).$$

The active power to be drawn from the supply system depends on the line voltage V_{Line} , the line current I_{Line} and the line-side power factor $\cos\phi_{\text{Line}}$ as defined by the relation

$$P_{\text{Line}} = \sqrt{3} \cdot V_{\text{Line}} \cdot I_{\text{Line}} \cdot \cos\phi_{\text{Line}}.$$

This is used to calculate the required line current I_{Line} of the Active Infeed as follows:

$$I_{\text{Line}} = P_{\text{Line}} / (\sqrt{3} \cdot V_{\text{Line}} \cdot \cos\phi_{\text{Line}}).$$

If the Active Infeed is operated according to the factory setting, i.e. with a line-side power factor of $\cos\phi_{\text{Line}} = 1$, so it draws only pure active power from the supply. Then the formula can be simplified to

$$I_{\text{Line}} = P_{\text{Line}} / (\sqrt{3} \cdot V_{\text{Line}}).$$

The Active Infeed must now be selected such that the permissible line current of the Active Infeed is higher or equal to the required value I_{Line} .

At operation with a line-side power factor $\cos\phi_{\text{Line}} = 1$, the resultant line current is generally lower than the motor current. This is due to the fact that the motor has a typical power factor $\cos\phi_{\text{Mot}} \leq 0.9$ and therefore requires a relatively high reactive current. However, this is drawn from the DC link capacitors rather than from the supply system, resulting in a line current that is lower than the motor current.

Due to the fact that the Active Infeed operates as a step-up converter, it maintains the DC link voltage at a constant level, even at significant line voltage variations and line voltage dips. If the drive must tolerate supply voltage dips of more than 15 % without tripping, the following points must be noted:

- The internal auxiliary supply must be fed by a secure, external supply with 230 V (e.g. by means of an uninterruptible power supply UPS).
- The line-side undervoltage trip level must be parameterized to a correspondingly low value.
- The Active Infeed must be capable of providing current reserves so that it can increase the current to compensate for the decreasing power in rectifier / regenerative mode resulting from the low voltage level during the line voltage dip.

More detailed information can be found in the section "Supply systems and supply system types" in the subsection "Behaviour of SINAMICS converters during supply voltage variations and dips".

At S150 converters and S120 Active Infeeds, the connected DC link is precharged by means of resistors in the Active Interface Modules, which creates losses. To precharge the DC link, the Active Interface Module and the associated Active Line Module are connected to the supply system on the line side via a precharging contactor and precharging resistors. Once precharging is complete, the bypass contactor is closed and the precharging contactor is opened again shortly afterwards. Due to the short overlapping time between the precharging contactor and the bypass contactor (required due to the structure of the Clean Power Filter), precharging and main circuit must have the same phase sequence, otherwise the precharging resistors may be overloaded and destroyed.

Fundamental Principles and System Description

Engineering Information

Due to the power losses which occur during precharging in the resistors, the permissible DC link capacitance of the connected inverter(s) is limited to a relatively low value. The maximum permissible DC link capacitance for the different S120 Active Interface Modules / Active Line Modules can be found in the section "Checking the maximum DC link capacitance" of the chapter "SINAMICS S120, General Information about Built-in and Cabinet Units".

To achieve an increased output power rating, it is possible to make a parallel connection of up to four S120 Active Line Modules with the matching Active Interface Modules. Further details can be found in the section "Parallel connections of converters".

Due to the principle of active pulsing combined with the line-side Clean Power Filter, the harmonic effects on the supply caused by the Active Infeed are virtually non-existent. The harmonic content of the line current is only very minor, meaning that there are scarcely any harmonics in the line voltage either. Each individual current harmonic and voltage harmonic is typically below 1% of the rated current or rated voltage with an Active Infeed. The Total Harmonic Distortion factors of the current THD(I) and voltage THD(U) are typically less than 3%

The criteria for defining of the required transformer power rating, taking into account the harmonic load are described in the section "Transformers".

Creating a separate network with the Active Infeed

The SINAMICS Active Infeed is designed as an Infeed component for SINAMICS drive systems. Therefore, it must be connected to an existing, three-phase supply system. By means of the Voltage Sensing Module VSM integrated into the Active Interface Module AIM, it measures the voltage of the supply system according to magnitude and phase angle, synchronises itself on the supply voltage and frequency and regulates the DC link voltage for the connected drive configuration to a constant value, which can be parameterized.

A separate network cannot currently be created by means of an Active Infeed since it is not equipped with a line frequency generator and line frequency controller. For this reason, applications that need to create a separate network by means of a self-commutated, line-side converter as an interface to the supply system are currently not compatible with SINAMICS Active Infeeds. Such applications include:

- Wind power plants with Active Infeeds for creating local separate networks
- Solar power systems with Active Infeeds for creating local separate networks
- Diesel-electric emergency power supply sets with Active Infeeds for creating local separate networks
- Wave generators on ships with Active Infeeds for creating on-board supply systems

Note:

The fact that the Active Infeed does not have a line frequency generator can lead to critical operating conditions if an Active Infeed in no-load operation is separated from the supply system by the opening of the main contactor or the circuit breaker without a preceding OFF command. Therefore, it is absolutely essential that the operation of the Active Infeed is always stopped with an OFF command before it is separated from the supply system.

Fundamental Principles and System Description

Engineering Information

Comparison of the properties of the different SINAMICS Infeeds

The table below shows a brief, general comparison of all the key properties of the different Infeed types.

SINAMICS Infeeds	Basic Infeed	Smart Infeed	Active Infeed
Mode of operation	Rectifier mode (2Q)	Rectifier / regenerative mode (4Q)	Rectifier / regenerative mode (4Q)
Stable operation in regenerative mode also during line supply failures	Not relevant	Yes	Yes
Power semiconductors	Thyristors / Diodes	IGBT modules	IGBT modules
Line-side reactor	2 %	4 %	Clean Power Filter in AIM
Power factor $\cos\phi$ (fundamental frequency)	> 0.96	> 0.96	Parameterizable (factory setting = 1)
Total Harmonic Distortion factor of the line current THD(I) - 6-pulse - 6-pulse with LHF - 12-pulse	Typically 30 % - 45 % Typically 8 % - 10 % Typically 8 % - 10 %	Typically 30 % - 45 % - Typically 8 % - 10 %	Typically 3 % - -
EMC filter category C3	Yes	Yes	Yes
DC link voltage at full load	$1.32 \cdot V_{\text{Line}}$ (non-stabilized)	Approx. $1.30 \cdot V_{\text{Line}}$ (non-stabilized)	$> 1.42 \cdot V_{\text{Line}}$ (stabilized and programmable)
Voltage at motor winding	Low	Low	Higher than with Basic Infeed and Smart Infeed
Precharging	- By means of the firing angle with thyristors - By means of resistors with diodes	By means of resistors	By means of resistors
Prechargeable DC link capacitance	- High with thyristors - Low with diodes	Low	Low
Efficiency	> 99.0 %	> 98.5 %	> 97.5 %
Volume	Low	Medium	High
Price	Low	Medium	High

Comparison of the properties of different SINAMICS Infeeds

Fundamental Principles and System Description

Engineering Information

Redundant line supply concepts

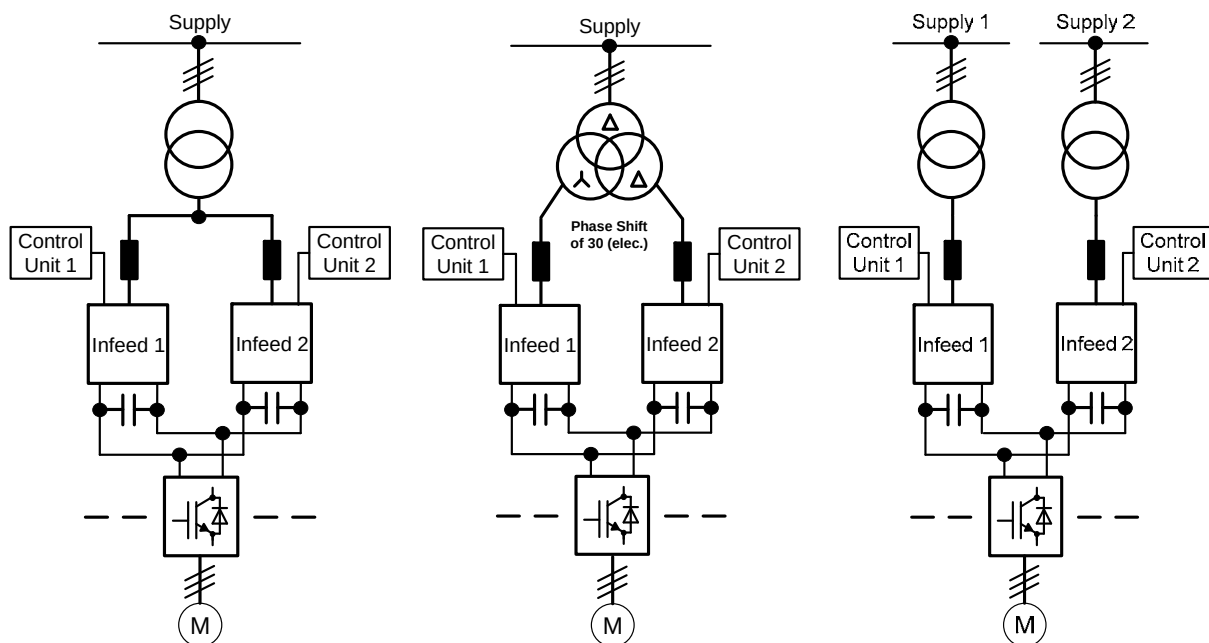
General

Certain applications require redundant infeeds for multi-motor drives or common DC link configurations to increase availability. This demand can basically be fulfilled by using several independent Infeed units working in parallel on the common DC link. If one Infeed unit fails the common DC link can be supplied by the remaining Infeed unit, usually without interruption. Depending on the power rating of the Infeed units the common DC link can continue to operate at between half and full power. The difference between redundant Infeeds and the parallel connection of Infeeds for increasing the power rating, as described in the section "Parallel connections of converters", is the arrangement of the Control Units. At redundant Infeeds each Infeed is controlled by its own Control Unit. Therefore, each Infeed is completely autonomous. At the parallel connection of Infeeds, a single Control Unit controls and synchronizes all power units in the parallel configuration, which behaves as a single Infeed with a higher power rating.

Note:

When several independent infeeds are used, this can considerably increase the availability of the DC busbar. In practice, however, 100% fault tolerance is impossible since certain fault scenarios can still cause an interruption in operation (such as a short circuit on the DC busbar). Even if these fault scenarios are extremely unlikely to occur, the risk of their occurring cannot be completely eliminated in practice.

Depending whether the demand for redundancy is related only to the Infeed units or also to the supplying transformers or the supply systems, different circuit concepts are possible, which are shown and explained below.



Variant 1:

Supply from a single supply system with a double-winding transformer

Variant 2:

Supply from a single supply system with a three-winding transformer

Variant 3:

Supply from two independent supply systems with two transformers

At **variant 1**, both redundant Infeeds with the same power rating are supplied from one supply system via a two-winding transformer. As both infeeds are supplied with exactly the same voltage on the line side, in normal operation the current distribution is largely symmetrical, even with unregulated infeeds. The infeeds can, therefore, be dimensioned so that each infeed can provide half of the total current taking into account a small current derating factor. If one infeed fails, only half of the power required will be available. If the full power is required when one infeed fails, each infeed must be dimensioned to provide the full power.

At **variant 2**, both redundant Infeeds with the same power rating are also supplied from one supply system, but via a three-winding transformer. Depending on the characteristics of the transformer, the line-side voltages of both infeeds can have small tolerances of approx. 0.5 % to 1 %. This leads in normal operation with unregulated infeeds to a current distribution which is slightly less symmetrical than at variant 1. This must be taken into account and covered by corresponding current derating factors. If the full power is required when one infeed fails, each infeed must be dimensioned to provide the full power.

At **variant 3**, both redundant Infeeds with the same power rating are supplied by two independent supply systems with two separate two-winding transformers. As the voltages of both independent supply systems can be noticeably different, very large imbalances in the current distribution can occur in normal operation with unregulated infeeds. If voltage tolerances between the two supply systems of between 5 % and 10 % have to be dealt with, it is absolutely necessary, when using unregulated Infeeds, to dimension each infeed to provide the full power.

The following paragraphs will explain which of the three redundant line supply concepts (variants 1 to 3) can be realized with the three Infeed types available with SINAMICS (Basic Infeed, Smart Infeed, Active Infeed) and which boundary conditions must be observed.

Redundant line supply concepts with the SINAMICS Basic Infeed

With the line-commutated, unregulated SINAMICS Basic Infeed all three variants can be used.

Variant 1 with SINAMICS Basic Infeed, boundary conditions to be observed:

- For each Basic Line Module a line reactor with a short-circuit voltage of 2 % is required.
- If it can be accepted that the common DC link is operating with half the power when a Basic Line Module fails, each Basic Line Module can be selected for half the input current taking into account a current derating of 7.5 % related to the rated current, as with the 6-pulse, parallel connection of Basic Line Modules. If the full power is still required by the common DC link when a Basic Line Module fails, each Basic Line Module must be selected for the full power.
- Each Basic Line Module must be able to precharge the complete common DC link capacitance.

Variant 2 with SINAMICS Basic Infeed, boundary conditions to be observed:

- If the three-winding transformer corresponds to the specification in the section "Transformers", subsection "Three-winding transformers", line reactors are not required.
- If the three-winding transformer corresponds to the specification in the section "Transformers", subsection "Three-winding transformers", and it can be accepted that the common DC link is operating with half the power when a Basic Line Module fails, each Basic Line Module can be selected for half the input current taking into account a current derating of 7.5 % related to the rated current, as with the 12-pulse, parallel connection of Basic Line Modules. If the full infeed power is required when a Basic Line Module fails, each of the two Basic Line Modules and their associated transformer windings must be dimensioned in line with the full power required for the DC link.
- Each Basic Line Module must be able to precharge the complete common DC link capacitance.

Variant 3 with SINAMICS Basic Infeed, boundary conditions to be observed:

- A line reactor with a short-circuit voltage of 2 % is not required.
- Due to the possibility of large voltage tolerances between both supply systems, it is absolutely necessary that each Basic Line Module is configured for the full power required by the common DC link.
- Each Basic Line Module must be able to precharging the complete common DC link capacitance.

Fundamental Principles and System Description

Engineering Information

Redundant line supply concepts with the SINAMICS Smart Infeed

With the line-commutated unregulated SINAMICS Smart Infeed only variant 2 can be used.

Variant 2 with SINAMICS Smart Infeed, boundary conditions to be observed:

- Each Smart Line Module requires a line reactor with a short-circuit voltage of 4 %.
- If the three-winding transformer corresponds to the specification in the section "Transformers", subsection "Three-winding transformers", and it can be accepted that the common DC link is operating with half the power when a Smart Line Module fails, each Smart Line Module can be selected for half the input current taking into account a current derating of 7.5 % related to the rated current, as with the 12-pulse, parallel connection of Smart Line Modules. If the full infeed power is required when a Smart Line Module fails, each of the two Smart Line Modules and their associated transformer windings must be dimensioned in line with the full power required for the DC link.
- Each Smart Line Module must be able to precharge the complete common DC link capacitance.

Redundant line supply concepts with SINAMICS Active Infeed (master-slave configuration)

The regulated SINAMICS Active Infeed allows variants 2 and 3 to be realized. The individual Active Infeeds, which comprise an Active Interface Module AIM and an Active Line Module ALM, must be configured and set up so that they are completely autonomous. They must operate in master-slave configuration. An autonomous setup means:

- Each Active Infeed must have a separate Control Unit CU320.
- The Control Unit CU320 for each of the Active Infeeds must only control the Active Infeed to which it is assigned.
- The Motor Modules on the DC link must be operated completely independently from the Infeed Modules on a separate Control Unit CU320 or several separate Control Units CU320.

The master infeed is operating in voltage control mode and regulates the DC link voltage V_{DC} of the DC link, while the slave infeed(s) is/are operating in current control mode, whereby one master infeed is required and not more than 3 slave infeeds are permissible.

The current setpoint for the slave infeed(s) can be transferred from the master infeed to the slave infeed(s) via PROFIBUS DP V2 slave-to-slave communication when a higher-level control system is used or via analog channels, when Terminal Modules TM31 are used. For more information about communication and parameterization, see the SINAMICS S120 Function Manual 1.

If a slave infeed fails, the master infeed and any other slave infeed will continue operation. If a master infeed fails, a slave infeed must switch over from slave operation in current control mode to master operation in voltage control mode. This can be done during operation (i.e. without the need for any downtime).

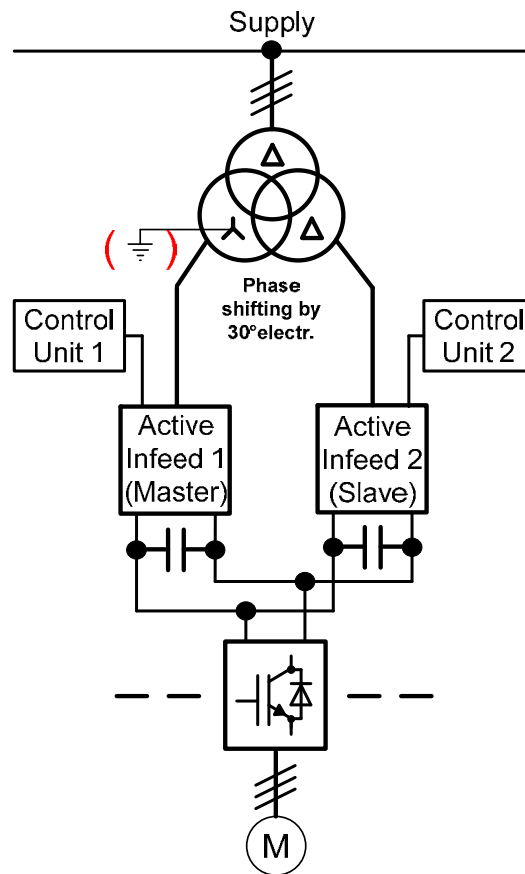
Note:

Master-slave configuration of SINAMICS S120 Active Infeeds will be available with firmware version V2.6 from autumn 2008.

Variant 2 with Active Infeed (master-slave configuration); boundary conditions to be observed:

- Both of the two Active Infeeds (master and slave) must be electrically isolated on the line side to prevent circulating currents that may otherwise occur between the systems as a result of autonomous, unsynchronized operation with two independent Control Units. This electrical isolation, which is absolutely essential, is ensured by means of the three-winding transformer.

Depending on the type of supply system required (grounded TN supply system or non-grounded IT supply system), the star point of the star winding supplying the master infeed can be grounded (TN supply system) or remain open (IT supply system). With respect to voltage loads on the DC link and on the motor windings to ground, however, operation with a non-grounded IT supply system is preferable. The winding for the slave infeed must remain non-grounded in all cases.



- If it is acceptable to operate the DC link at half power if an Active Infeed fails, each Active Infeed can be dimensioned for half the infeed current, taking into account a current derating of 5% with respect to the rated current. If the full infeed power is required if an Active Infeed fails, each of the two Active Infeeds and the associated transformer windings must be dimensioned for the full power required for the DC link.
- Each Active Line Module in conjunction with its Active Interface Module must be able to precharge the complete common DC link capacitance.

Variant 3 with Active Infeed (master-slave configuration); boundary conditions to be observed:

- The Active Infeeds (master and slave(s)) must be electrically isolated on the line side to prevent circulating currents that may otherwise occur between the systems as a result of autonomous, unsynchronized operation with independent Control Units.

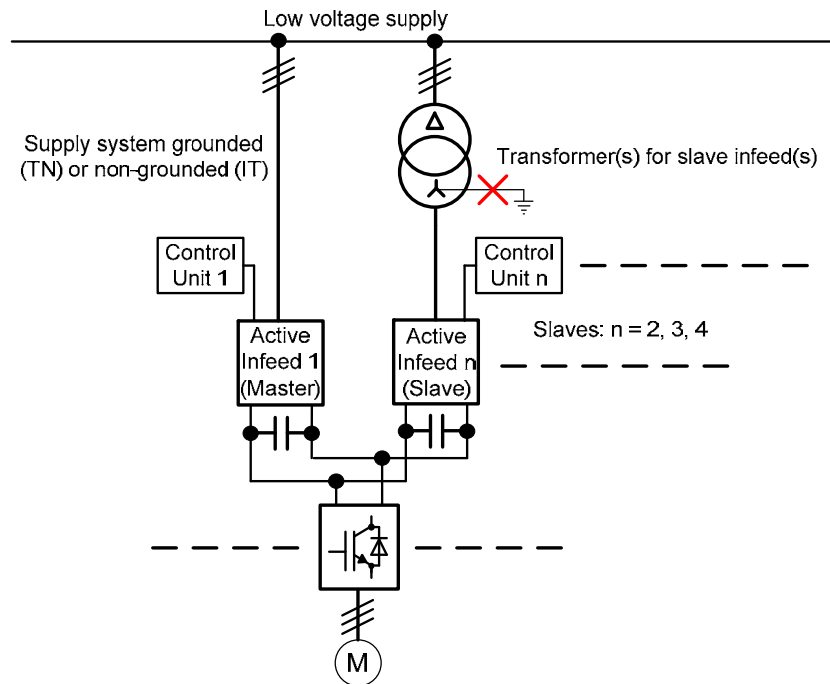
Depending on whether the Active Infeeds are supplied from a common low-voltage supply system or from different medium-voltage supply systems, a distinction is made between two configurations:

a) Supply from a common low-voltage supply system:

- The master infeed is connected directly to the low-voltage supply system, whereby the supply system can be operated as either a grounded (TN) or non-grounded (IT) supply system. With respect to voltage loads on the DC link and on the motor windings to ground, however, operation with a non-grounded IT supply system is preferable.
- The slave infeed(s) must be supplied by its / their own isolation transformer, whereby all secondary windings must be non-grounded.

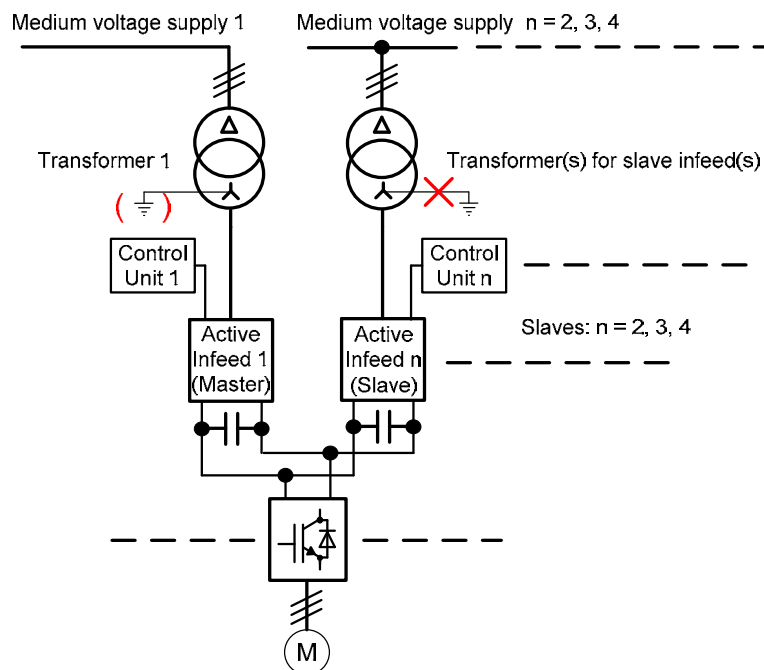
Fundamental Principles and System Description

Engineering Information



b) Supply from different medium-voltage supply systems:

- The master infeed is supplied via isolation transformer 1, whereby the secondary winding can be either grounded (TN supply system) or non-grounded (IT supply system). With respect to voltage loads on the DC link and on the motor windings to ground, however, operation with a non-grounded IT supply system is preferable.
- The slave infeed(s) must be supplied by its/their own isolation transformer, whereby all secondary windings must be non-grounded.



- If it is acceptable to operate the DC link at reduced power if an Active Infeed fails, each Active Infeed can be dimensioned for the respective proportion of the full infeed current, taking into account a current derating of 5% with respect to the rated current. If the full infeed power is required if an Active Infeed fails, each of the Active Infeeds and associated transformers must be oversized accordingly.
- The Active Line Modules that remain in operation if a fault occurs must, in conjunction with the Active Interface Modules, be able to precharge the complete common DC link capacitance.

Fundamental Principles and System Description

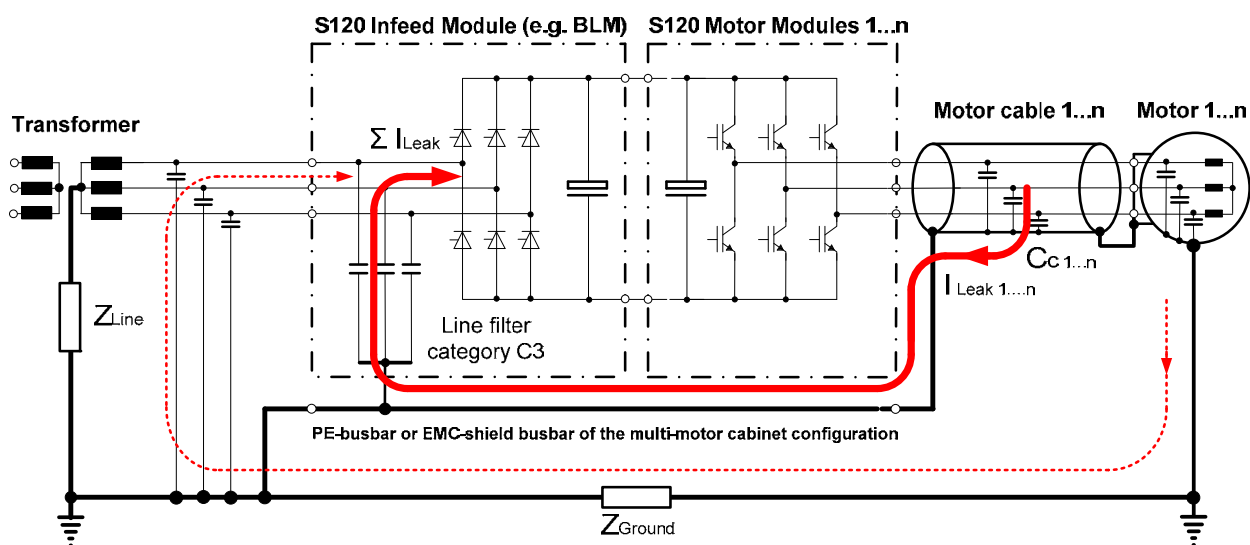
Engineering Information

Permissible total cable length for S120 Infeed Modules feeding multi-motor drives

General

In the case of SINAMICS S120 multi-motor drives where an S120 Infeed Module supplies a DC busbar with more than one S120 Motor Module, not only the length of the cable between each individual Motor Module and its associated motor is limited, but also the total cable length (i.e. the sum of the motor cable lengths for all the Motor Modules that are fed from a common Infeed Module via a common DC busbar).

The total cable length must be restricted to ensure that the resulting total capacitive leakage current ΣI_{Leak} (sum of the capacitive leakage currents I_{Leak} generated from the individual Motor Modules 1...n), which depends on the overall motor cable length, does not overload the Infeed Module. This current is flowing back to the DC busbar via either the line filter of the Infeed Module or the supply system and via the Infeed Module itself.



Route of the resulting total leakage current ΣI_{Leak} for a multi-motor drive with SINAMICS S120

If the total cable length and, in turn, the total leakage current ΣI_{Leak} are not sufficiently restricted, the integrated line filters according to category C3 of EN 61800-3, the power components of the Infeed Module, and the snubber circuits for the power components in the Infeed Module may be overloaded due to an excessive current or dv/dt load.

The permissible total cable lengths are device specific and are, therefore, specified in the relevant catalogs or in the section "Checking the total cable length with multi-motor drives" of the chapter "SINAMICS S120, General Information about Built-in and Cabinet Units".

For more information about the cause of capacitive leakage currents and their magnitude, see section "Line filters".

EMC information

SINAMICS S120 multi-motor drives with a total cable length of several kilometers generally only meet the criteria of category C4 according to the EMC product standard EN 61800-3. The standard, however, clearly states that this is permissible for complex systems of this type with rated currents of more than 400 A used in an industrial environment, as well as for IT supply systems used in an industrial environment. In such cases, system integrators and plant operators must define an EMC plan, which means customized, system-specific measures to ensure compliance with the EMC requirements.

This applies regardless of whether the SINAMICS S120 multi-motor drive is operated on a grounded TN supply system with line filters integrated in the SINAMICS Infeed Module as standard, or on a non-grounded IT supply system with a deactivated line filter.

■ Effects of using fast-switching power components (IGBTs)

IGBTs (Insulated Gate Bipolar Transistors) are the only type of power semiconductors used in the power units of the SINAMICS motor-side inverters. One of the characteristics of these modern power components is that they are capable of very fast switching. As a result, the power losses incurred in the inverter with every switching operation are kept low and the inverter can therefore be operated at a relatively high pulse frequency. It is thus possible to obtain a motor current which is very close to sinusoidal and the oscillating torques and stray losses caused in the motor by the converter operation remain low.

The fast switching of the IGBTs does, however, cause undesirable side effects.

When long motor cables are used, the substantial motor cable capacitances are charged and discharged very quickly with every switching operation of the IGBTs, thereby loading the inverter output with high additional current peaks.

Furthermore, the propagation time of the electromagnetic waves moving along the motor cable causes voltage reflections at the motor terminals which increase the voltage on the motor winding.

Another effect is the increased current flow in the motor bearings caused by the high voltage rate of rise at the motor terminals of converter-fed drives.

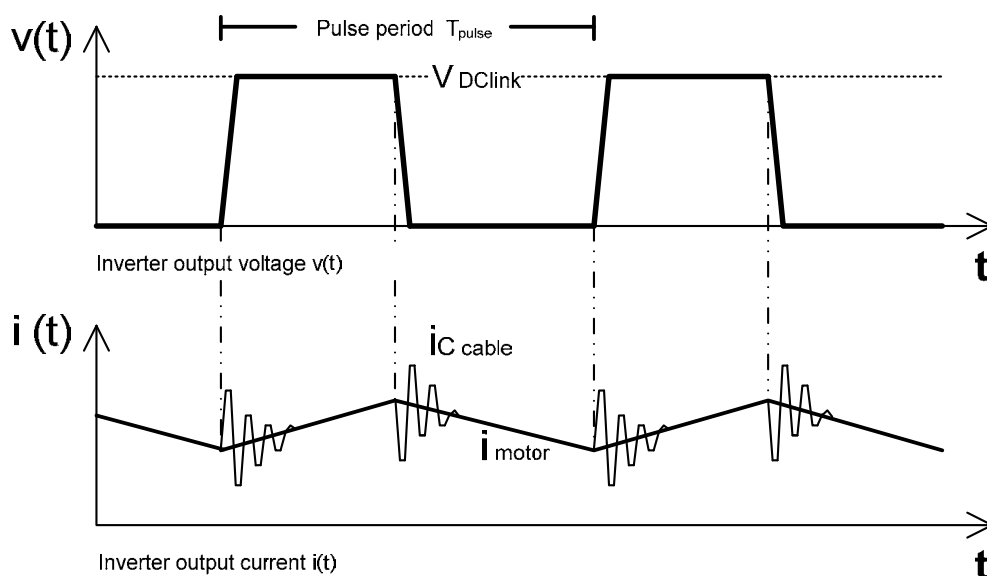
All these effects need to be considered when the drive is configured to prevent the inverter from shutting down with the error message "Overcurrent" before it reaches its configured output current and to protect the motor against premature failure due to winding or bearing damage.

The individual side effects and appropriate corrective actions are discussed in more detail below.

Increased current load on the inverter output as a result of long motor cables

The cable capacitance of motor cables is in proportion to their length. The cable capacitance on very long motor cables is therefore substantial, particularly if the cables are shielded or several cables are installed in parallel in the case of drives with high power ratings.

This capacitance is charged and discharged with every switching operation of the IGBTs in the inverter, as a result of which additional current peaks are superimposed on the actual motor current, as the diagram below illustrates.



Instantaneous values of inverter output voltage and inverter output current with long motor cables

Fundamental Principles and System Description

Engineering Information

The amplitude of these current peaks is in proportion to the cable capacitance, i.e. the cable length, and to the voltage rate of rise dv/dt at the converter output in accordance with the relation

$$I_{c \text{ Cable}} = C_{\text{Cable}} \cdot dv/dt.$$

Although the additional current peaks decay within a period of a few μs , the inverter must be able to provide them for this short period in addition to the motor current. The inverter is capable of providing the peak currents up to a specific limit of the motor cable capacitance. However, if this limit is exceeded because the motor cables are too long or too many of them are connected in parallel, the inverter will shut down with error message "Overcurrent".

At the drive configuration stage, therefore, it is important to observe the motor cable lengths and cross-sections specified for individual inverter units. Alternatively, additional measures have to be taken to allow the connection of greater cable lengths and cross-sections.

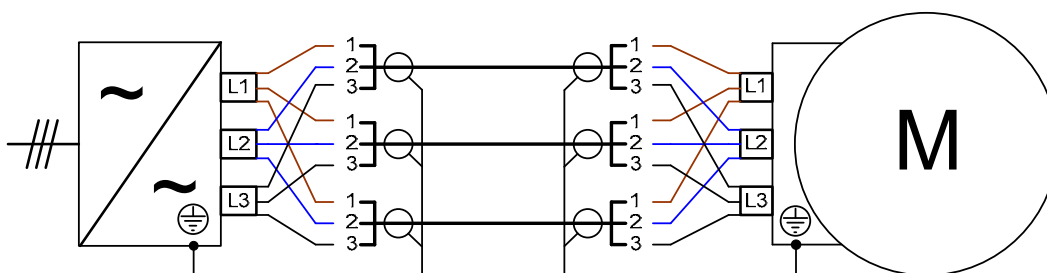
For basic configurations, i.e. without motor reactors, dv/dt filters plus VPL or sine-wave filters at the inverter output, the permissible cable lengths which apply as standard to SINAMICS G130, G150, S150, S120 Motor Modules (Chassis and Cabinet Modules) are listed in the table below:

Line supply voltage	Max. permissible motor cable lengths for basic configurations	
	Shielded cable e.g. Protodur NYCWY	Unshielded cable e.g. Protodur NYY
380 V – 480 V 3AC	300 m	450 m
500 V – 600 V 3AC	300 m	450 m
660 V – 690 V 3AC	300 m	450 m

Permissible motor cable lengths for basic configurations of SINAMICS G130 Chassis, SINAMICS G150 and S150 cabinets and SINAMICS S120 Motor Modules in the format Chassis and Cabinet Modules

Note:

The specified motor cable lengths always refer to the distance between inverter output and motor along the cable route and already allow for the fact that several cables must be routed in parallel for drives in the higher power range. The recommended and the maximum connectable cross-sections plus the permissible number of parallel motor cables are unit-specific values. These values can be found in the unit-specific chapters of this engineering manual or in the relevant catalogs. Where more than one motor cable is routed in parallel, please note that each individual motor cable must contain all three conductors of the three-phase system. This helps to minimize the magnetic leakage fields and thus also the magnetic interference on other loads. The diagram below shows an example of three motor cables routed in parallel.



Symmetrical connection to the converter and motor of several motor cables routed in parallel

Example:

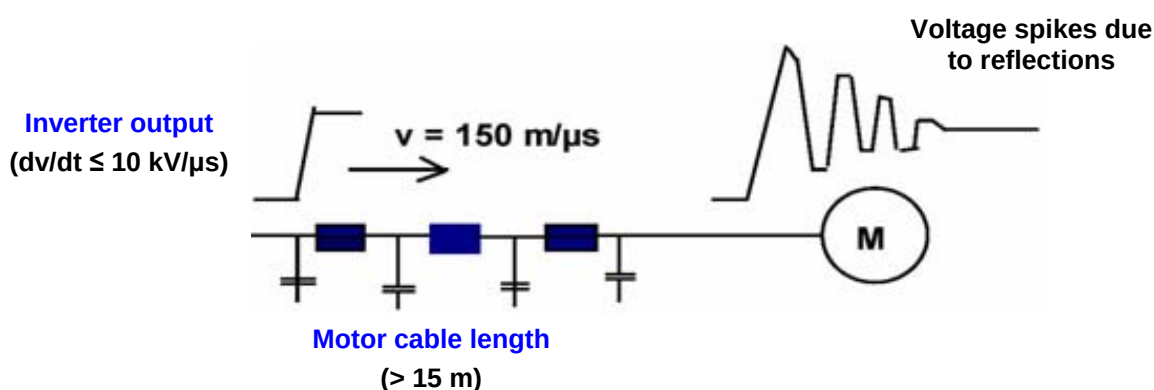
In the case of the SINAMICS G150 cabinet, 380 V to 480 V, 560 kW, catalog D11 recommends the routing of four parallel cables with a cross-section each of 185 mm^2 for the motor connection. According to the table above, converter output and motor can be positioned at a distance of 300 m along the cable route when shielded cables are used. With this constellation, therefore, $4 \cdot 300 \text{ m} = 1200 \text{ m}$ of cable would need to be installed in order to implement the maximum permissible cable distance of 300 m between the inverter and motor.

If the specified motor cable lengths are not sufficient for some special drive constellations, suitable measures must be taken to allow the use of greater motor cable lengths and cross-sections. This can be achieved, for example, by using appropriately dimensioned motor reactors which attenuate the additional current peaks and allow the connection of a higher motor cable capacitance (see section "Motor reactors").

Increased voltage stress on the motor winding as a result of long motor cables

The IGBTs used in SINAMICS inverters connect the DC link voltage V_{DCLink} to the inverter output with a rise time of $T_r \geq 0.1 \mu s$. In the case of a 690 V supply with a DC link voltage of virtually 1000 V, this corresponds to a voltage jump with a rate of rise of $dv/dt \leq 10 \text{ kV}/\mu s$. The typical average values of voltage rate of rise for SINAMICS inverters are $dv/dt = 3 \text{ kV}/\mu s$ to $6 \text{ kV}/\mu s$. If the inverter output is connected directly to the motor cable, i.e. no motor-side options such as motor reactors, dv/dt filters plus VPL or sine-wave filters are installed at the inverter output, this voltage jump moves along the motor cable towards the motor with a velocity of about $150 \text{ m}/\mu s$ (half the speed of light).

Since the impedance $Z_{W \text{ Motor}}$ of the motor is significantly higher than the impedance $Z_{W \text{ Cable}}$ of the motor cable, the voltage jump arriving at the motor winding is reflected, causing brief voltage spikes on the motor winding which can reach values of twice the magnitude of the DC link voltage V_{DCLink} .



Characteristic voltage at the inverter output and the motor when a long motor cable is used

The voltage reflection on the motor winding reaches its maximum value when the propagation time t_{prop} along the motor cable is greater than the rise time T_r of the voltage jump at the inverter output, i.e.

$$T_r < t_{prop} = \frac{l_{Cable}}{v}$$

With a minimum rise time of the voltage jump of $T_r = 0.1 \mu s$ and a propagation velocity along the motor cable of $v = 150 \text{ m}/\mu s$, the critical cable length at which the voltage reflection reaches its maximum value can be calculated as

$$l_{Cable} > v \cdot T_r = 150 \frac{m}{\mu s} \cdot 0.1 \mu s = 15 \text{ m}$$

The voltage reflection can therefore reach its maximum value already at relatively short motor cable lengths of 15 m and above. We must therefore assume that in most applications where the inverter output is directly connected to the motor cable and no motor reactors or motor filters are installed, significant voltages spikes of up to twice the magnitude of the DC link voltage will occur on the motor caused by reflections.

In cases where motor cable lengths of $> 15 \text{ m}$ are used and voltage spikes due to reflections must be expected, the absolute magnitude of the reflection-related voltage spikes on the motor are depending on two influencing variables,

- the DC link voltage V_{DCLink} of the inverter and
- the reflection factor r at the motor terminals.

The DC link voltage V_{DCLink} of the inverter is itself depending on three influencing variables,

- the line supply voltage V_{Line} of the drive,
- the type of Infeed (Basic Infeed / Smart Infeed or Active Infeed), and
- the operating conditions of the drive (normal motor operation or braking operation using the $V_{DC \text{ max}}$ controller or a braking unit).

Fundamental Principles and System Description

Engineering Information

The Infeed type determines the relation between the DC link voltage and the line voltage.

The Basic Infeed used with G130, G150 and as S120 Basic Infeed, as well as with the S120 Smart Infeed, provides a DC link voltage which, in normal operation, is typically higher than the line supply voltage by a factor of between 1.32 (full load) and 1.35 (partial load)

$$V_{\text{DCLink}}/V_{\text{Line}} \approx 1.35$$

Active Infeeds which are used on the S150 and as S120 Active Infeed (self-commutated IGBT inverters) operate as step-up converters and the DC link voltage always needs to be controlled to a value higher than the amplitude of the line voltage. The ratio $V_{\text{DCLink}}/V_{\text{Line}}$ must therefore always be greater than 1.42. The ratio $V_{\text{DCLink}}/V_{\text{Line}}$ can be parameterized on Active Infeeds. The factory setting is

$$V_{\text{DCLink}}/V_{\text{Line}} = 1.50$$

This setting should not be changed without a valid reason. Reducing the factory-set value tends to impair the control quality while increasing it unnecessarily increases the voltage on the motor winding.

The operating conditions of the drive also influence the level of the DC link voltage, particularly on units with Basic Infeeds. As these cannot regenerate energy to the power supply system, unlike Smart or Active Infeeds with regenerative feedback capability, the DC link voltage level rises when the motor is braking. To prevent shutdown on over-voltage in the DC link, it is often necessary to activate the $V_{\text{DC max}}$ controller or to use a braking unit on drives with a Basic Infeed. Both of these mechanisms limit the rise of the DC link voltage level during braking.

The $V_{\text{DC max}}$ controller performs this function by manipulating the deceleration ramp. It increases the deceleration time to a value at which the drive only generates as much braking energy as can be converted to heat by the drive power losses.

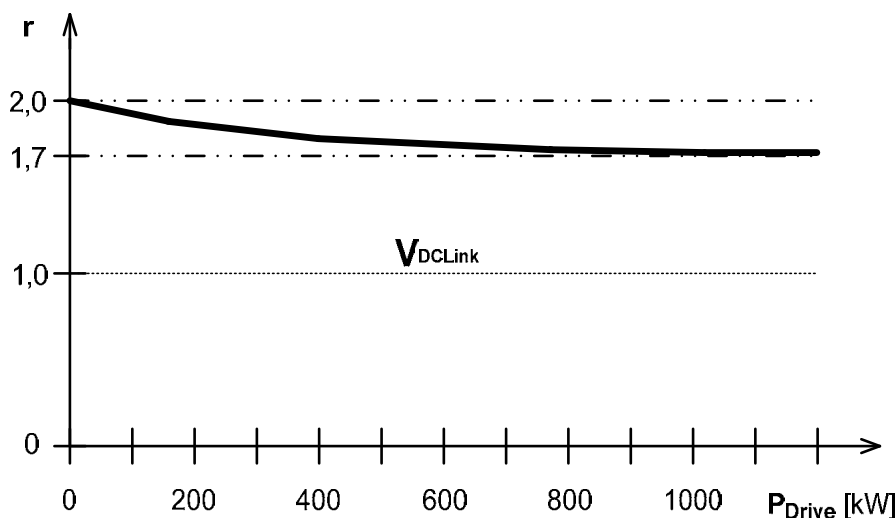
The braking unit limits the DC link voltage level by converting the generated braking energy into heat in the braking resistor.

The DC link voltage level which represents the activation threshold or the operating range for the $V_{\text{DC max}}$ controller and the braking units is virtually identical for both mechanisms and is approximately 20 % higher than the DC link voltage level on drives operating in motor mode with a Basic Infeed.

The reflection factor r is defined as the ratio between the peak voltage phase-to-phase V_{PP} at the motor terminals and the DC link voltage V_{DCLink} of the inverter:

$$r = V_{\text{PP}}/V_{\text{DCLink}}$$

On drives in the output power range of a few kW, the impedance ratio $Z_{\text{W Motor}}/Z_{\text{W Cable}}$ is so high that at maximum reflection a reflection factor of $r = 2$ must be expected. However, as the drive rating increases, the impedance ratio $Z_{\text{W Motor}}/Z_{\text{W Cable}}$ becomes ever more favorable, which means that at maximum reflection the reflection factor to be expected on drives of > 800 kW is only $r = 1.7$, as illustrated by the diagram below.



Typical reflection factor at the motor terminals as a function of drive rating

Fundamental Principles and System Description

Engineering Information

On the basis of the relations and diagrams given above, the peak value of voltage V_{PP} on the motor winding for motor cable lengths of > 15 m can be calculated exactly:

$$V_{PP} = V_{Line} \cdot \frac{V_{DCLink}}{V_{Line}} \cdot r$$

The following tables provide an overview of the peak values of V_{PP} occurring on the motor winding as a function of the above influencing factors for typical SINAMICS drive constellations with motor cable lengths of > 15 m.

The peak values of motor voltage V_{PP} are the lowest on drives with Basic Infeeds operating in motor mode (G130, G150, S120 Basic Line Modules) or on drives with Smart Infeeds.

Line supply voltage V_{Line}	DC link voltage $V_{DCLink} \approx 1.35 \cdot V_{Line}$	Peak voltage V_{PP} on motor winding with a reflection factor of 1.7	Peak voltage V_{PP} on motor winding with a reflection factor of 2.0
400 V	540 V	920 V	1080 V
480 V	650 V	1100 V	1300 V
500 V	675 V	1150 V	1350 V
600 V	810 V	1380 V	1620 V
660 V	890 V	1510 V	1780 V
690 V	930 V	1580 V	1860 V

Peak values of motor voltage V_{PP} with motor cable length > 15 m and a Basic Infeed or Smart Infeed

The peak values of motor voltage V_{PP} are somewhat higher when Active Infeeds are used as these operate as step-up converters (S150, S120 Active Line Modules).

Line supply voltage V_{Line}	DC link voltage set to factory value $V_{DCLink} = 1.5 \cdot V_{Line}$	Peak voltage V_{PP} on motor winding with a reflection factor of 1.7	Peak voltage V_{PP} on motor winding with a reflection factor of 2.0
400 V	600 V	1020 V	1200 V
480 V	720 V	1220 V	1440 V
500 V	750 V	1270 V	1500 V
600 V	900 V	1530 V	1800 V
660 V	990 V	1680 V	1980 V
690 V	1035 V	1760 V	2070 V

Peak values of motor voltage V_{PP} with motor cable length > 15 m and an Active Infeed

Motor voltage V_{PP} reaches the highest peak values during braking when the $V_{DC \max}$ controller or a connected braking unit is active. In the case of a braking unit, it is assumed that its activation threshold has been adjusted to suit the line voltage, i.e. that the lower activation threshold of the braking unit is selected for low line voltages. Details can be found in the unit-specific chapters, e.g. G130 or G150.

Line supply voltage V_{Line}	Activation voltage of braking unit	Peak voltage V_{PP} on motor winding with a reflection factor of 1.7	Peak voltage V_{PP} on motor winding with a reflection factor of 2.0
400 V	673 V (lower threshold)	1140 V	1350 V
480 V	774 V (upper threshold)	1320 V	1550 V
500 V	841 V (lower threshold)	1430 V	1680 V
600 V	967 V (upper threshold)	1640 V	1934 V
660 V	1070 V (lower threshold)	1820 V	2140 V
690 V	1158 V (upper threshold)	1970 V	2320 V

Peak values of motor voltage V_{PP} with motor cable length > 15 m and braking operation with a braking unit

Fundamental Principles and System Description

Engineering Information

The values specified for peak voltage V_{PP} combined with the voltage jump rise time value T_r given at the beginning of this section are the basis for selecting the correct motor insulation and therefore determine whether motors with standard insulation or special insulation are required for converter-fed operation. This applies irrespective of whether the low-voltage motors are supplied by Siemens or another manufacturer.

For further details about Siemens low-voltage motors, please refer to the chapter "Motors". Nevertheless, a brief explanation of how to correctly match the motor insulation of Siemens low-voltage motors to SINAMICS drive systems is given below as the matching criteria are especially easy to understand at this point.

Selection of correct motor insulation for Siemens series 1LA and 1LG low-voltage motors

The table below specifies the permissible voltage limits as a function of insulation system for Siemens low-voltage motors with round-wire windings operating on supplies up to 690 V.

Winding insulation	Line supply voltage V_{Line}	Phase-to-phase V_{PP} permissible	Phase-to-earth V_{PE} permissible	DC link voltage V_{DCLink} permissible
Standard insulation	≤ 500 V	1500 V	1100 V	750 V
Special insulation	> 500 V to 690 V	2250 V	1500 V	1125 V

Permissible voltage limits for Siemens low-voltage motors with round-wire windings up to 690 V

Line supply voltage ≤ 500 V

Motors with standard insulation and a permissible voltage $V_{PP} = 1500$ V (green line) must be used for drives with line supply voltages of ≤ 500 V.

If we compare the peak values V_{PP} occurring at line supply voltages of ≤ 500 V in the tables for drives with Basic Infeeds / Smart Infeeds or Active Infeeds (also green lines), then we see that they are always ≤ 1500 V independent of the reflection factor.

In braking operation with a braking unit, the upper permissible limit of 1500 V for V_{PP} at line supply voltages of ≤ 500 V (also green lines) can generally be maintained only if the reflection factor is $r < 2$ at line voltages of 480 V and 500 V. This applies in the case of G130, G150, S150 and S120 Chassis and Cabinet Modules due to the drive rating of > 75 kW (as shown in diagram: Reflection factor as a function of drive rating).

Line supply voltage > 500 V to 690 V

Motors with special insulation and a permissible voltage $V_{PP} = 2250$ V (yellow line) must be used for drives with line supply voltages of between 500 V and 690 V.

If we compare the peak values V_{PP} occurring at line supply voltages of > 500 V in the tables for drives with Basic Infeeds / Smart Infeeds or Active Infeeds (also yellow lines), then we see that motors with special insulation are required for converter-fed operation on these supply systems.

In braking operation with a braking unit, the upper permissible value for V_{PP} of the special insulation of 2250 V at line supply voltages of > 500 V (also yellow lines) can generally be maintained only if the reflection factor is $r < 2$ at a line voltage of 690 V. This applies in the case of G130, G150, S150 and S120 Chassis and Cabinet Modules due to the drive rating of > 75 kW (as shown in diagram: Reflection factor as a function of drive rating).

Note:

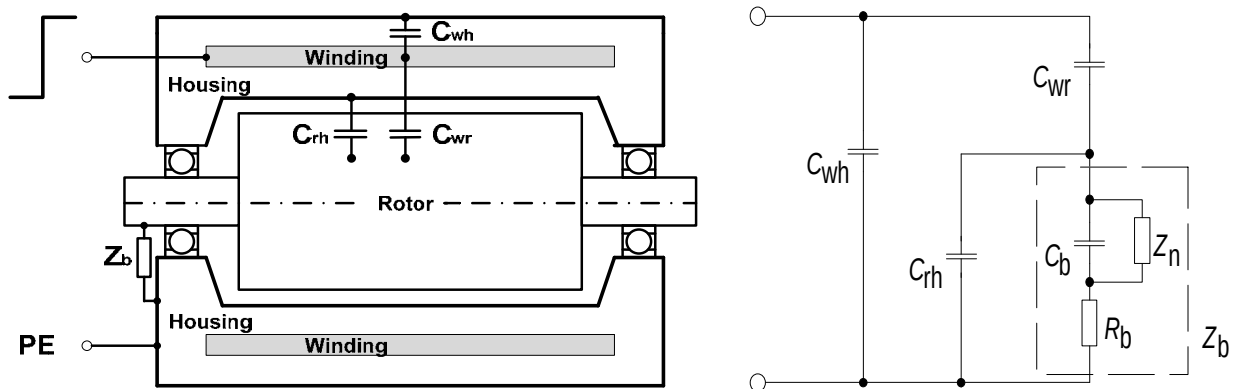
All data in this section are specified on the assumption that the motor cables are directly connected to the inverter output and no motor reactors, dv/dt filters plus VPL or sine-wave filters are used.

Using dv/dt filters plus VPL or sine-wave filters makes a critical difference to the voltage rates of rise and voltage spikes on the motor and alters the conditions to such an extent that motors with special insulation are not required. The use of these filters does however impose certain limitations and these are described in detail in sections "dv/dt filters with VPL" and "Sine-wave filters".

Bearing currents caused by steep voltage edges on the motor

The steep voltage edges caused by the fast switching of the IGBTs in the inverter generate currents through the internal capacitances of the motor. As a result of a variety of physical phenomena, these produce currents in the motor bearings. In the worst-case scenario, these bearing currents can reach very high values, damage the bearings and reduce the bearing lifetime.

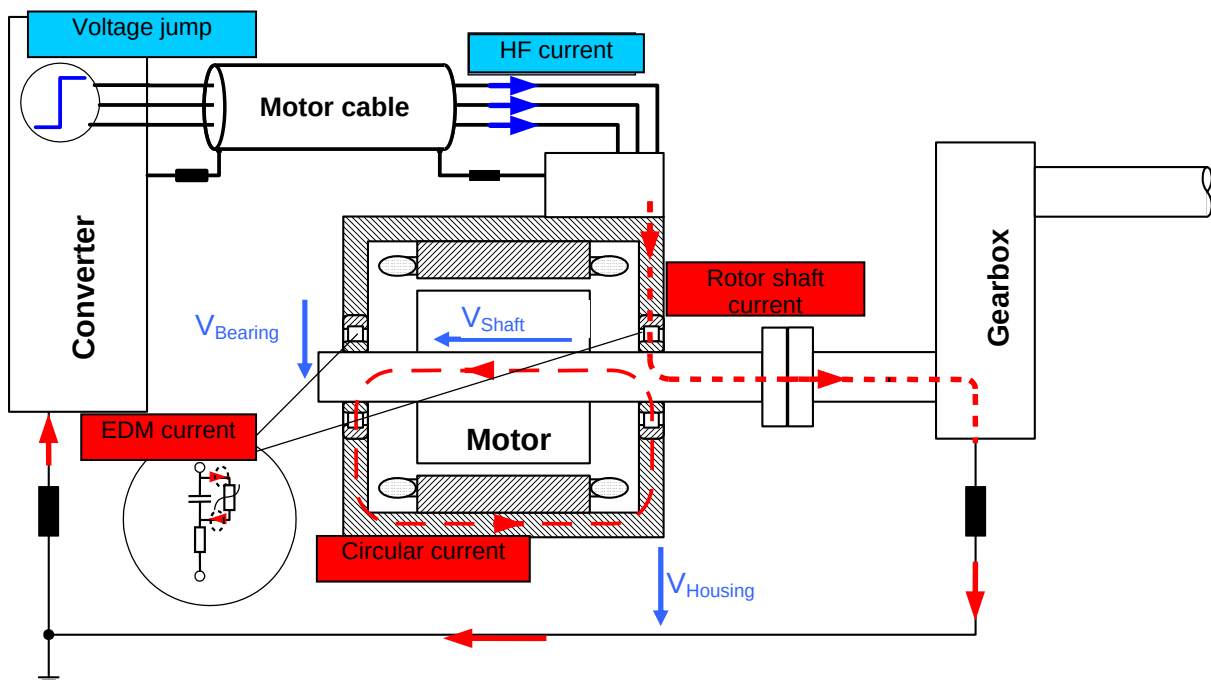
In order to describe the causes of bearing currents, a block diagram of the motor with its internal capacitances as well as the electrical equivalent circuit diagram derived from it, are shown below.



Schematic representation of the motor with its internal capacitances and the associated electrical equivalent circuit diagram

The stator winding has a capacitance C_{wh} in relation to the motor housing and a capacitance C_{wr} in relation to the rotor. The rotor itself has a capacitance C_{rh} in relation to the motor housing. The bearing can be defined by non-linear impedance Z_b . As long as the lubricating film acts as insulation, the bearing can be regarded as capacitance C_b . However, if the voltages on the bearing increase so much as to cause the lubricating film to break down, the bearing starts to behave like a non-linear, voltage-dependent resistance Z_n . Resistance R_b represents the ohmic resistance of the bearing rings and rolling elements.

The following diagram shows how the motor is integrated in the drive system as well as the various bearing current types.



Integration of the motor into the drive system and types of bearing current

Fundamental Principles and System Description

Engineering Information

The circular current

In the same way as the motor cable capacitance changes its polarity with every switching edge at the inverter output, the polarity of the capacitance C_{wh} between the winding and housing is also reversed with every switching edge. This creates a kind of high-frequency, capacitive "leakage current" between the winding and the housing and thus to ground. This leakage current leads to a magnetic imbalance in the motor which induces a high-frequency shaft voltage V_{Shaft} . If the insulating capacity of the lubricating film on the motor bearing cannot withstand this shaft voltage, a capacitive circular current flows through the circuit: Shaft → bearing at non-drive end (NDE bearing) → motor housing → bearing at drive end (DE bearing) → shaft. This circular current therefore flows from the shaft to the housing in one bearing and from the housing back to the shaft in the other.

The EDM current

Each edge of the phase-to-ground voltage on the winding (also referred to as "common mode voltage") charges the capacitance C_b in the bearing via capacitance C_{wr} between the winding and rotor. The time characteristic of the voltage on the bearing is thus an image of the phase-to-ground voltage on the motor winding. The amplitude of this voltage is however reduced in accordance with the capacitive BVR (Bearing Voltage Ratio) which is generally of the order of about 5 % on standard motors:

$$BVR = \frac{V_{Bearing}}{V_{Winding / Phase-Ground}} = \frac{C_{wr}}{C_{wr} + C_{rh} + C_b}$$

In the worst-case scenario, the bearing voltage $V_{Bearing}$ can reach such high values that the lubricating film on the bearing breaks down and the capacitance C_b and C_{rh} are discharged by a short, high current pulse. This current pulse is referred to as the EDM current (Electrostatic Discharge Machining).

The rotor shaft current

The high-frequency, capacitive "leakage current" flowing through the capacitance C_{wh} between winding and housing to cause the circular current must flow from the motor housing back to the inverter. If the motor housing is badly grounded for the purpose of high-frequency currents, the high-frequency "leakage current" encounters a significant resistance between the motor housing and grounding system across which a relatively high voltage drop $V_{Housing}$ occurs. If the coupled gearbox or driven machine is more effectively grounded for the purposes of high-frequency current, however, the current may flow along the following path to encounter the least resistance: Motor housing via the motor bearing – motor shaft – coupling – gearbox or driven machine to the grounding system and from there to the inverter. With a current following this path, there is not only a risk of damage to the motor bearings, but also to the bearings of the gearbox or the driven machine.

Measures for reducing bearing currents

Since there is a range of different bearing current types caused by different physical phenomena, it is generally necessary to take a series of measures in order to reduce the resultant bearing currents to a non-critical level. These measures are described in detail on the following pages.

For drives in the power rating range of SINAMICS G130, G150, S150 and S120 (Chassis and Cabinet Modules), the first two of the described measures are absolutely mandatory, i.e. installation in accordance with EMC guidelines combined with an insulated bearing at the non-drive end of the motor. This combination generally provides sufficient protection against bearing damage.

All the other measures described should be regarded as supporting precautions, although it can certainly be worthwhile to implement them in certain critical drive constellations. This applies particularly if it should not be possible to achieve high-quality implementation of the first two measures.

If it is not practically possible to achieve EMC-compliant installation standards when extending an existing plant which already features a poor grounding system and/or unshielded cables, for example, it can be very worthwhile to provide in addition to an insulated motor bearing, filters at the converter output. Alternatively, a shaft-grounding brush can be installed in combination with an insulated coupling. Which of the alternative measures is the most beneficial will depend on the weak points of the individual installation.

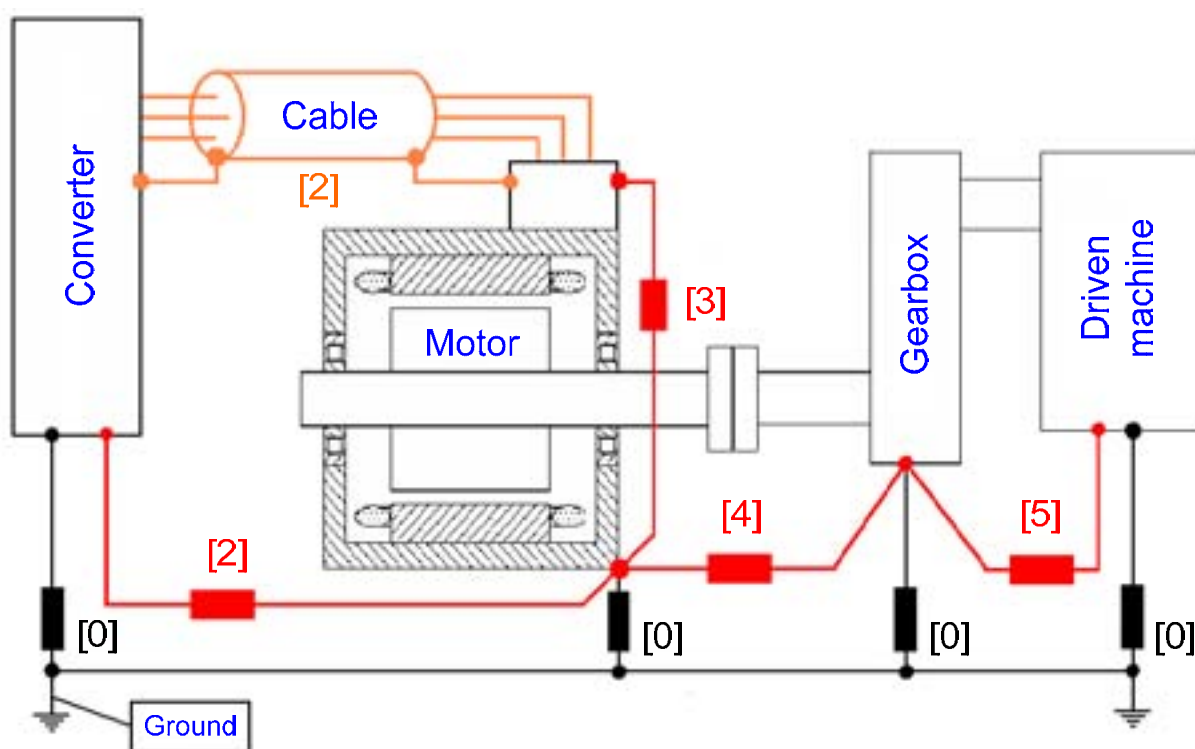
1. EMC-compliant installation for optimized equipotential bonding in the drive system

The purpose of any equipotential bonding measure is to ensure that all drive system components (transformer, converter, motor, gearbox and driven machine) stay at exactly the same potential, i.e. at ground potential (PE) to prevent the development of undesirable equalizing currents, e.g. rotor shaft currents.

Effective equipotential bonding is achieved by grounding the drive components by means of a well-designed grounding system at the site of installation. Where possible, this should be constructed as a meshed network with a large number of connections to the foundation ground so as to provide optimized equipotential bonding in the low-frequency range.

Of equal importance, however, is proper installation of the complete drive system including gearbox and driven machine with respect to the high-frequency point of view, i.e. that there is effective equipotential bonding in the high frequency range between all drive components in each drive.

The diagram shows a complete drive plus all the major grounding and equipotential bonding measures between the individual components of the drive.



Drive system with equipotential bonding system for reducing bearing currents

The description below explains how proper installation can reduce the inductance of connections, particularly of those which are colored orange and red in the diagram. On the one hand, this helps to minimize the voltage drops caused by high-frequency currents in the drive system. On the other hand, most of the high-frequency currents remain in the drive system in which they originate and so do not have any significant impact on other drive systems and loads.

Grounding of the components of the drive system [0]

All electrical and mechanical drive components (transformer, converter, motor, gearbox and driven machine) must first be bonded with the grounding system. These bonding points are shown in black in the diagram and are made with standard, heavy-power PE cables that are not required to have any special high-frequency properties.

In addition to these connections, the converter (as the source of high-frequency current) and all other components in each drive system, i.e. motor, gearbox and driven machine, must be interconnected with respect to the high-frequency point of view. These connections must be made using special cables with good high-frequency properties.

Fundamental Principles and System Description

Engineering Information

Optimized connection for high-frequencies between the converter and motor terminal box [2]

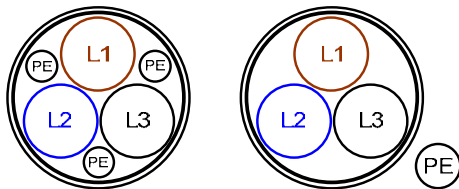
The connection between the converter and motor must always be made with a shielded, symmetrical, 3-wire, three-phase cable.

Shielded cables with symmetrically arranged three-phase conductors L1, L2 and L3 and an integrated, 3-wire, symmetrically arranged PE conductor, such as the PROTOFLEX EMV cable, type 2YSLCY-J supplied by Prysmian, are ideal.



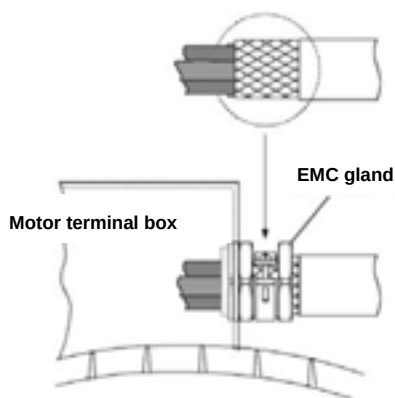
Shielded, symmetrically arranged three-phase cable with 3-core PE conductor

Alternatively, it is also possible to use a shielded cable containing only three-phase conductors L1, L2 and L3 in a symmetrical arrangement. In this case, the PE conductor must be installed separately.

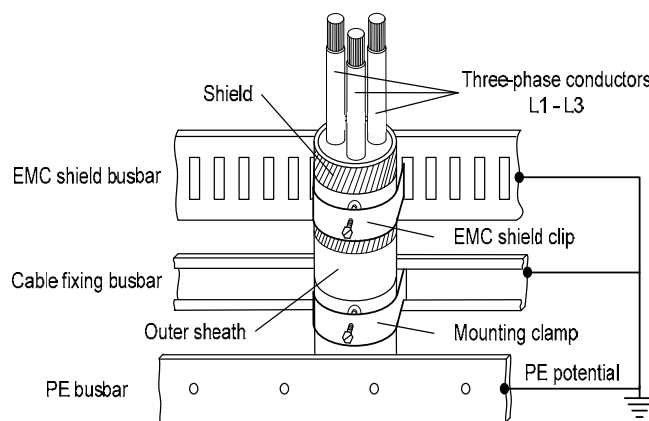


Symmetrical 3-wire three-phase cables with concentric copper or aluminum shield

Effective shield bonding is achieved if EMC cable glands are used to create a solid 360° contact between the shield and motor terminal box and, at the other side in the converter cabinet, a solid 360° contact with the EMC shield busbar using EMC shield clips. An alternative shield connection to the PE busbar in the converter using only long, braided "pigtaills" is less suitable, particularly if the pigtaills are very long, as this type of shield bond represents a relatively high impedance for high-frequency currents. Further additional shield bonds between the converter and motor, e.g. in intermediate terminal boxes, must never be created as the shield will then become far less effective.



Shield bonding to motor terminal box using an EMC gland



Shield bonding to the EMC shield busbar in the converter using an EMC shield clip

The cable symmetry combined with the concentric shield with good bonding connections at both sides ensures effective high-frequency equipotential bonding between the converter and motor terminal box.

Where the cables used have a shield with poor high-frequency properties or the grounding systems are bad, it is recommended to install a supplementary equipotential bonding conductor made of finely stranded, braided copper wire with a large cross-section ($\geq 95 \text{ mm}^2$) between the PE busbar of the converter and the motor housing.

Fundamental Principles and System Description

Engineering Information

Optimized connections for high-frequencies between the motor terminal box and motor housing [3]

Since the electrical connection between the motor terminal box to which the motor cable shield is bonded and the motor housing is not generally designed to offer optimum high-frequency properties, it is recommended to install an additional equipotential bonding connection with good high-frequency properties between the terminal box and the motor housing. This connection should be made with short ground conductors with a large cross-section ($\geq 95 \text{ mm}^2$). These must be designed to have a low impedance over a wide frequency range, e.g. made of finely stranded, braided round copper wires or finely stranded, braided flat copper strips. Examples of suitable conductors are shown below.



Finely stranded, braided round copper wires



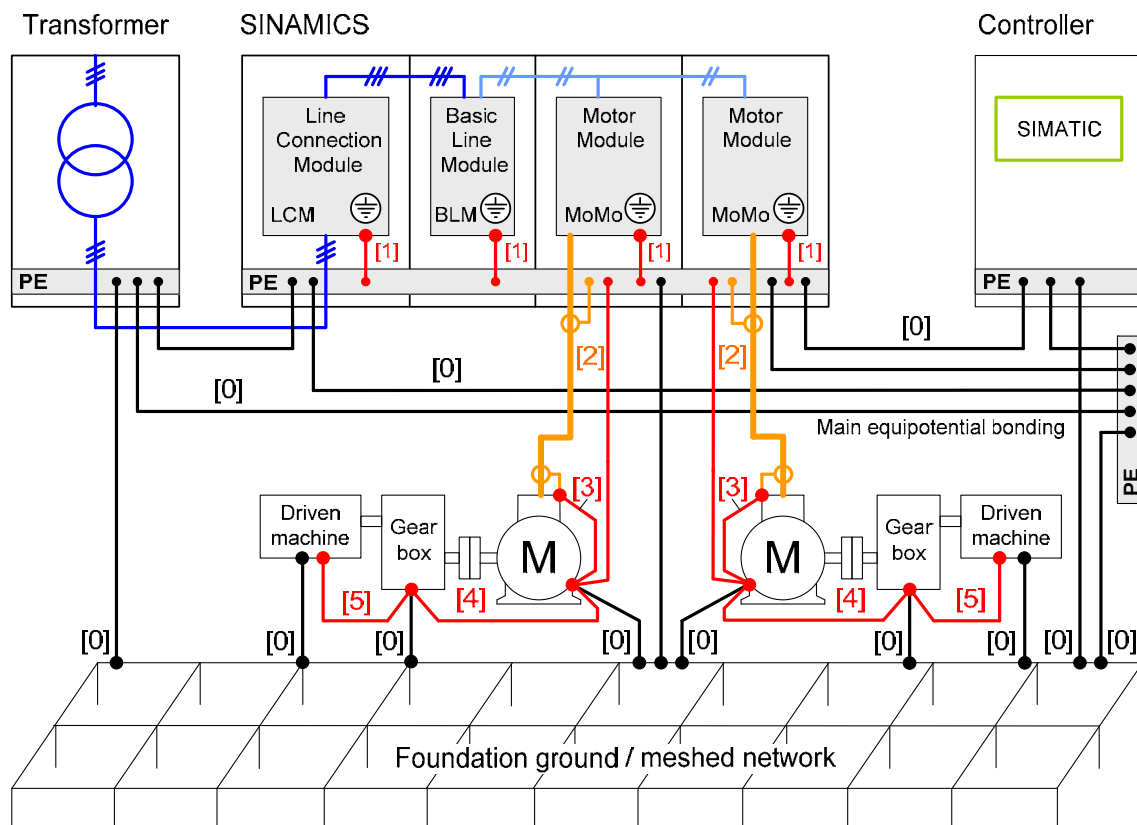
Finely stranded, braided flat copper strips

Optimized connection for high-frequencies between motor housing, gearbox and driven machine [4], [5]

The final measure in this equipotential bonding system is to link the motor housing to the gearbox and the driven machine in a conductive connection with good high-frequency properties. A lead made of finely stranded, braided copper cable with a large cross-section ($\geq 95 \text{ mm}^2$) should also be used for this purpose.

Overview of grounding and equipotential bonding measures

The following diagram illustrates all grounding and high-frequency equipotential bonding measures using the example of a typical installation comprising several SINAMICS S120 Cabinet Modules.



Grounding and high-frequency equipotential bonding measures for reducing bearing currents

Fundamental Principles and System Description

Engineering Information

The ground connections shown in black [0] represent the conventional grounding system for the drive components. They are made with standard, heavy-power PE conductors without special high-frequency properties and ensure low frequency equipotential bonding as well as protection against injury.

The connections shown in red inside the SINAMICS cabinets [1] provide solid bonding for high-frequency currents between the metal housings of the integrated chassis components and the PE busbar and the EMC shield busbar of the cabinet. These internal connections can be made via a large area using non-isolated metal construction components of the cabinet. In this case, the contact surfaces must be bare metal and each contact area must have a minimum cross-section of several cm². Alternatively, these connections can be made with short, finely stranded, braided copper wires with a large cross-section ($\geq 95 \text{ mm}^2$).

The shields of the motor cables shown in orange [2] provide high-frequency equipotential bonding between the Motor Modules and the motor terminal boxes. The finely stranded, braided copper cables shown in red can be routed in parallel with the cable shields when cables with poor high-frequency properties are used or in installations with bad grounding systems.

The connections shown in red [3], [4] and [5] provide a solid, high-frequency bond between the motor housing and the motor terminal box or the gearbox and the driven machine.

The equipotential bonding measures described above can practically eliminate the rotor shaft currents. It is therefore possible to dispense with insulated couplings between the motor and gearbox/driven machine. This is always an advantage in cases where insulating couplings cannot be used for any number of reasons.

2. Insulated bearing at the non-drive end (NDE end) of the motor

Apart from an EMC-compliant installation which essentially prevents rotor shaft currents, the use of a motor with an insulated bearing at the non-drive end is the second most important measure for reducing bearing currents.

Essentially, the insulated NDE bearing reduces the capacitive circular current in the motor by increasing the impedance in the circuit, thus compromising the shaft – NDE bearing – motor housing – DE bearing – shaft.

Insulated NDE bearings are standard on all motors in the 1LA8 series designed for converter operation. An insulated NDE bearing is available as an option for series 1LG4 and 1LG6 motors, frame size 225 and above. This option is highly recommended at converter operation.

In systems with speed encoders, it must be ensured that the encoder is not installed in such a way that it bridges the bearing insulation, i.e. the encoder mounting must be insulated or an encoder with insulated bearings must be used.

3. Other measures

Motor reactors or motor filters at the converter output

EMC-compliant installation and the use of a motor with insulated NDE bearing are generally perfectly adequate for the purpose of maintaining bearing currents at a non-critical level, even under worst-case conditions when stochastic disruptive discharges attributable to the EDM effect occur in the bearing.

In exceptional cases, it may be necessary to take additional measures to further reduce bearing currents.

This can be achieved with common mode filters consisting of toroidal cores made of highly permeable magnetic material. They are mounted at the converter output and enclose all three phases of the motor cable. These filters present a high resistance to the high-frequency currents (EDM current and rotor shaft current) flowing to ground and reduce them.

As common mode filters are not generally needed on SINAMICS drives, they are not offered as a standard option. They are available only on request.

As a general rule, all measures implemented at the converter output which serve to reduce the voltage rate of rise dv/dt have a positive impact on bearing current levels in the motor.

Motor reactors reduce the voltage rate of rise on the motor as a function of the motor cable length. Although they help in principle to reduce bearing currents, they cannot be regarded as a substitute to EMC-compliant installation and the use of motors with insulated NDE bearings.

The capability of dv/dt filters and sine-wave filters to reduce the voltage rate of rise on the motor is generally not affected by the motor cable length and achieves dv/dt values lower than those obtained with motor reactors. The values attained with sine-wave filters in particular are markedly lower.

In consequence, it is possible to dispense with insulated motor bearings when dv/dt filters, or more particularly, sine-wave filters are installed at the output of SINAMICS converters.

Grounding of the motor shaft with a grounding brush

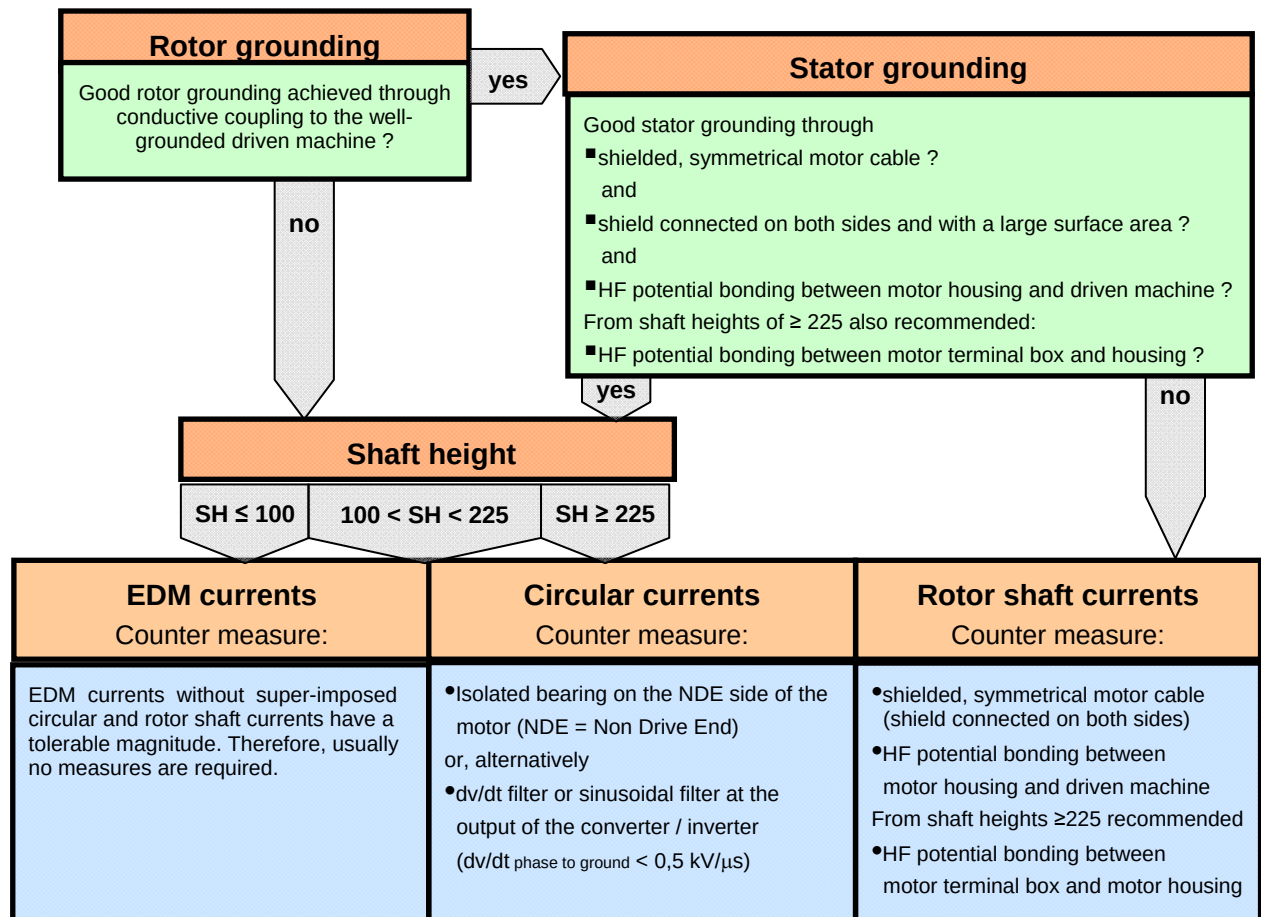
A shaft-grounding brush at the motor drive end can also reduce bearing currents as the brush shorts the bearing. However, there are problems associated with shaft-grounding brushes. They are very difficult to construct for smaller motors, they are sensitive to contamination and also require a great deal of maintenance. As a result, shaft-grounding brushes are not generally a recommended solution for low-voltage motors in the low to medium power range.

IT system

In operation on an IT system, the transformer neutral is not electrically connected to ground as it is with TN systems. The ground connection is purely capacitive in nature, causing the impedance to increase in the circuit in which high-frequency, common mode currents are flowing. The result is a reduction in the common mode currents and thus also in the bearing currents. With respect to bearing currents, therefore, non-grounded IT systems are more beneficial than grounded TN systems.

Brief overview of the different types of bearing currents

The following overview shows the different types of bearing currents depending on the shaft height and the grounding conditions of stator and rotor.



Dominant bearing current types dependent on the shaft height and the grounding conditions of stator and rotor

With a good rotor grounding, achieved by means of a conductive coupling to the well-grounded driven machine and simultaneous poor stator grounding due to poor installation, the rotor shaft currents can become very large and thus easily damage the bearings of the motor and the load machine. Such a situation must be avoided with a good stator grounding, achieved by means of an EMC-compliant installation and/or the use of an isolating coupling.

Fundamental Principles and System Description

Engineering Information

If, by means of a good stator grounding with an EMC-compliant installation and/or an isolating coupling, the occurrence of rotor shaft currents is prevented, EDM currents are dominant in smaller motors with shaft heights of up to 100. Circular currents play a secondary role here. So the resulting bearing currents are on a low-risk level for the bearings and no further measures usually need to be taken. As the shaft height increases, the EDM currents change slightly, while the circular currents continually increase. From shaft heights of 225 the circular currents become dominant and critical for the bearings. Therefore, from shaft heights of 225, the use of an isolated bearing on the NDE side of the motor is very highly recommended.

In principle a dv/dt filter or a sinusoidal filter can also be used at the output of the converter, as alternative to an isolated bearing in the motor.

Motor reactors

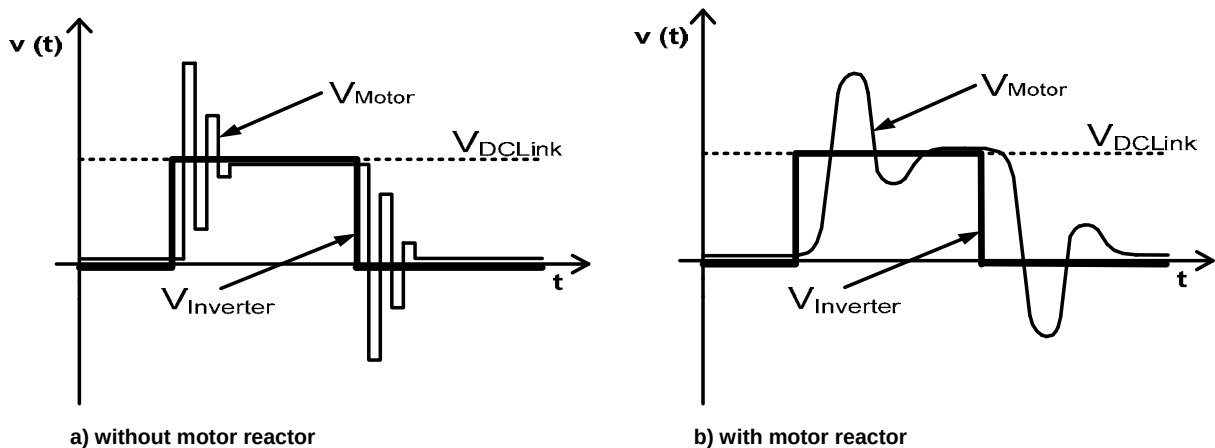
Reduction of the voltage rate of rise dv/dt at the motor terminals

As described in detail in the section "Effects of using fast-switching power components (IGBTs)", very high voltage rate of rise dv/dt occurs at the inverter output and the motor terminals.

This rate of rise can be reduced through the use of motor reactors.

In systems without motor reactors, the voltage edges at the inverter output which have a rate of rise dv/dt of typically $3 \text{ kV}/\mu\text{s} - 6 \text{ kV}/\mu\text{s}$, move along the cable towards the motor and reach the motor terminals with a virtually unchanged rate of rise. The resultant voltage reflections cause voltage spikes which can reach up to twice the DC link voltage, see Figure a) in diagram below.

As a result, the motor winding is subjected in two respects to a higher voltage stress than would normally be imposed by a sinusoidal supply. The voltage rate of rise dv/dt is very steep and the voltage spikes V_{PP} caused by the reflection are also very high.



Voltage $v(t)$ at the inverter output and at the motor terminals

When motor reactors are installed, the reactor inductance and the cable capacitance are forming an oscillating circuit which reduces the voltage rate of rise dv/dt . The higher the cable capacitance is, i.e. the longer the cable is, the greater the reduction in the rate of rise. When long, shielded cables are used, the voltage rate of rise drops to just a few $100 \text{ V}/\mu\text{s}$, see Figure b) in diagram. Unfortunately, however, the oscillating circuit built by the reactor inductance and the cable capacitance is only relatively weakly damped so that severe voltage overshoots can occur. The voltage spikes at the motor terminals are therefore of the same order of magnitude as the spikes caused by reflections in systems without motor reactor.

Since the motor reactor reduces only the voltage rate of rise dv/dt rather than the voltage spikes V_{PP} , there is no fundamental difference in the quality of the voltage stress for the winding as compared to systems without a motor reactor.

The use of a motor reactor is thus not a suitable solution for improving the voltage stress for the winding of the motor with line supply voltages of between 500 V and 690 V to such an extent that it is possible to dispense with special insulation in the motor. This level of improvement can be achieved only by means of dv/dt filters plus VPL or sine-wave filters (see sections "dv/dt filters plus VPL" and "Sine-wave filters").

Although the reduction of the voltage rate of rise attenuates the bearing currents in the motor, this is not sufficient to completely obviate the need for an insulated NDE bearing in the motor.

Reduction of additional current peaks when long motor cables are used

As a result of the high voltage rate of rise of the fast-switching IGBTs, the cable capacitance of long motor cables changes polarity very quickly with every switching operation in the inverter, thereby loading the inverter output with high additional current peaks.

The use of motor reactors reduces the magnitude of these additional peaks because the cable capacitance changes polarity more slowly due to the reactor inductance, thereby attenuating the amplitudes of the current peaks.

Suitably dimensioned motor reactors or series connections of motor reactors therefore offer a solution which allows a higher capacitance and thus also longer motor cables to be connected.

Fundamental Principles and System Description

Engineering Information

Permissible motor cable lengths with motor reactor(s) for single-motor and multi-motor drives

Permissible motor cable lengths for drives with one motor (single-motor drives)

The tables below specify the permissible motor cable lengths in systems with one motor reactor or two series-connected motor reactors for SINAMICS G130, G150 and S150, S120 Motor Modules (Chassis and Cabinet Modules).

Line supply voltage	Maximum permissible motor cable length			
	with 1 reactor		with 2 series-connected reactors	
	Shielded cable e.g. Protodur NYCWY	Unshielded cable e.g. Protodur NYY	Shielded cable e.g. Protodur NYCWY	Unshielded cable e.g. Protodur NYY
380 V – 480 V 3AC	300 m	450 m	On request	On request
500 V – 600 V 3AC	300 m	450 m	On request	On request
660 V – 690 V 3AC	300 m	450 m	On request	On request

Maximum permissible motor cable lengths with 1 or 2 motor reactors for SINAMICS G130 Chassis and SINAMICS G150 cabinets

Line supply voltage	Maximum permissible motor cable length			
	with 1 reactor		with 2 series-connected reactors	
	Shielded cable e.g. Protodur NYCWY	Unshielded cable e.g. Protodur NYY	Shielded cable e.g. Protodur NYCWY	Unshielded cable e.g. Protodur NYY
380 V – 480 V 3AC	300 m	450 m	525 m	787 m
500 V – 600 V 3AC	300 m	450 m	525 m	787 m
660 V – 690 V 3AC	300 m	450 m	525 m	787 m

Maximum permissible motor cable lengths with 1 or 2 motor reactors for SINAMICS S150 cabinets and SINAMICS S120 Motor Modules in the format Chassis and Cabinet Modules

Note:

The specified motor cable lengths always refer to the distance between inverter output and motor along the cable route and already allow for the fact that several cables must be routed in parallel for drives in the higher power range. The recommended and the maximum connectable cross-sections plus the permissible number of parallel motor cables are unit-specific values. These values can be found in the unit-specific chapters of this engineering manual or in the relevant catalogs.

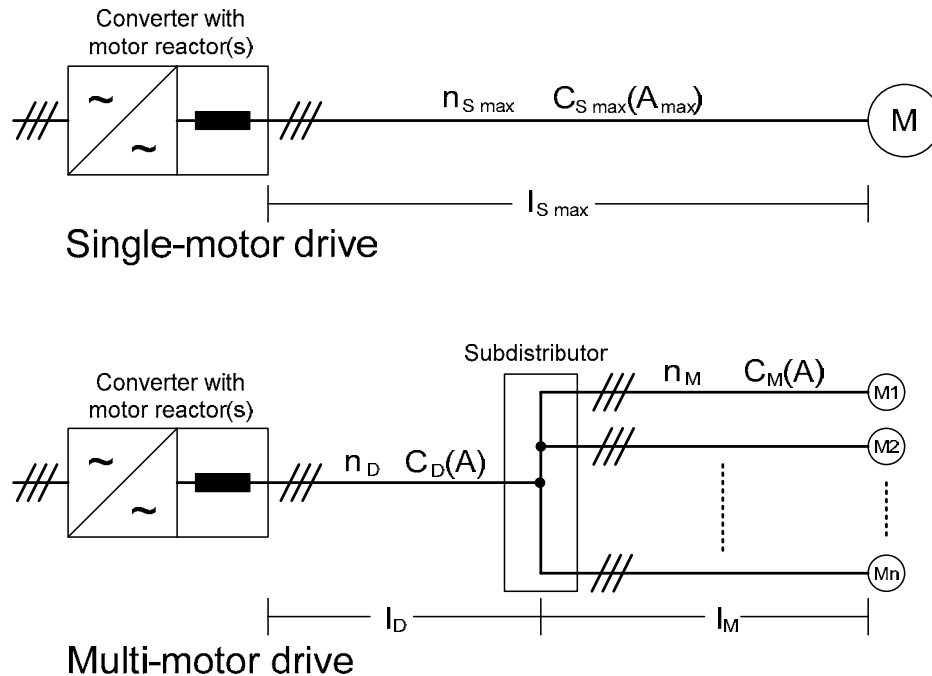
Permissible motor cable lengths for drives with several motors at the converter output (multi-motor drives)

Normally a single motor is connected to the converter output. There are however applications such as roller drives or gantry drives on container cranes which require a large number of identical, low-power-output motors to be supplied by a single converter of sufficiently high output rating. This type of configuration is referred to as a "multi-motor drive". Within the narrower context of the calculation procedure described below, the term "multi-motor drive" always applies if the number of motors connected to the converter output is higher than the maximum permissible number of parallel motor cables specified in the catalog.

Motor reactors (or motor filters) must always be installed for multi-motor drives. The individual motors are connected by cables of very small cross-section due to their low power rating. The capacitance per unit length of these cables is significantly lower than that of the large cross-section cables used for single-motor drives. As a result of this reduced capacitance per unit length, the total permissible cable lengths per converter output for multi-motor drives can exceed the values specified in the above tables by a significant amount without violating the maximum permissible capacitance values stipulated for the converter and motor reactor.

A method of calculating the permissible cable lengths for multi-motor drives l_M based on the catalog data for single-motor drives is described below.

The diagram explains the quantities and terms used for both single-motor and multi-motor drives.



Block diagram of single-motor drive and multi-motor drive with relevant quantities and terms

The permissible motor cable length per motor on a multi-motor drive is calculated with the formula:

$$l_M = \frac{n_{S \max} \cdot C_{S \max}(A_{\max}) \cdot l_{S \max} - n_D \cdot C_D(A) \cdot l_D}{n_M \cdot C_M(A)}$$

Definition and meaning of applied quantities:

- l_M Permissible cable length between the subdistributor and each motor in a multi-motor drive.
- $n_{S \max}$ Maximum number of motor cables which can be connected in parallel in a single-motor drive. This value can be found in the chapters on specific units or in the relevant catalogs.
- $C_{S \max}(A_{\max})$ Capacitance per unit length of a shielded motor cable with the maximum permissible cross-section $A_{\max}$ for a single-motor drive. This value can be found in the table on the next page and is depending on the maximum permissible cross-section $A_{\max}$ specified in the chapters on specific units or the relevant catalogs.
- $l_{S \max}$ Permissible motor cable length for single-motor drive as specified in the tables on the previous page (depending on the number of motor reactors (1 or 2) and whether the cable is shielded or unshielded).
- n_D Number of parallel cables between the converter and subdistributor on a multi-motor drive.
- $C_D(A)$ Capacitance per unit length of the cable between the converter and subdistributor on a multi-motor drive.
- l_D Length of the cable between the converter and subdistributor on a multi-motor drive.
- n_M Number of parallel cables on motor side of subdistributor = number of motors.
- $C_M(A)$ Capacitance per unit length of cables on motor side of subdistributor.

Fundamental Principles and System Description

Engineering Information

The calculation formula given above allows for arrangements in which a large-cross-section cable is taken from the converter to a subdistributor to which motors are connected by small cross-section cables, as well as arrangements in which the cables to individual motors are directly connected to the converter. In systems without a subdistributor, the term $n_D \cdot C_D(A) \cdot l_D$ must be set to "0".

The formula is valid for converters and inverters with one or two motor reactors at the output and for shielded and unshielded motor cables. Allowance for the number of motor reactors (1 or 2) and the cable type (shielded or unshielded) is made exclusively by the value $l_{S \max}$, which is specified according to the configuration to be calculated in the relevant columns of the tables two pages above. It must however be taken into account that this formula is not suitable for calculating mixtures of shielded and unshielded cables, e.g. in cases where a shielded cable is used up to the subdistributor and unshielded cables to the motor.

Since only the ratio of capacitance values of motor cables with different cross-sections is relevant in the formula rather than the absolute capacitance value itself, the capacitance per unit length values for cable type Protodur NYCWY stated in the table below as a function of the cable cross-section can be applied for all shielded and unshielded cable types for the purposes of this calculation.

Cross-section A [mm ²]	Capacitance per unit length C' [nF/m]
3 x 2.5	0.38
3 x 4.0	0.42
3 x 6.0	0.47
3 x 10	0.55
3 x 16	0.62
3 x 25	0.65
3 x 35	0.71
3 x 50	0.73
3 x 70	0.79
3 x 95	0.82
3 x 120	0.84
3 x 150	0.86
3 x 185	0.94
3 x 240	1.03

Capacitance per unit length C' of shielded, three-wire, motor cables of type Protodur NYCWY as a function of the cable cross-section A

Calculation example:

A roller table with 25 motors, each with an output power rating of 10 kW, is to be supplied by a SINAMICS G150 converter. A converter with a supply voltage of 400 V and an output power of 250 kW is selected for this application. The roller table application data are as follows:

The converter is sited in an air-conditioned room and will supply a subdistributor via two parallel, shielded cables, 50 m in length, each with a cross-section of 150 mm². 25 motors are connected to the subdistributor via shielded cables, each on average 40 m in length with a cross-section of 1 x 10 mm².

Since this is a multi-motor drive with a large number of parallel motor cables, it is absolutely essential to install a motor reactor. We shall now use a calculation to check whether the selected converter combined with a motor reactor can fulfill the requirements.

1st step:

Calculation of the quantities $n_{S \max}$, $C_{S \max}(A_{\max})$ and $l_{S \max}$ for single-motor drives from the data given in the chapter "Converter Cabinet Units SINAMICS G150" or the specifications in catalog D11 by applying the information in the above table of capacitance per unit length as a function of the cable cross-section:

According to catalog D11, a maximum of two parallel motor cables, each with a maximum cross-section of 240 mm² can be connected to the motor terminals of converter type SINAMICS G150 / 400 V / 250 kW. The maximum motor cable length for shielded motor cables in combination with one motor reactor is 300 m according to catalog D11. From this data we can calculate:

- $n_{S \max} = 2$
- $C_{S \max}(A_{\max}) = C_{S \max}(240 \text{ mm}^2) = 1.03 \text{ nF/m}$
- $l_{S \max} = 300 \text{ m}$

2nd step:

Calculation of quantities n_D , $C_D(A)$ and l_D for the cable between the converter and subdistributor:

- $n_D = 2$
- $C_D(A) = C_D(150 \text{ mm}^2) = 0.86 \text{ nF/m}$
- $l_D = 50 \text{ m}$

3rd step:

Calculation of quantities n_M , $C_M(A)$ for the cable between the subdistributor and each motor:

- $n_M = 25$
- $C_M(A) = C_M(10 \text{ mm}^2) = 0.55 \text{ nF/m}$

4th step:

Calculation of the permissible motor cable length between the subdistributor and each motor using calculation formula:

$$l_M = \frac{2 \cdot 1.03 \text{ nF/m} \cdot 300 \text{ m} - 2 \cdot 0.86 \text{ nF/m} \cdot 50 \text{ m}}{25 \cdot 0.55 \text{ nF/m}}$$

$$l_M = \frac{618 \text{ nF} - 86 \text{ nF}}{13.75 \text{ nF}} \text{ m} = 38.7 \text{ m} \approx 40 \text{ m}$$

The required cable length of 40 m per motor is within a 10 % tolerance band around the calculated value $l_M = 38.7 \text{ m}$ which means that the arrangement can be implemented as planned.

If we compare the maximum cable distance of 600 m which may be connected to the converter for a single-motor drive (two parallel cables, each 300 m in length and each with a cross-section of 240 mm^2) and the cable distance of 1068 m for the multi-motor drive (two parallel cables, each 50 m in length and each with a cross-section of 150 mm^2 to the subdistributor plus 25 parallel cables to the motors, each 38.7 m in length and with a cross-section of 10 mm^2), we can see that the reduction in cross-section for the multi-motor drive nearly doubles the maximum permissible cable distance allowed for single-motor drives, even though the total capacitance is the same.

Supplementary conditions which apply when motor reactors are used

With the cabinet versions G150 and S150 as well as the S120 Motor Modules in the format Cabinet Modules, it must be noted that an additional cabinet may be required if two reactors are connected in series.

The pulse frequency and output frequency must be limited for thermal reasons when motor reactors are installed:

- The maximum pulse frequency is limited to twice the factory setting value, i.e. to 4 kHz for units with factory setting 2 kHz and to 2.5 kHz for units with factory setting 1.25 kHz.
- The maximum output frequency is limited to 150 Hz.

The voltage drop across the motor reactor is approximately 1 %.

The motor reactor should be sited in the immediate vicinity of the converter or inverter output. The cable length between the motor reactor and the output of the converter or inverter should not exceed about 5 m.

As part of the drive commissioning process, the motor reactor should be selected with parameter setting P0230 = 1 and the reactor inductance entered in parameter P0233. This ensures that optimum allowance will be made for the effect of the reactor in the vector control mode.

Fundamental Principles and System Description

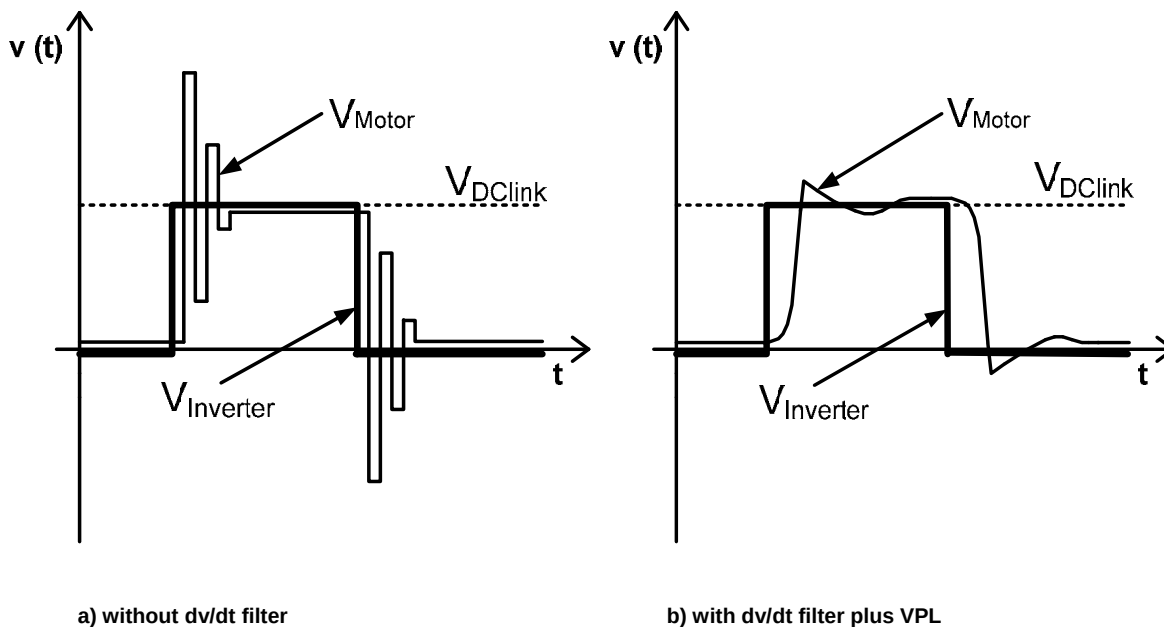
Engineering Information

■ dv/dt filter plus VPL

The dv/dt filter plus VPL (Voltage Peak Limiter) consists of two components, i.e. a dv/dt reactor and a voltage limiting network.

The dv/dt reactor achieves the same effect as the motor reactor. In combination with the capacitance of the connected motor cable and the internal capacitance of the limiting network, it forms an oscillating circuit which limits the voltage rate of rise dv/dt to values of $< 500 \text{ V}/\mu\text{s}$ independent from the length of the connected motor cable.

The limiting network basically comprises a diode bridge and is connected to the output of the dv/dt reactor and the inverter DC link. The diode bridge limits the voltage overshoots at the dv/dt reactor output to approximately the level of the DC link voltage and thus restricts the peak voltage V_{PP} on the motor cable. Due to the reduced voltage gradient, the voltage conditions at the output of the dv/dt filter and the motor terminals are practically identical.



Voltage $v(t)$ at the inverter output and motor terminals

dv/dt filters plus VPL very effectively limit both the voltage rate of rise dv/dt and the peak voltage V_{PP} on the motor winding to the following values:

- Voltage rate of rise $dv/dt < 500 \text{ V}/\mu\text{s}$
- Voltage peaks V_{PP} (typically) $< 1000 \text{ V}$ for $V_{Line} < 575 \text{ V}$
- Voltage peaks V_{PP} (typically) $< 1250 \text{ V}$ for $660 \text{ V} < V_{Line} < 690 \text{ V}$

The use of dv/dt filters plus VPL is thus a suitable method of reducing the voltage stress on the motor winding at line supply voltages of 500 V to 690 V to such an extent that special insulation in the motor can be dispensed with. Bearing currents are also reduced significantly. Using these filters therefore allows standard motors with standard insulation and without insulated bearing to be operated on SINAMICS up to line supply voltages of 690 V. This applies to both Siemens motors and motors supplied by other manufacturers.

Fundamental Principles and System Description

Engineering Information

The table below specifies the permissible motor cable lengths with dv/dt filters plus VPL for SINAMICS G130, G150, S150, S120 Motor Modules (Chassis and Cabinet Modules).

Line supply voltage	Maximum permissible motor cable length with dv/dt filter plus VPL	
	Shielded cable e.g. Protodur NYCWY	Unshielded cable e.g. Protodur NYY
380 V – 480 V 3AC	300 m	450 m
500 V – 600 V 3AC	300 m	450 m
660 V – 690 V 3AC	300 m	450 m

Maximum permissible motor cable lengths with dv/dt filters plus VPL for SINAMICS G130, G150, S150 and SINAMICS S120 Motor Modules in format Chassis and Cabinet Modules

These cable lengths apply to drives on which only one motor is connected to the filter output. Longer motor cable lengths can be used for drives with multiple motors. Please refer to section "Motor reactors" for information on how to calculate the permissible motor cable lengths for multi-motor drives. If this calculation method is used for converters with dv/dt filters, it has to be taken in account that instead of the maximum number of parallel cables $n_{E\ max}$ and the maximum cross-sections A_{max} the relevant recommended values $n_{E\ rec}$ and A_{rec} from the catalog have to be used.

In the case of cabinet units G150 and S150, it must also be noted that an additional cabinet is required for units above a certain output rating. An additional cabinet is always needed for S120 Motor Modules in the format Cabinet Modules.

The pulse frequency and output frequency must be limited for thermal reasons when dv/dt filters plus VPL are installed:

- The maximum pulse frequency is limited to twice the factory setting value, i.e. to 4 kHz for units with factory setting 2 kHz and to 2.5 kHz for units with factory setting 1.25 kHz.
- The maximum output frequency is limited to 150 Hz.

The voltage drop across the dv/dt filter plus VPL is approximately 1 %.

The dv/dt filter plus VPL should be sited in the immediate vicinity of the converter or inverter output. The cable length between the dv/dt filter plus VPL and the output of the converter or inverter must not exceed 5 m.

dv/dt filters plus VPL must be selected with parameter setting P0230 = 2 when the drive is commissioned. This ensures that optimum allowance will be made for the effect of the filter in the vector control model.

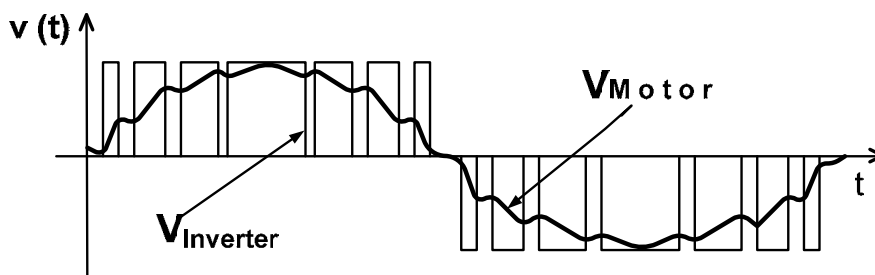
Restrictions do not apply to the permissible pulse patterns of the gating unit, i.e. pulse-edge modulation can be used freely which means that the attainable output voltage is virtually identical to the input voltage.

dv/dt filters plus VPL can be used in both grounded systems (TN/TT) and non-grounded systems (IT).

■ Sine-wave filters

Sine-wave filters are LC low-pass filters and constitute the most sophisticated filter solution. They are significantly more effective than dv/dt filters plus VPL in reducing the voltage rate of rise dv/dt and peak voltages V_{PP} , but operation with sine-wave filters imposes substantial restrictions in terms of the possible pulse frequency settings and utilization of the inverter current and voltage.

As the schematic sketch below illustrates, the sine-wave filter filters the fundamental component output of the inverter pulse pattern. As a result, the voltage applied to the motor terminals is sinusoidal with an extremely small harmonic content.



Schematic sketch of the voltage $v(t)$ at the inverter output and motor terminals with a sine-wave filter

Sine-wave filters very effectively limit both the rate of voltage rise dv/dt and the peak voltage V_{PP} on the motor winding to the following values:

- Voltage rate of rise $dv/dt < 50 \text{ V}/\mu\text{s}$
- Voltage peaks $V_{PP} < 1.1 \cdot \sqrt{2} \cdot V_{Line}$

As a result, the voltage stress on the motor winding is virtually identical to the operating conditions of motors directly connected to the mains supply. Bearing currents are also reduced significantly. Using these filters therefore allows standard motors with standard insulation and without insulated bearing to be operated on SINAMICS. This applies to both Siemens motors and motors supplied by other manufacturers.

Due to the very low voltage rate of rise on the motor cable, the sine-wave filter also has a positive impact in terms of electromagnetic compatibility which means that it is not absolutely essential to use shielded motor cables to achieve the required standard of EMC.

Since the voltage applied to the motor is not pulsed, the converter-related stray losses and additional noise in the motor are also reduced considerably and the noise level of the motor is approximately equivalent to the level produced by mains-fed motors.

Sine-wave filters are available

- in the 380 V to 480 V voltage range up to a converter rated output of 250 kW at 400 V,
- in the 500 V to 600 V voltage range up to a converter rated output of 132 kW at 500 V,

To make allowance for the resonant frequency of the filter, the pulse frequency setting for drives with sine-wave filters is fixed at 4 kHz (380 V – 480 V) or at 2.5 kHz (500 V – 600 V).

For this reason, the permissible output current is reduced to the values given in the table.

Fundamental Principles and System Description

Engineering Information

Line supply voltage	Rated output power at 400 V resp. 500 V without sine-wave filter	Rated output current without sine-wave filter	Current derating factor with sine-wave filter	Output current with sine-wave filter
380 V – 480 V 3AC	110 kW	210 A	82 %	172 A
380 V – 480 V 3AC	132 kW	260 A	83 %	216 A
380 V – 480 V 3AC	160 kW	310 A	88 %	273 A
380 V – 480 V 3AC	200 kW	380 A	87 %	331 A
380 V – 480 V 3AC	250 kW	490 A	78 %	382 A
500 V – 600 V 3AC	110 kW	175 A	87 %	152 A
500 V – 600 V 3AC	132 kW	215 A	87 %	187 A

Current derating factor and permissible output current with sine-wave filter

Furthermore, space vector modulation SVM is the only permitted modulation mode.

As a result, the achievable output voltage for G130, G150 and S120 Motor Modules which are supplied by Basic or Smart Infeeds is limited to 85 % (380 V to 480 V) or 83 % (500 V – 600 V) of the input voltage. In consequence, the drive switches earlier to field-weakening operation. As the converter cannot supply the rated voltage of the motor, the motor can operate at rated output only if it is supplied with a current in excess of its rated current.

With S150 and S120 Motor Modules that are supplied by Active Infeeds, the DC link voltage is so high, as a result of the step-up converter operating principle of the Active Infeed, that the voltage applied to the motor reaches the line supply value even in space vector modulation mode.

The maximum output frequency is limited to 150 Hz.

The following table lists the permissible motor cable lengths with sine-wave filter for SINAMICS G130, G150, S150, S120 Motor Modules (Chassis and Cabinet Modules).

Line supply voltage	Maximum permissible motor cable length with sine-wave filter	
	Shielded cable e.g. Protodur NYCWY	Unshielded cable e.g. Protodur NYY
380 V – 480 V 3AC	300 m	450 m
500 V – 600 V 3AC	300 m	450 m

Maximum permissible motor cable lengths with sine-wave filters for SINAMICS G130, G150, S150 and SINAMICS S120 Motor Modules in format Chassis and Cabinet Modules

These cable lengths apply to drives on which only one motor is connected to the filter output. Longer motor cable lengths can be used for drives with multiple motors. Please refer to section "Motor reactors" for information on how to calculate the permissible motor cable lengths for multi-motor drives. If this calculation method is used for converters with sine-wave filters, it has to be taken in account that instead of the maximum number of parallel cables $n_{E \max}$ and the maximum cross-sections $A_{\max}$ the relevant recommended values $n_{E \text{ rec}}$ and A_{rec} from the catalog have to be used.

The sine-wave filter should be sited in the immediate vicinity of the converter or inverter output. The cable length between the sine-wave filter and the output of the converter or inverter should not exceed about 5 m.

Sine-wave filters must be selected with parameter P0230 when the drive is commissioned.

P230 must be set to "3" for sine-wave filters of the SINAMICS converter range. This ensures that all the required parameter changes relating to the sine-wave filter are made correctly.

P230 must be set to "4" for sine-wave filters supplied by manufacturers other than Siemens. In this case, the technical data of the sine-wave filter must be entered in other parameters.

Sine-wave filters can be used in both grounded systems (TN/TT) and non-grounded systems (IT).

Fundamental Principles and System Description

Engineering Information

Load duty cycles

General

In many applications, especially constant-torque applications, variable-speed drives are required to operate under overload for brief periods, e.g. in order

- to overcome breakaway torques on starting,
- to produce acceleration torques for short periods,
- to shut down drives rapidly in emergency situations.

For the converters and inverters to be able to produce this overload capacity for brief periods, they must not reach the limits of their thermal capacity in normal operation. For this reason, the base-load current for drives with overload capacity must be lower than the continuously permissible rated current. The more the base load current is reduced from rated current value, the higher will be the thermal reserves for brief periods of overload duty.

Standard load duty cycles

For SINAMICS G130 converter Chassis, SINAMICS G150 and S150 converter cabinets and SINAMICS S120 Motor Modules SINAMICS S120 (Chassis and Cabinet Modules), the overload capability is defined by two standard load duty cycles:

- Load duty cycle for low overload (LO) with a base load current I_L that is marginally lower (3 % to 6 %) than the rated output current I_{rated} .
- Load duty cycle for high overload (HO) with a base load current I_H that is significantly lower (10 % to 25 %) than the rated output current I_{rated} .

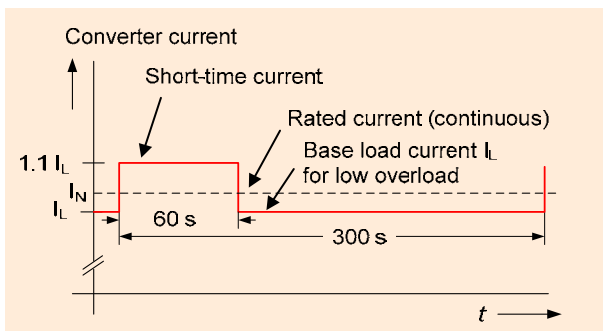
The diagrams below show the load duty cycle definitions for operation under low and high overloads.

- The base load current I_L for low overload is based on a load duty cycle of 110 % for 60 s or 150 % for 10 s.
- The base load current I_H for a high overload is based on a load duty cycle of 150 % for 60 s or 160 % for 10 s.

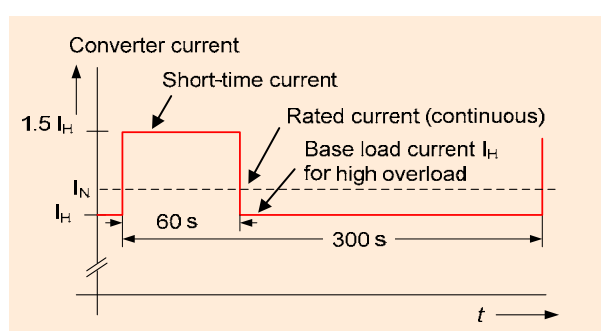
The maximum possible short-term current of the load duty cycle **low overload (LO)** is $1.5 \cdot I_L$ for 10 s. This value is always slightly higher than the maximum possible short-term current of the load duty cycle **high overload (HO)**, which is $1.6 \cdot I_H$ for 10 s. Thus the maximum possible output current I_{max} of the power unit is defined by $I_{max} = 1.5 \cdot I_L$. This maximum value is set in the firmware and can, therefore, not be exceeded, not even in short-term operation.

The values for the base load currents I_L and I_H , as well as for the maximum output current I_{max} , are unit-specific and must therefore be taken from the relevant catalogs or the chapters on specific unit types in this engineering manual.

These overload values apply on the condition that the converter is operated with the default pulse frequency at its base load current before and after the period of overload on the basis of a load duty cycle duration of 300 s in each case.



Definition of the standard load duty cycle low overload



Definition of the standard load duty cycle high overload

Free load duty cycles

Many applications require load duty cycles which deviate more or less from the standard load duty cycles defined above. For this reason, the physical design criteria on which load duty cycles are based and methods by which free load duty cycles can be correlated mathematically with standard load duty cycles are described below.

Three criteria must always be fulfilled in each load duty cycle to prevent the power unit from becoming overloaded, which could cause fault tripping or initiate an overload reaction or reduce the lifetime of the converter:

- The magnitude of the short-time current must be limited.
- The average power loss in the power unit must be limited for the duration of the load duty cycle.
- The frequency or the magnitude of the temperature variations of the IGBT chips must be limited during the load duty cycle to ensure that the lifetime of the power unit is not affected.

The magnitude of the short-time current must be limited for several reasons. The first reason is that there needs to be a sufficient margin between the short-time current and the overcurrent trip level of the power unit in order to prevent shutting down on overcurrent. The second reason is that the chip temperature in the IGBT rises during the overload period. This rise is in proportion to the square of the short-time current, which means that the permissible overload duration decreases more than the short-time current rises. As a result, the converter would trip extremely fast due to thermal overloading of the chip when the short-time current is too high.

The average power loss in the power unit during the load duty cycle must be limited and must not exceed the corresponding power loss during steady-state continuous operation with the permissible output current for which the power unit has been dimensioned.

The frequency or magnitude of the temperature variations of the IGBT chips must be limited during the load duty cycle to ensure that the lifetime of the power unit is not affected. This is due to the fact that the number of permissible temperature cycles of an IGBT is limited and decreases in proportion to the rise of the temperature swing ΔT_{Chip} . The lifetime of the IGBT, therefore, also decreases accordingly in proportion to the rise of the temperature swing ΔT_{Chip} . This means:

If, during a free periodic load duty cycle, the frequency of the temperature swing ΔT_{Chip} is low due to long load duty cycles, the magnitude of the short-time current does not need to be limited with respect to the lifetime in addition to the above-mentioned criteria. This applies in the case of long load duty cycles with durations of $T \geq 60$ s.

If, during a free periodic load duty cycle, the frequency of the temperature swing ΔT_{Chip} is high due to short load duty cycles, the magnitude of the short-time current must be limited with respect to the lifetime in addition to the above-mentioned criteria. This applies in the case of short load duty cycles with durations of $T < 60$ s.

Note:

In the case of load duty cycles that are extremely short (i.e. a few seconds ($T < \text{app. } 10$ s)), servo control should be used instead of vector control due to the high dynamic response.

If the above-mentioned criteria are applied to the SINAMICS G130, G150 and S150 converters and to the SINAMICS S120 Motor Modules (Chassis and Cabinet Modules), then free load duty cycles are permissible whenever the following conditions are fulfilled:

- The short-time current $I_{\text{ShortTime}}$ must not exceed $1.5 \cdot I_H \cdot k_D$.
(In the case of parallel connections of S120 Motor Modules, $I_{\text{ShortTime}}$ is the short-time current of a partial inverter resp. one Motor Module)
- The I^2t value, averaged over a load duty cycle duration T of max. 300 s, must not exceed 100 %.

The I^2t value is the evaluation criterion for losses and temperature rise in the power unit for the duration of the load duty cycle and is defined as follows:

$$I^2t \text{ value} = \frac{1}{T} \cdot \int_0^T \left(\frac{I(t)}{I_{\text{Rated}} \cdot k_D} \right)^2 dt \cdot 100 \%$$

Fundamental Principles and System Description

Engineering Information

Key to equation:

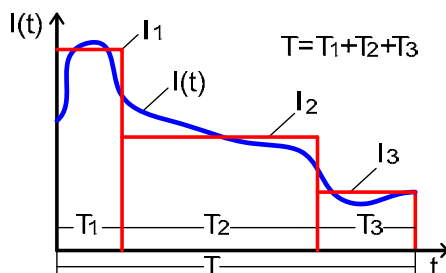
- $I(t)$ RMS value of the output current of the converter or inverter as a function of time
(In the case of parallel connections of S120 Motor Modules, $I(t)$ is the RMS value of the output current of a partial inverter resp. one Motor Module.)
- I_{Rated} Rated output current of the converter or inverter
(In the case of parallel connections of S120 Motor Modules, I_{Rated} is the rated output current of a partial inverter resp. one Motor Module, not taking into account the derating factor for parallel operation.)
- k_D Current derating factor (see below for its definition)
- T Load duty cycle duration which must not exceed the 300 s setting for the standard load duty cycle

For the practical calculation of the I^2t value, it is generally helpful to apply a finite number n of phases of constant current in each case as an approximate substitute to the output current time characteristic required by the application. This simplifies the calculation as the integration is replaced by a simple summation.

$$I^2t \text{ value} = \frac{1}{T} \cdot \left[\left(\frac{I_1}{I_{\text{Rated}} \cdot k_D} \right)^2 \cdot T_1 + \left(\frac{I_2}{I_{\text{Rated}} \cdot k_D} \right)^2 \cdot T_2 + \dots + \left(\frac{I_n}{I_{\text{Rated}} \cdot k_D} \right)^2 \cdot T_n \right] \cdot 100 \%$$

where $\sum_1^n T_n = T$,

i.e. the sum of all phases T_1 to T_n equals the load duty cycle duration T , where T must be ≤ 300 s. The diagram below illustrates the correlations:



Approximation of the current characteristic over time using time phases with constant current

The current derating factor k_D specified in the equations takes into account all of the factors that require the output current of the converter or inverter to be reduced:

$$k_D = k_{\text{Temp}} \cdot k_{\text{Puls}} \cdot k_{\text{Parallel}} \cdot k_{\text{ShortDutyCycle}}$$

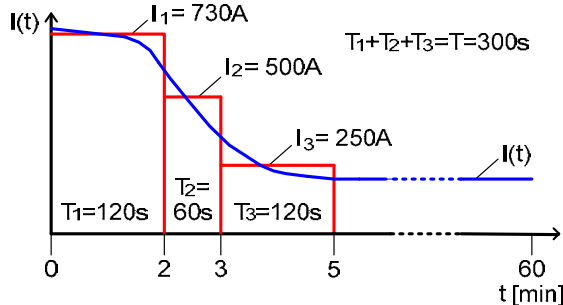
Key to equation:

- k_D Current derating factor (total derating factor)
- k_{Temp} Derating factor for increased ambient temperatures of from 40 °C to 50 °C
- k_{Puls} Derating factor for pulse frequencies greater than the factory setting
- k_{Parallel} Derating factor for parallel operation of S120 Motor Modules
- $k_{\text{ShortDutyCycle}}$ Derating factor for short load duty cycles with $T < 60$ s).

The derating factors k_{Temp} and k_{Puls} can be found in the relevant catalogs or device-specific sections of this engineering manual. The derating factor k_{Parallel} has generally the value of 0.95 for SINAMICS S120 Motor Modules. The derating factor $k_{\text{ShortDutyCycle}}$ for short load duty cycles with $T < 60$ s has generally the value of 0.9 for the SINAMICS G130, G150 and S150 converters and S120 Motor Modules (Chassis and Cabinet Modules), which are described in this engineering manual.

Calculation example:

A variable-speed drive must perform a heavy duty start at intervals of 60 min on a 690 V supply system. The diagram below shows the motor current $I(t)$ characteristic as a function of time. The maximum ambient temperature in the converter room is specified as 45 °C and the installation altitude is 400 m.



Motor current $I(t)$ over time during starting

A SINAMICS G150 in degree of protection IP20 is selected as the drive converter. Its rated data are $V = 690$ V and $I_{rated} = 575$ A. It has, according to the catalog D11, a base load current I_H of 514 A and therefore a short-time current $I_{ShortTime}$ of $1.5 \cdot I_H = 771$ A. We shall now use a calculation to check whether the selected converter operating on the factory-set pulse frequency is the right unit for the required load duty cycle under the specified conditions:

1. Determine the current derating factor:

With the following derating factors

- $k_{Temp} = 0.95$ (ambient temperature 45 °C, installation altitude < 2000 m, degree of protection IP20),
- $k_{Puls} = 1.0$ (factory-set pulse frequency)
- $k_{Parallel} = 1.0$ (no parallel connection of S120 Motor Modules)
- $k_{ShortDutyCycle} = 1.0$ (duty cycle duration $T \geq 60$ s)

the current derating factor k_D is

$$k_D = k_{Temp} \cdot k_{Puls} \cdot k_{Parallel} \cdot k_{ShortDutyCycle} = 0.95 \cdot 1.0 \cdot 1.0 \cdot 1.0 = 0.95$$

2. Determine the permissible short-time current:

With a base load current $I_H = 514$ A and a derating factor $k_D = 0.95$, the permissible short-time current is

$$I_{ShortTime} = 1.5 \cdot I_H \cdot k_D = 1.5 \cdot 514 \text{ A} \cdot 0.95 = 732 \text{ A}$$

This value practically corresponds to the motor current of 730 A required at the beginning of the starting process and is therefore just within the permissible limit.

3. Determine the I^2t value of the motor current:

For the purpose of simplifying the calculation, the actual time characteristic of the motor current $I(t)$ during starting is approximated by three time phases, i.e. T_1 to T_3 , each with a constant current I_1 to I_3 ; in this case, the last phase T_3 must be selected such that the total of phases $T_1 + T_2 + T_3$ does not exceed the maximum permissible load duty cycle duration of $T = 300$ s. The calculation for the I^2t value is therefore

$$I^2t \text{ value} = \frac{1}{T} \cdot \left[\left(\frac{I_1}{I_{Rated} \cdot k_D} \right)^2 \cdot T_1 + \left(\frac{I_2}{I_{Rated} \cdot k_D} \right)^2 \cdot T_2 + \left(\frac{I_3}{I_{Rated} \cdot k_D} \right)^2 \cdot T_3 \right] \cdot 100 \%$$

$$I^2t \text{ value} = \frac{1}{300s} \cdot \left[\left(\frac{730A}{546A} \right)^2 \cdot 120s + \left(\frac{500A}{546A} \right)^2 \cdot 60s + \left(\frac{250A}{546A} \right)^2 \cdot 120s \right] \cdot 100 \%$$

$$I^2t \text{ value} = \frac{1}{300s} \cdot [215s + 50s + 25s] \cdot 100\% = \frac{290s}{300s} \cdot 100\% = 97\%$$

The I^2t value of 97 % is lower than the maximum permissible value of 100 % and is thus acceptable within the limits of accuracy of the approximations used to calculate the current characteristic over time.

Fundamental Principles and System Description

Engineering Information

Thermal monitoring of the power unit during load duty cycles and continuous operation

In both load duty cycle mode and continuous operation, the power unit of the SINAMICS G130, G150, S150 converters and S120 Motor Modules (Chassis and Cabinet Modules) is thermally monitored by three different methods:

- The output current is monitored by an I^2t calculation.
- The heatsink temperature is monitored by direct temperature measurements.
- The chip temperature of the IGBTs is monitored by the thermal model which can calculate the exact temperature of the IGBT chips on the basis of the heatsink temperature measurement plus other electrical quantities such as pulse frequency, DC link voltage and output current.

If a power unit overload is detected by these monitoring functions, an overload reaction defined by the setting in parameter P0290 is triggered. The following overload reactions can be parameterized:

- Reduce output current in vector control mode or output frequency in V/f mode.
- No reduction, but shutdown (trip) when the overload threshold is reached.
- Reduce the output current or output frequency and pulse frequency (not by I^2t).
- Reduce the pulse frequency (not by I^2t)

With many applications, the parameterizable overload reaction makes it possible to prevent instantaneous shutdown when the power unit is overloaded briefly. For example, it is perfectly tolerable with most pump and fan applications for the flow rate to drop briefly when the output current is reduced. If the drive is operating on a higher pulse frequency than the factory setting in order to achieve a reduction in motor noise, for example, a possible overload reaction would be to reduce the pulse frequency and thus maintain the flow rate.

If the parameterized overload reaction cannot reduce the overload sufficiently, then the drive will always shut down in order to protect the power unit. This means that the risk of irreparable damage to the power unit as a result of excessive IGBT temperatures is absolutely eliminated in all operating modes.

These protection mechanisms implemented in the SINAMICS units do, however, demand precise configuring of the converter in relation to its load profile so that the drive can perform all the required functions without interruption by overload reactions.

■ Efficiency of SINAMICS converters at full load and at partial load

In many applications energy savings can be made by the use of variable-speed drives instead of conventional drive solutions. Particularly at pump and fan drives with a quadratic load characteristic, variable-speed drives can achieve considerable energy savings at partial load operation. This is because these drives have a good efficiency in a wide speed range. In order to be able to quantify these savings, precise information about the efficiency of converter and motor are required depending on the load and the speed of the drive. The following paragraphs will explain how the efficiency of the SINAMICS converters G130, G150 and S150 can be determined at full and partial load.

Definition of the converter efficiency

The efficiency of a converter is defined as the ratio of the active electrical power delivered at the output P_{Out} to the active electrical power taken at the input P_{In} . If it is taken into consideration that the active electrical power taken at the input P_{In} , is bigger than the active electrical power at the output P_{Out} due to the power losses P_L of the converter, the following general formula can be used for calculating the converter efficiency η :

$$\eta = \frac{P_{Out}}{P_{In}} = \frac{P_{Out}}{P_{Out} + P_L}.$$

Converter efficiency at full load

The determination of the converter efficiency at full load η_{100} is based on the operation of the converter on an asynchronous motor, which is adapted to the rated data of the converter regarding rated voltage and rated current and which operates at its rated point. In order to calculate the efficiency η_{100} at this rated point, the active power at the output of the converter $P_{Out-100}$ and the power losses of the converter P_L must be specified.

The active power at the output of the converter at full load is

$$P_{Out-100} = \sqrt{3} \cdot V_{Out-100} \cdot I_{Out-100} \cdot \cos \varphi_{Mot}.$$

The output voltage $V_{Out-100}$ of SINAMICS converters in vector control mode, is, when operating with pulse-edge modulation, almost equal to the supply voltage on the input side V_{Line} . The output current $I_{Out-100}$ is the rated output current I_{Rated} of the converter and the power factor $\cos \varphi_{Mot}$ is the power factor of an asynchronous motor, which is adapted to the rated voltage and the rated current of the converter and which is operated at its rated point. Thus, at full load, the active power at the output of the converter is

$$P_{Out-100} = \sqrt{3} \cdot V_{Line} \cdot I_{Rated} \cdot \cos \varphi_{Mot}.$$

The power losses of the converter at full load P_{L-100} can be found in the technical data of the catalogs or operating instructions (equipment manuals) for SINAMICS G130, G150 and S150 converters.

From the active power $P_{Out-100}$ and the power losses P_{L-100} , the efficiency of the converter at full load can be calculated as

$$\eta_{100} = \frac{P_{Out-100}}{P_{Out-100} + P_{L-100}} = \frac{\sqrt{3} \cdot V_{Line} \cdot I_{Rated} \cdot \cos \varphi_{Mot}}{\left(\sqrt{3} \cdot V_{Line} \cdot I_{Rated} \cdot \cos \varphi_{Mot} \right) + P_{L-100}}. \quad (1)$$

With this formula, the efficiency at full load of SINAMICS G130, G150 and S150 converters can be individually calculated, depending on the supply voltage and the power factor of the connected motor.

If one does the efficiency calculation for the given converters, taking a typical power factor of $\cos \varphi_{Mot} = 0.88$ as a basis (4-pole asynchronous motor in the power range between 100 kW and 1000 kW), the following typical converter efficiencies at full load will be calculated:

- SINAMICS G130 and G150 with pulse frequency according to factory settings: $\eta_{100} = 97.7 \% - 98.3 \%$.
- SINAMICS S150 with pulse frequency according to factory settings: $\eta_{100} = 96.0 \% - 96.5 \%$.

Fundamental Principles and System Description

Engineering Information

Converter efficiency at partial load

Partial load efficiency of SINAMICS G130 and G150 converters

The following diagrams show the efficiency at partial load for SINAMICS G130 and G150 converters for constant-torque drives. Basis of the calculations is a typical value for the efficiency of the converter at full load of 98 %. The representation of the efficiency is done in two different ways. The first representation shows the efficiency in dependency on the converter output frequency for different values of the output current. The second representation shows the efficiency in dependency on the converter output current for different values of the output frequency.

Fig. 1a) shows the converter efficiency for constant-torque drives in dependency on the converter output frequency $f_{\text{Out}}/f_{\text{Rated}}$, which is in proportion to the motor speed n/n_{Rated} . The representation is done for different values of the output current $I_{\text{Out}}/I_{\text{Rated}}$, which is in proportion to the motor torque M/M_{Rated} .

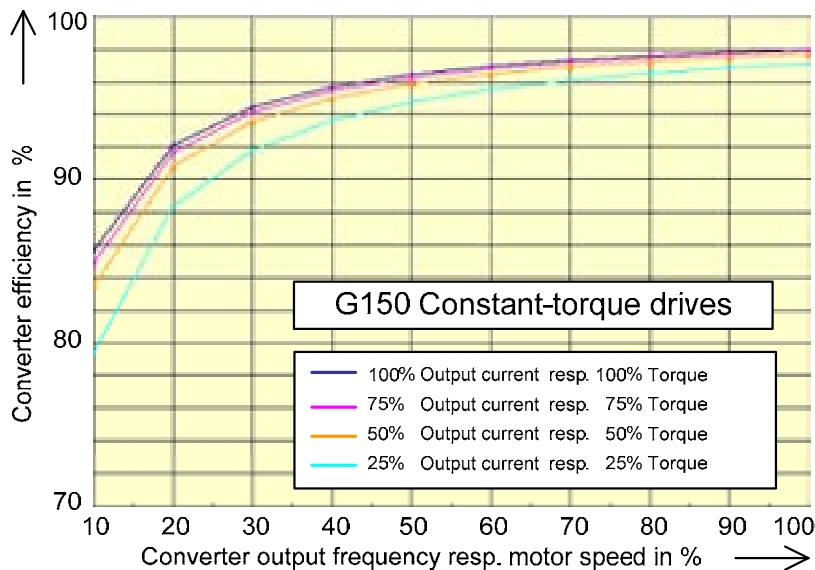


Fig. 1a)

Efficiency of SINAMICS G130 and G150 converters for constant-torque drives in dependency on the converter output frequency (specified in %)

Fig. 1b) shows the converter efficiency for constant-torque drives in dependency of the converter output current $I_{\text{Out}}/I_{\text{Rated}}$, which is in proportion to the motor torque M/M_{Rated} . The representation is done for different values of the output frequency $f_{\text{Out}}/f_{\text{Rated}}$, which is in proportion to the motor speed n/n_{Rated} .

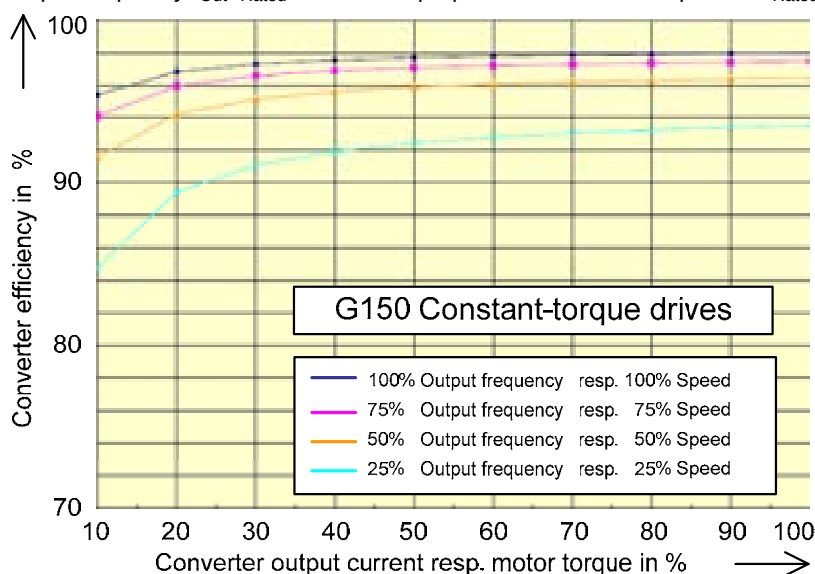


Fig. 1b)

Efficiency of SINAMICS G130 and G150 converters for constant-torque drives in dependency on the converter output current (specified in %)

Fundamental Principles and System Description

Engineering Information

The following diagrams show the efficiency at partial load for SINAMICS G130 and G150 converters for drives with quadratic load characteristic $M \sim n^2$. Basis of the calculations is a typical value for the efficiency of the converter at full load of 98 %. The representation of the efficiency is done in three different ways, the first in dependency on the converter output frequency, the second in dependency on the converter output current and the third in dependency of the converter output power.

Fig. 2a) shows the converter efficiency for drives with quadratic load characteristic in dependency on the converter output frequency $f_{\text{Out}}/f_{\text{Rated}}$, which is in proportion to the motor speed n/n_{Rated}

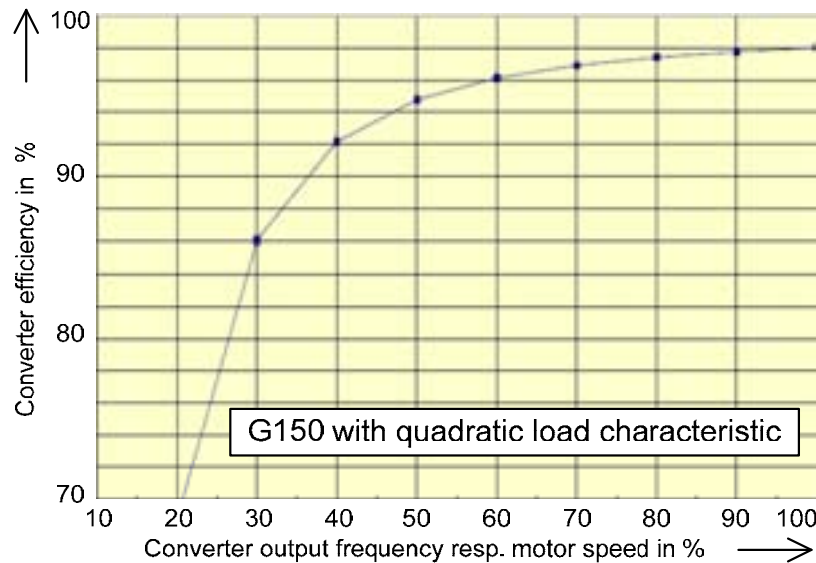


Fig. 2a)
Efficiency of SINAMICS G130 and G150 converters for drives with quadratic load characteristic in dependency on the converter output frequency (specified in %)

Fig 2b) shows the converter efficiency for drives with quadratic load characteristic in dependency on the converter output current $I_{\text{Out}}/I_{\text{Rated}}$, which is in proportion to the motor torque M/M_{Rated} .

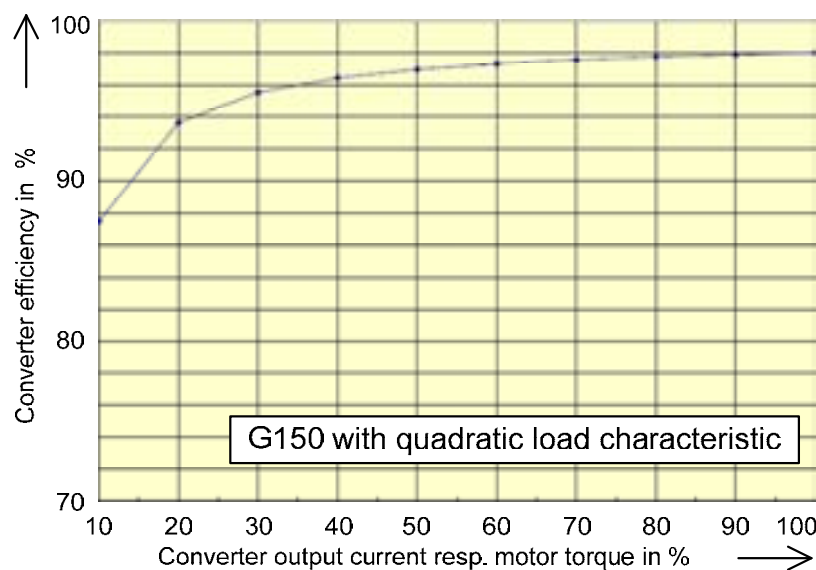


Fig. 2b)
Efficiency of SINAMICS G130 and G150 converters for drives with quadratic load characteristic in dependency on the converter output current (specified in %)

Fundamental Principles and System Description

Engineering Information

Fig. 2c) shows the converter efficiency for drives with quadratic load characteristic in dependency on the converter output power $P_{\text{Out}}/P_{\text{Out-100}}$, which is in proportion to the motor power P/P_{Rated} .

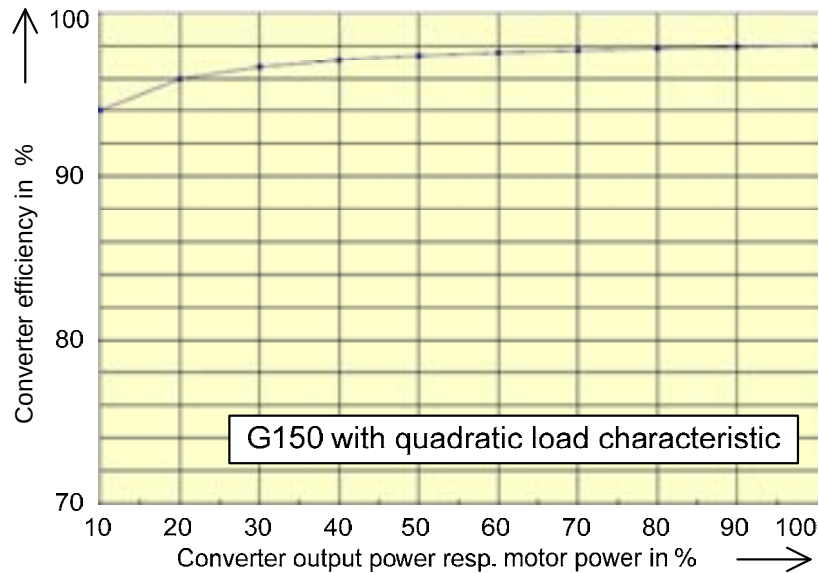


Fig. 2c)

Efficiency of SINAMICS G130 and G150 converters for drives with quadratic load characteristic in dependency on the converter output power (specified in %)

Partial load efficiency of SINAMICS S150 converters

The following diagrams show the efficiency at partial load for SINAMICS S150 converters for constant-torque drives. Basis of the calculations is a typical value for the efficiency of the converter at full load of 96 %. The representation of the efficiency is done in two different ways. The first representation shows the efficiency in dependency on the converter output frequency for different values of the output current. The second representation shows the efficiency in dependency on the converter output current for different values of the output frequency.

Fig. 1a) shows the converter efficiency for constant-torque drives in dependency on the converter output frequency $f_{\text{Out}}/f_{\text{Rated}}$, which is in proportion to the motor speed n/n_{Rated} . The representation is done for different values of the output current $I_{\text{Out}}/I_{\text{Rated}}$, which is in proportion to the motor torque M/M_{Rated} .

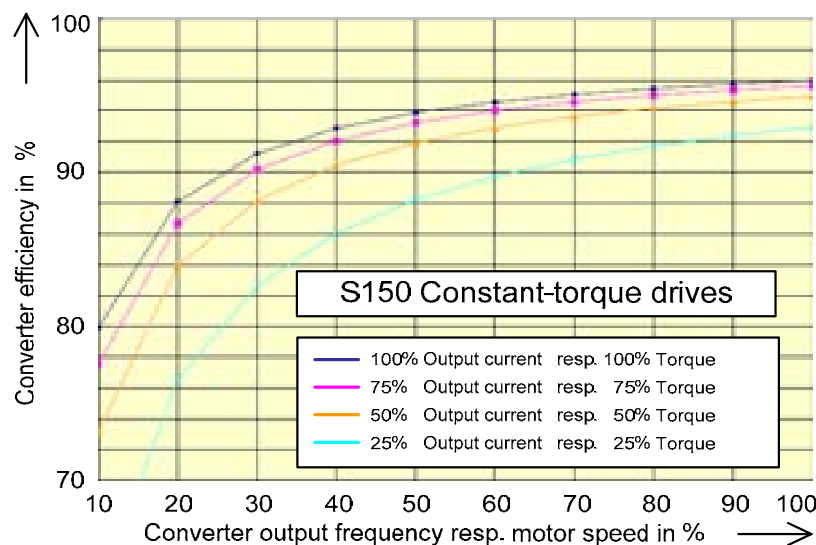


Fig. 1a)
Efficiency of SINAMICS S150 converters for constant-torque drives
in dependency on the converter output frequency (specified in %)

Fig. 1b) shows the converter efficiency for constant-torque drives in dependency of the converter output current $I_{\text{Out}}/I_{\text{Rated}}$, which is in proportion to the motor torque M/M_{Rated} . The representation is done for different values of the output frequency $f_{\text{Out}}/f_{\text{Rated}}$, which is in proportion to the motor speed n/n_{Rated} .

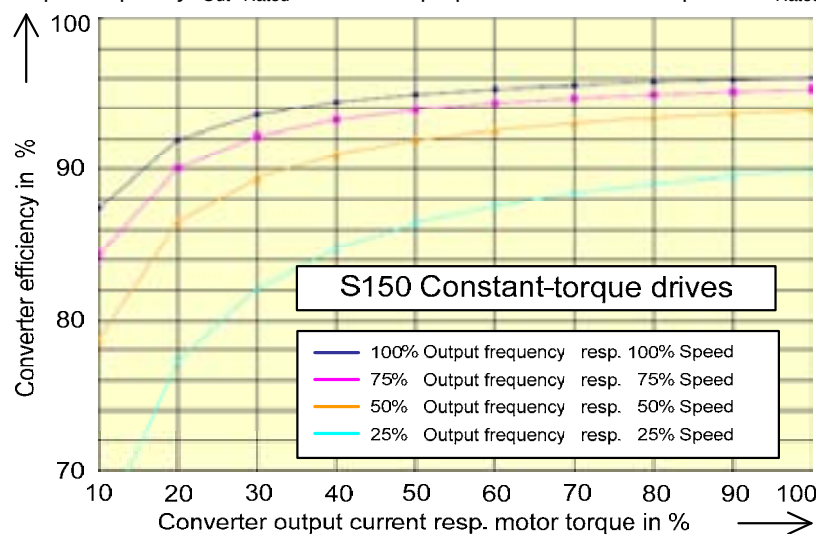


Fig. 1b)
Efficiency of SINAMICS S150 converters for constant-torque drives
in dependency on the converter output current (specified in %)

Fundamental Principles and System Description

Engineering Information

The following diagrams show the efficiency at partial load for SINAMICS S150 converters for drives with quadratic load characteristic $M \sim n^2$. Basis of the calculations is a typical value for the efficiency of the converter at full load of 96 %. The representation of the efficiency is done in three different ways, the first in dependency on the converter output frequency, the second in dependency on the converter output current and the third in dependency of the converter output power.

Fig. 2a) shows the converter efficiency for drives with quadratic load characteristic in dependency on the converter output frequency $f_{\text{Out}}/f_{\text{Rated}}$, which is in proportion to the motor speed n/n_{Rated}

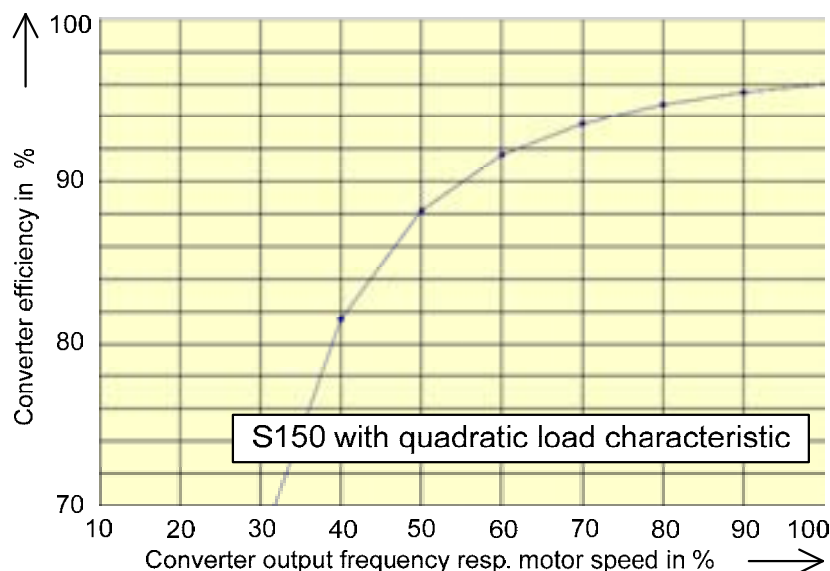


Fig. 2a)
Efficiency of SINAMICS S150 converters for drives with quadratic load characteristic in dependency on the converter output frequency (specified in %)

Fig 2b) shows the converter efficiency for drives with quadratic load characteristic in dependency on the converter output current $I_{\text{Out}}/I_{\text{Rated}}$, which is in proportion to the motor torque M/M_{Rated} .

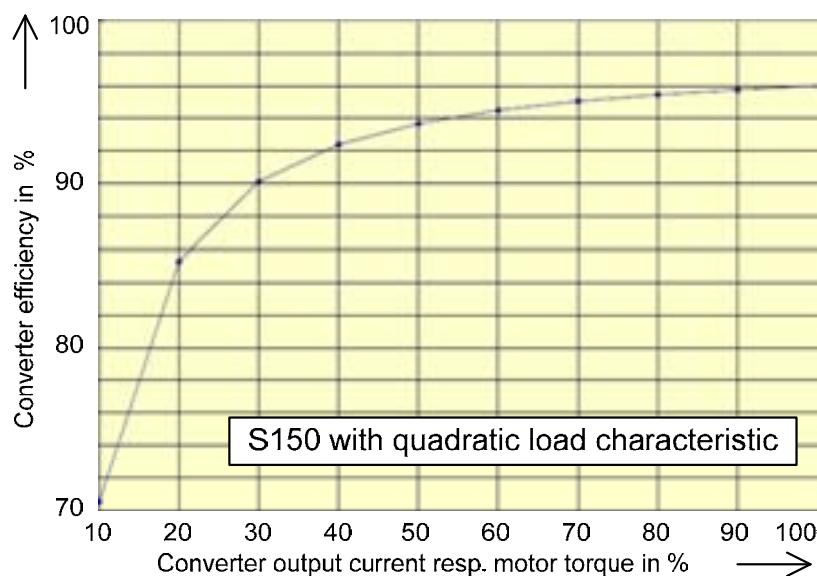


Fig. 2b)
Efficiency of SINAMICS S150 converters for drives with quadratic load characteristic in dependency on the converter output current (specified in %)

Fig. 2c) shows the converter efficiency for drives with quadratic load characteristic in dependency on the converter output power $P_{\text{Out}}/P_{\text{Out-100}}$, which is in proportion to the motor power P/P_{Rated} .

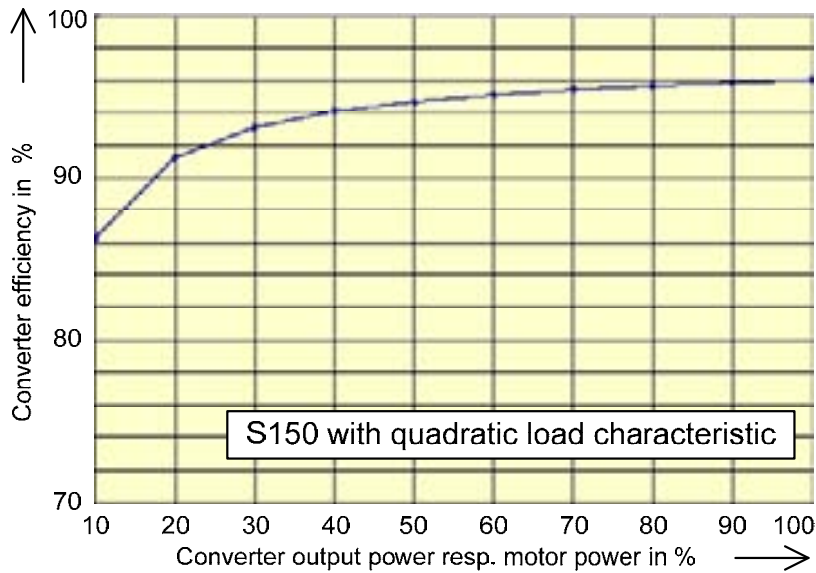


Fig. 2c)
Efficiency of SINAMICS S150 converters for drives with quadratic load characteristic in dependency on the converter output power (specified in %)

Fundamental Principles and System Description

Engineering Information

■ Parallel connections of converters

General

It can be useful to connect complete converters and their components (Infeed Modules and Motor Modules) in parallel for a number of reasons:

- To increase the converter output power if it is not technically or economically feasible to achieve the required output power by any other means. For example, it is a relatively complicated procedure to create parallel connections of large numbers of IGBT modules within the same power unit which means that using parallel connection of complete power units can be the simpler and more cost-effective solution.
- To increase the availability in cases where it is necessary after a converter malfunction to maintain emergency operation during which the unit can operate at a lower output than its rated value. In the event of more or less minor defects within the power unit, for example, it is feasible to deactivate the affected power unit via the converter control system without shutting down the power unit that are still functional.

The parallel connection strategy for SINAMICS units is essentially designed to increase the converter power output. The parallel-connected modules (Infeed and Motor Modules) are driven and monitored by a single Control Unit and are constructed of exactly the same hardware components as the equivalent modules for single drives. All the functions required for parallel operation are stored in the firmware of the Control Unit. The use of a single shared Control Unit for the parallel-connected modules and the fact that each fault in any module leads to immediate shutdown of the entire paralleled system means that a converter parallel connection can be regarded in practical terms as a single, high-power-output converter.

Parallel connections of SINAMICS converters

SINAMICS converters can be connected in parallel with firmware version V2.3 and higher.

The modular SINAMICS S120 drive system provides the option of operating Infeed Modules and Motor Modules in parallel on S120 units in the Chassis and Cabinet Modules format. SINAMICS S120 units in Booksize and Blocksize format cannot be operated in parallel.

S120 Motor Modules can be operated in parallel for vector-type drive objects (vector control), but not for servo-type drive objects (servo control).

The higher-output G150 cabinets ($P \geq 630$ kW for 400 V units, $P \geq 630$ kW for 500 V units and $P \geq 1000$ kW for 690 V units) are also designed as a parallel connection based on two lower-output converter cabinets. The details and special features of the G150 converter parallel connection are described more detailed at the end of the chapter "Converter Cabinet Units SINAMICS G150".

This section will provide a more detailed description of the basic options for making parallel connections of units of the SINAMICS S120 modular drive system in Chassis and Cabinet Modules format.

A SINAMICS S120 converter parallel connection consists of:

- Up to four Infeed Modules (line-side rectifiers) connected in parallel
- Up to four Motor Modules (motor-side inverters) connected in parallel
- A single Control Unit which controls and monitors the parallel-connected line and motor-side power units, so that, in addition to the line and motor-side parallel configuration, no further Motor Modules can be controlled by the Control Unit.
- Components on the line and motor side for de-coupling the parallel-connected power units and for ensuring symmetrical current distribution

Fundamental Principles and System Description

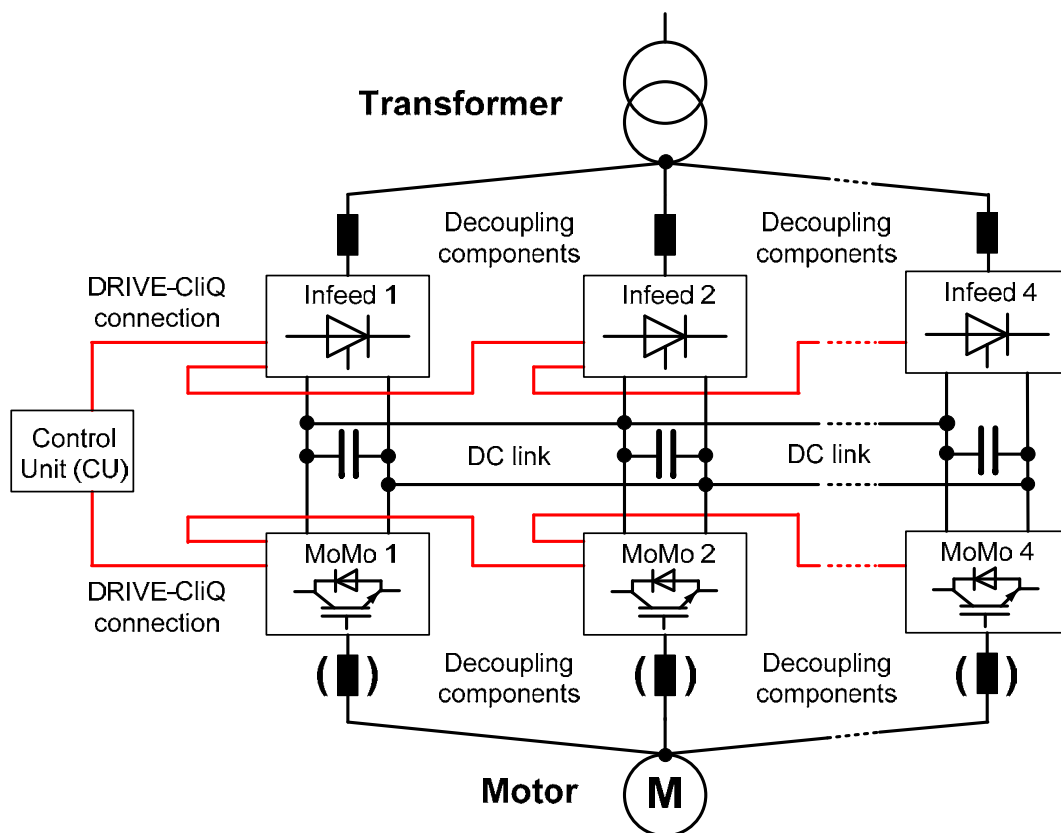
Engineering Information

The following S120 Modules can be connected in parallel:

- Basic Line Modules, 6-pulse and 12-pulse (with the relevant line reactors in each case)
- Smart Line Modules, 6-pulse and 12-pulse (with the relevant line reactors in each case)
- Active Line Modules (with the relevant Active Interface Modules in each case)
- Motor Modules as vector-type drive objects (vector control)

It is important to note that the parallel-connected Infeed Modules or Motor Modules, which are absolutely identical to the corresponding modules for single drives in terms of hardware, must be of exactly the same type and for the same rated voltage and rated output. The firmware versions and version releases of the CIB boards must also be identical. It is therefore not permissible to mix different variants of Infeed Module within the same parallel connection (e.g. a mixture of Basic Line Modules with Smart Line Modules or Basic Line Modules with Active Line Modules).

The diagram below shows the basic design of a SINAMICS S120 converter parallel connection.



Principle of the SINAMICS S120 converter parallel connection

As a result of unavoidable tolerances in the electrical components (e.g. diodes, thyristors and IGBTs) and imbalances in the mechanical design of the parallel connection, symmetrical current distribution cannot be assured automatically. The mechanical dimensions of the converters are particularly large with multiple parallel connections, resulting inevitably in imbalances in the busbars and cabling which have a negative impact on current distribution.

There is a range of different measures which can be taken to ensure symmetrical current distribution between the parallel-connected power units:

- Use of selected components with low forward voltage tolerances (this option is not, however, used on SINAMICS equipment due to a variety of disadvantages associated with it, e.g. high costs and problems with spare parts stocking)
- Use of current-balancing system components such as line reactors or motor reactors
- Use of the most symmetrical mechanical design that is possible

Fundamental Principles and System Description

Engineering Information

- Symmetrical power cabling at the plant side between the transformer and the parallel-connected Infeeds and between the parallel-connected Motor Modules and the motor (use of cables of the same type with identical cross-section and length)
- Use of an electronic current sharing control (ΔI control)

In practice, however, it is not generally possible to achieve an absolutely symmetrical current distribution, even when several of the above measures are combined. As a result, a slight current reduction of a few per cent below the rated current must be taken into account when parallel connections of power units are configured.

The current reduction from the rated value of the individual modules is as follows:

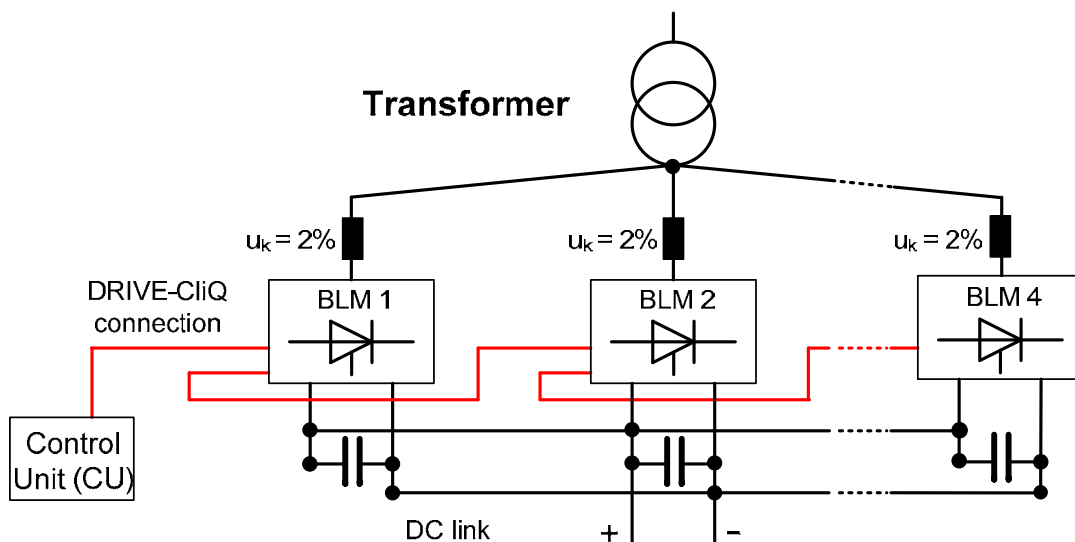
- 7.5 % for parallel connections of S120 Basic Line Modules and S120 Smart Line Modules because the modules are not equipped with an electronic current sharing control
- 5.0 % for parallel connections of S120 Active Line Modules and S120 Motor Modules because the modules are equipped with an electronic current sharing control

Parallel connection of S120 Basic Line Modules

Parallel connections of Basic Line Modules can be implemented as either a 6-pulse circuit if the parallel-connected modules are connected to a two-winding transformer, or as a 12-pulse circuit if the parallel-connected modules are connected to a three-winding transformer with secondary windings that supply voltages with a phase shift of 30° .

6-pulse parallel connection of S120 Basic Line Modules

With the 6-pulse parallel connection, up to four Basic Line Modules are supplied by a common two-winding transformer on the line side and controlled by a common Control Unit.



6-pulse parallel connection of S120 Basic Line Modules

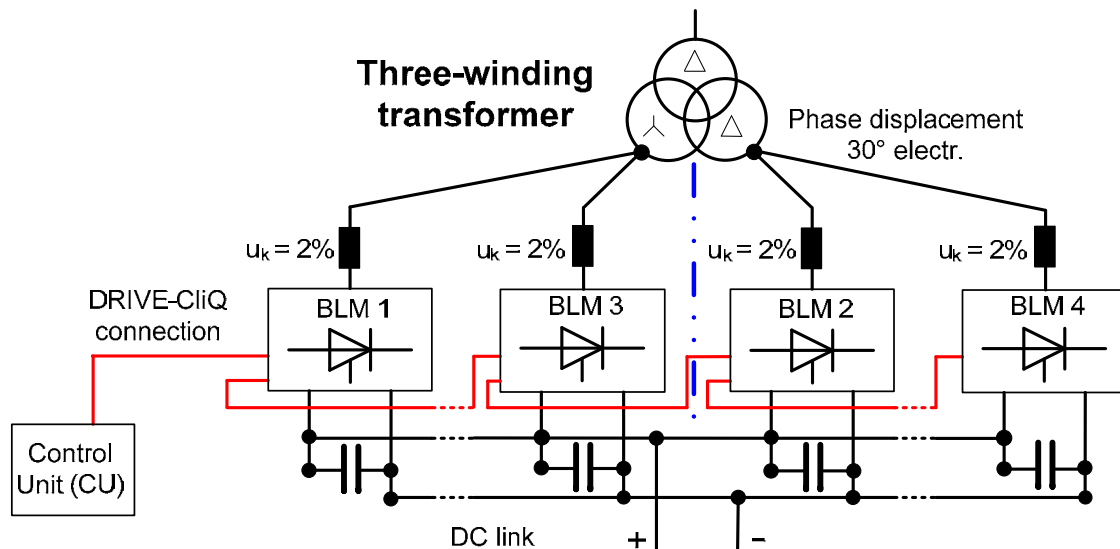
As Basic Line Modules have no electronic current sharing control, the current must be balanced by the following measures:

- Use of line reactors with a relative short-circuit voltage of $u_k = 2\%$
- Use of symmetrical power cabling between the transformer and the parallel-connected BLMs (cables of identical type with the same cross-section and length)

The current reduction from the rated value for individual Basic Line Modules in a parallel connection is 7.5 %.

12-pulse parallel connection of S120 Basic Line Modules

With 12-pulse parallel connections, up to four Basic Line Modules are supplied by a three-winding transformer on the line side. In this case, an even number of modules, i.e. two or four, must be divided between the two secondary windings. The Basic Line Modules of both secondary windings are controlled by a common Control Unit, despite of the 30° phase-displacement. This is possible because the Basic Line Modules produce their gating impulses for the thyristors, which must have a phase displacement by 30° due to the 12-pulse circuit, by independent gating units in the individual Basic Line Module, which are not synchronized by the Control Unit.



12-pulse parallel connection of S120 Basic Line Modules

As Basic Line Modules have no electronic current sharing control, three-winding transformer, power cabling and line reactors must meet the following requirements in order to provide a balanced current:

- Three-winding transformer must be symmetrical, recommended vector groups Dy5d0 or Dy11d0.
- Relative short-circuit voltage of three-winding transformer $u_k \geq 4\%$.
- Difference between relative short-circuit voltages of secondary windings $\Delta u_k \leq 5\%$.
- Difference between no-load voltages of secondary windings $\Delta V \leq 0.5\%$.
- Use of symmetrical power cabling between the transformer and the Basic Line Modules (cables of identical type with the same cross-section and length)
- Use of line reactors with a relative short-circuit voltage of $u_k = 2\%$. (Line reactors can be omitted if a double-tier transformer is used and only one BLM is connected to each secondary winding of the transformer).

A double-tier transformer is generally the only means of meeting the requirements of a three-winding transformer for this application. Line reactors must always be installed if other types of three-winding transformer are used. Alternative solutions for obtaining a phase displacement of 30°, such as two separate transformers with different vector groups, cannot be used due to the inadmissibly high tolerances involved.

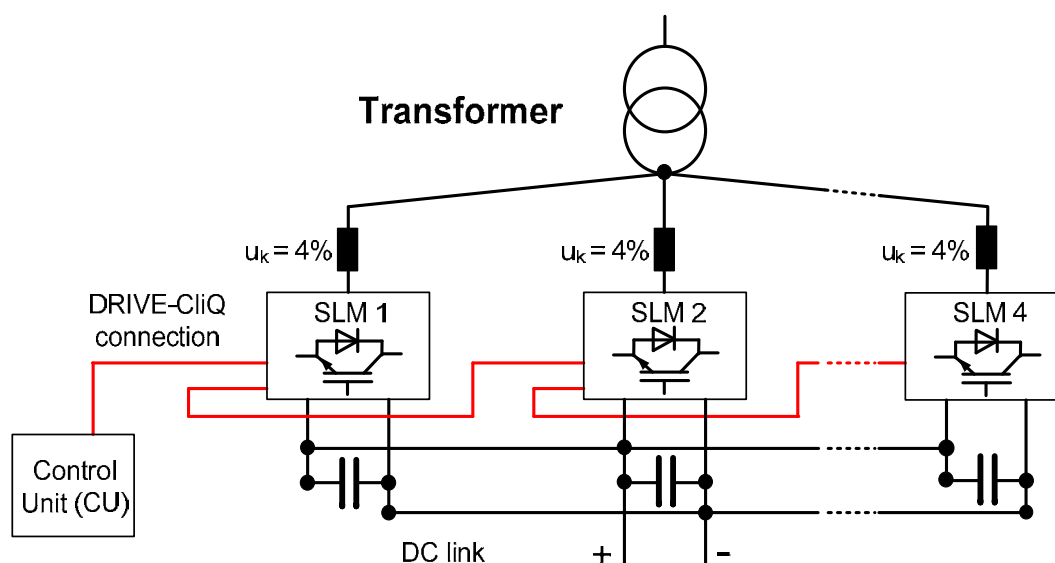
The current reduction from the rated value for individual Basic Line Modules in a parallel connection is 7.5%. This is also valid for the simplest form of a 12-pulse parallel configuration, if only one Basic Line Module is connected to each secondary transformer winding, because also in this configuration the transformer's tolerance can lead to an uneven current distribution.

Parallel connection of S120 Smart Line Modules

Parallel connections of Smart Line Modules can be implemented as either a 6-pulse circuit if the parallel-connected modules are connected to a two-winding transformer, or as a 12-pulse circuit if the parallel-connected modules are connected to a three-winding transformer with secondary windings that supply voltages with a phase shift of 30 °.

6-pulse parallel connection of S120 Smart Line Modules

With the 6-pulse parallel connection, up to four Smart Line Modules are supplied by a common two-winding transformer on the line side and controlled by a common Control Unit.



6-pulse parallel connection of S120 Smart Line Modules

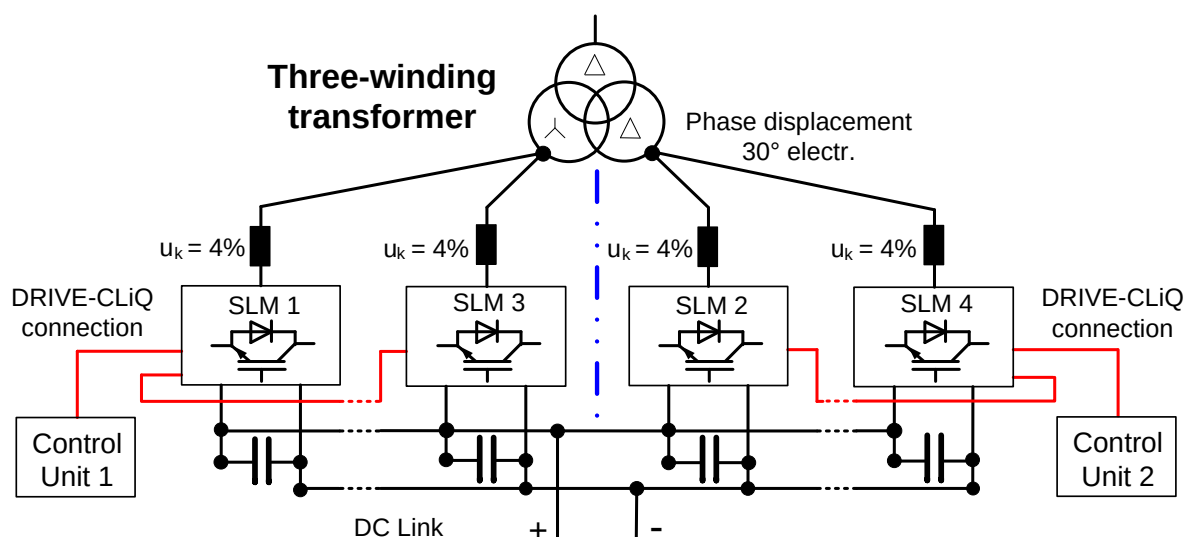
As Smart Line Modules have no electronic current sharing control, the current must be balanced by the following measures:

- Use of line reactors with a relative short-circuit voltage of $u_k = 4\%$
- Use of symmetrical power cabling between the transformer and the Smart Line Modules (cables of identical type with the same cross-section and length)

The current reduction from the rated value for individual Smart Line Modules in a parallel connection is 7.5 %.

12-pulse parallel connection of S120 Smart Line Modules

With 12-pulse parallel connections, up to four Smart Line Modules are supplied by a three-winding transformer on the line side. In this case, an even number of modules, i.e. two or four, must be divided between the two secondary windings. **It is absolutely essential that the Smart Line Modules of both secondary windings are controlled by means of two Control Units because of the phase displacement of 30°. The use of two Control Units is necessary because, in contrast to the Basic Line Modules, the gating impulses for the IGBTs in Smart Line Modules are synchronized by the Control Unit. Thus all Smart Line Modules controlled by one Control Unit must be connected to the same transformer winding with equal phase position.**



12-pulse parallel connection of S120 Smart Line Modules

As Smart Line Modules have no electronic current sharing control, three-winding transformer, power cabling and line reactors must meet the following requirements in order to provide a balanced current:

- Three-winding transformer must be symmetrical, recommended vector groups Dy5d0 or Dy11d0.
- Relative short-circuit voltage of three-winding transformer $u_k \geq 4\%$.
- Difference between relative short-circuit voltages of secondary windings $\Delta u_k \leq 5\%$.
- Difference between no-load voltages of secondary windings $\Delta V \leq 0.5\%$.
- Use of symmetrical power cabling between the transformer and the Smart Line Modules (cables of identical type with the same cross-section and length)
- Use of line reactors with a relative short-circuit voltage of $u_k = 4\%$.

A double-tier transformer is generally the only means of meeting the requirements of a three-winding transformer for this application. Alternative solutions for obtaining a phase displacement of 30°, such as two separate transformers with different vector groups, cannot be used due to the inadmissibly high tolerances involved.

The current reduction from the rated value for individual Smart Line Modules in a parallel connection is 7.5 %. This is also valid for the simplest form of a 12-pulse parallel configuration, if only one Smart Line Module is connected to each secondary transformer winding, because also in this configuration the transformer's tolerance can lead to an uneven current distribution.

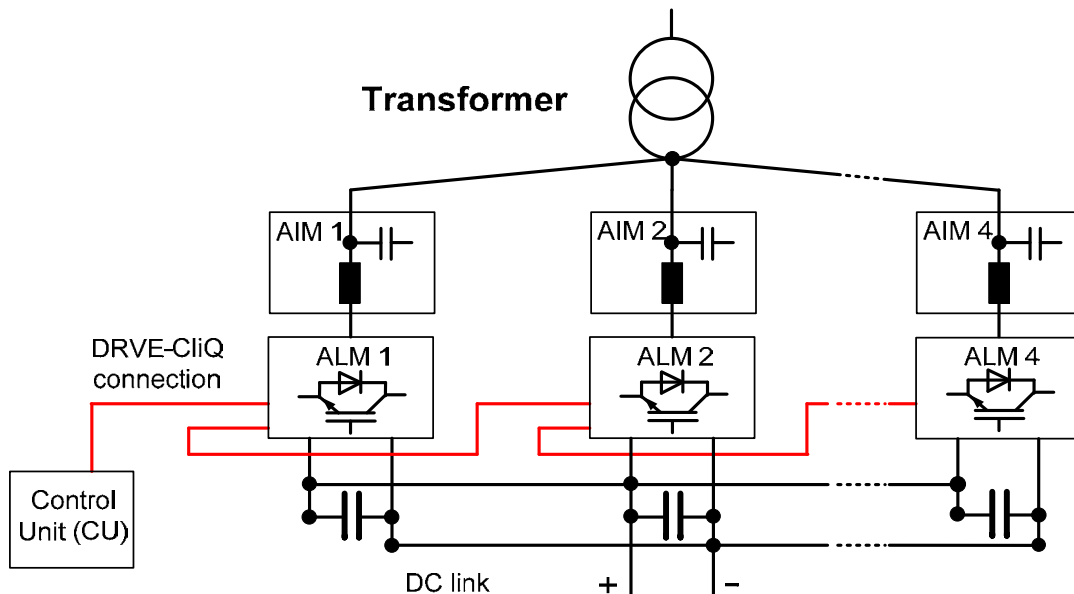
Due to the phase displacement of 30° between both secondary winding systems and the control of both systems by separate Control Units, it is generally not possible to ensure, that both systems contribute equally to the pre-charging of the connected DC link. In order to prevent the overloading of individual systems during precharging, the 12-pulse parallel connection of Smart Line Modules must be dimensioned in such a way that each system is individually able to pre-charge the DC link.

Fundamental Principles and System Description

Engineering Information

Parallel connection of S120 Active Line Modules

The parallel connection of up to four Active Line Modules is supplied by a common two-winding transformer and controlled by a common Control Unit. This is necessary because the gating impulses for the IGBTs in Active Line Modules are synchronized by the Control Unit. Thus all Active Line Modules controlled by one Control Unit must be connected to the same transformer winding with equal phase position. It is not, therefore, admissible to supply this type of parallel connection by a three-winding transformer with out-of-phase secondary voltages. Since the harmonic effects on the supply caused by the Active Infeed are only very minor, this type of arrangement would not improve the conditions in relation to harmonic content.



Parallel connection of S120 Active Line Modules

The following measures help to ensure balanced currents in parallel connections of Active Line Modules:

- Use of an electronic current sharing control (ΔI control)
- Reactors in the Clean Power Filters of the Active Interface Modules
- Use of symmetrical power cabling between the transformer and the parallel-connected Active Interface Modules / Active Line Modules (cables of identical type with the same cross-section and length)

The current reduction from the rated value for individual Active Interface Modules / Active Line Modules in a parallel connection is 5 %.

Parallel connection of S120 Motor Modules

Up to four Motor Modules operating in parallel can supply a single motor in vector control mode. The motor can have electrically isolated winding systems or a common winding system. The type of winding system defines

- the decoupling measures to be implemented at the outputs of the parallel-connected Motor Modules
- the modulation systems which may be used to generate the pulse patterns.

In combination with the type of Infeed, the modulation systems determine the magnitude of the maximum attainable output voltage or the maximum attainable motor voltage (details can be found in sections "Maximum attainable output voltage with space vector modulation SVM" and "Maximum attainable output voltage with pulse-edge modulation PEM").

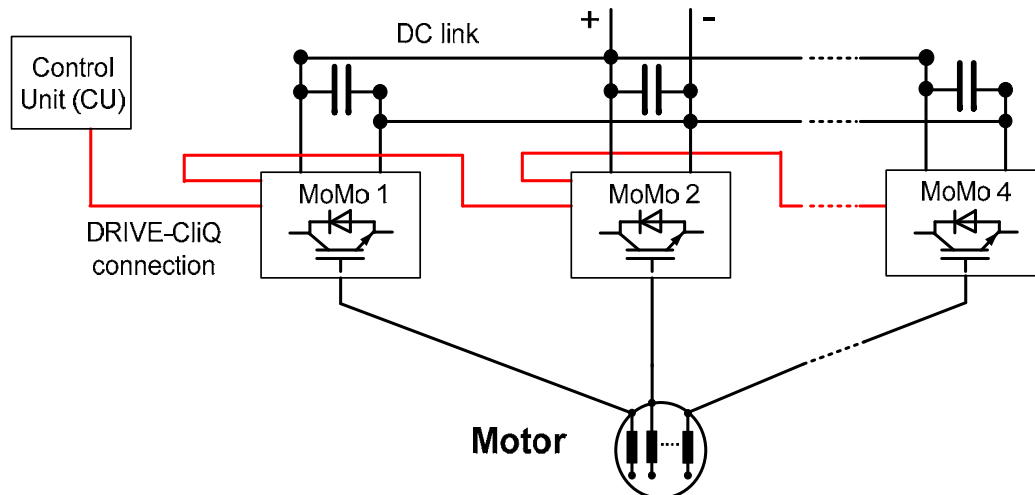
The two possible variants, i.e.

- motor with electrically isolated winding systems and
- motor with a common winding system

are discussed in more detail below.

Motors with electrically isolated winding systems

Motors in the power range from about 1 MW to 4 MW, which is the usual range for converter parallel connections, generally feature several parallel windings. If these parallel windings are not interconnected inside the motor, but taken separately to its terminal box(es), then the motor winding systems are separately accessible. In such cases, it is often possible to dimension the parallel connection of S120 Motor Modules in such a way that each motor winding system is effectively supplied by a separate Motor Module of the parallel connection. The diagram below shows this type of arrangement.



Motor with electrically isolated winding systems supplied by a parallel connection of S120 Motor Modules

Due to the electrical isolation of the winding systems, this arrangement offers the following advantages:

- No decoupling measures need to be implemented at the converter output in order to limit any potential circulating currents between the parallel-connected Motor Modules (no minimum cable lengths and no motor reactors)
- Both types of modulation system, i.e. space vector modulation and pulse-edge modulation can be used, i.e. when the parallel connection is supplied by Basic Infeeds or Smart Infeeds, the maximum obtainable output voltage is almost equal to the input voltage from the Infeeds at the three-phase side (97 %). When the parallel connection is supplied by Active Infeeds, a higher output voltage than the input voltage at the three-phase side can be obtained due to the increased DC link voltage.

The current reduction from the rated value for the individual Motor Modules in a parallel connection is 5 %.

Note:

The number of separate winding systems that can be implemented in the motor depends on the number of motor poles. This means that it is not always possible to achieve an optimum assignment between parallel-connected Motor Modules and winding systems. For instance, a parallel connection of two Motor Modules might be the best solution in terms of cost and volume for a motor which can, however, be designed with only three separate winding systems. In this case, it would be necessary to select three lower-power-output Motor Modules for the parallel connection, or the motor would need to be connected up as a motor with a common winding system. If the latter option were chosen, decoupling measures would need to be implemented and it would not be possible to use pulse-edge modulation.

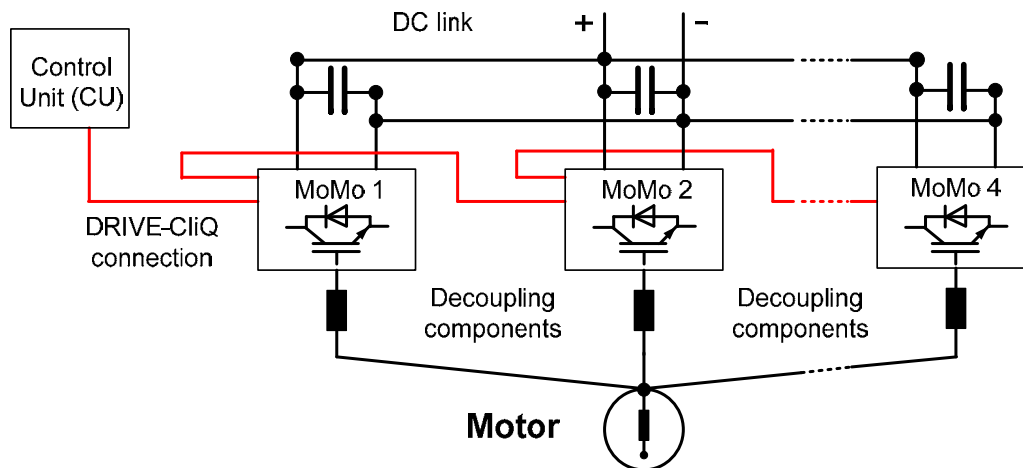
To make best use of the advantages described above, new installations should always be assessed for the possibility of using a motor with separate winding systems and a coordinated parallel connection of Motor Modules. If this variant is feasible, it should be used whenever possible.

Fundamental Principles and System Description

Engineering Information

Motors with a common winding system

It is not possible to use motors with electrically isolated winding systems for many applications, e.g. it might not be possible to implement the required number of winding systems due to the pole number or because the motor is not supplied by Siemens or because a motor with a common winding system is already available for the application. In such cases, the outputs of the parallel-connected Motor Modules are interconnected via the motor cables in the motor terminal box. The diagram below shows this type of arrangement.



Motor with common winding system supplied by a parallel connection of S120 Motor Modules

Due to the electrical coupling of the winding systems, the following disadvantages are associated with this arrangement:

- Decoupling measures have to be implemented at the converter output in order to limit any potential circulating currents between the parallel-connected Motor Modules. Decoupling can be implemented through the use of cables of minimum lengths between the Motor Modules and the motor or alternatively through the installation of motor reactors at the output of each Motor Module. (For details of minimum cable lengths, please refer to the section "Parallel connection of Motor Modules" of the chapter "Modular Cabinet Unit System SINAMICS S120 Cabinet Modules".
- Space vector modulation is the only permissible modulation system. Pulse-edge modulation cannot be utilized. The electrical coupling between the winding systems means that the transition between space vector and pulse-edge modulation modes cannot be controlled and shutdown on over-current on changeover from one mode to the other would be unavoidable. Since pulse-edge modulation mode is not available, the maximum output voltage is limited to about 92 % of the three-phase input voltage when the parallel connection is supplied by Basic Infeeds or Smart Infeeds. When the parallel connection is supplied by Active Infeeds, a higher output voltage than the input voltage can be obtained due to the increased DC link voltage, even when the unit cannot operate in pulse-edge modulation mode.

The current reduction from the rated value for the individual Motor Modules in a parallel connection is 5 %.

Admissible and inadmissible winding systems for parallel connections of SINAMICS converters

The previous sections have discussed the subject of motors with electrically isolated winding systems and motors with a common winding system, but without exactly defining the properties that are required of "electrically isolated winding systems" or "common winding systems" to make them suitable for operation with parallel connections of SINAMICS converters.

The possible variants of winding systems for converter parallel connections are discussed in more detail below and the systems are categorized as either admissible or inadmissible for parallel connections of SINAMICS converters.

Fundamental Principles and System Description

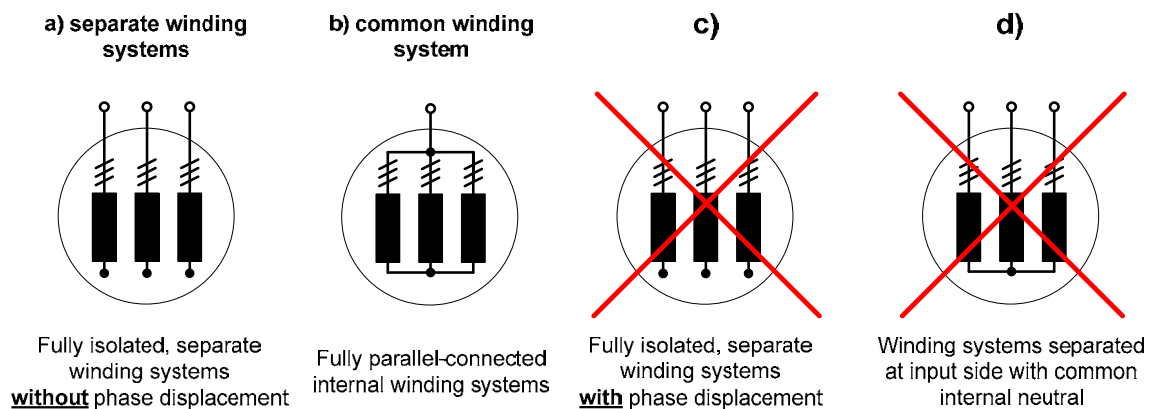
Engineering Information

The following are admissible:

- Motors with electrically isolated winding systems** in which the individual systems are not electrically coupled and not out of phase with one another.
- Motors with a common winding system** in which all parallel windings inside the motor are interconnected in the winding overhang or in the terminal box in such a way that they have the external appearance of one single winding system.

The following are inadmissible:

- Motors with electrically isolated winding systems** in which the individual systems are out of phase with one another.
- Motors with separate winding systems on the input side** which have a common, internal neutral.



Admissible and inadmissible winding systems for parallel connections of converters illustrated by the example of motors with three parallel windings

Comments on a)

The variant with completely electrically isolated winding systems in which a separate Motor Module in the parallel connection is assigned to each winding system should be selected where possible because

- No decoupling measures need to be implemented at the converter output,
- Both modulation modes, i.e. space vector and pulse-edge, can be utilized,
- No circulating currents can develop between the systems,
- The best possible current balance is achieved.

It is however absolutely essential for the separate winding systems to be in-phase, as the pulse patterns of the parallel-connected Motor Modules are synchronized by the Control Unit and therefore absolutely identical.

Comments on b)

The variant with one common winding system that is fully parallel-connected inside the motor is also feasible, but has several disadvantages as compared to variant a):

- Decoupling measures are required.
- Pulse-edge modulation mode cannot be utilized.
- Circulating currents between the parallel-connected Motor Modules cannot be eliminated completely.
- The quality of current balance between the Motor Modules in the parallel connection is not as high.

Fundamental Principles and System Description

Engineering Information

Comments on c)

The variant with winding systems that are completely electrically isolated and out of phase is not suitable for parallel connections of SINAMICS converters, as the pulse patterns of the parallel-connected Motor Modules are synchronized by the Control Unit and are therefore absolutely identical.

These types of winding were previously used in conjunction with parallel connections of current-source DC link converters SIMOVERT A in 12-pulse operation. As a result, windings of this type may exist in installations where older models of current-source DC link converter are replaced by SINAMICS, but the motors are to be retained.

Comments on d)

This variant with separate winding systems at the input side and internally coupled neutral is essentially a hybrid of variants a) and b). The problem with this variant is that circulating currents can develop between the systems due to the electrically coupled neutrals. These currents increase the losses in the motor and can therefore lead to a significant temperature rise in the motor. This risk of motor overheating is the reason why this variant cannot be used in parallel connections of SINAMICS converters.

SINAMICS S120 Liquid-Cooled units in chassis format

General

The units of the modular SINAMICS S120 drive system in chassis format are available in both air-cooled and liquid-cooled variants.

Liquid cooling allows much more efficient heat dissipation than air cooling. Therefore, liquid-cooled units are more compact than comparable air-cooled units with the same output power rating. Due to the fact that the power losses in the units are almost entirely absorbed by the coolant, no fans or only very small fans are required for the cooling of the electronic boards. Consequently, the units are very quiet. Due to their compactness and their almost neglectable cooling air requirement, the use of liquid-cooled units is recommended where very little space is available and/or harsh ambient conditions exist. Hermetically-sealed cabinet units with degree of protection IP54 or higher can be built easily using liquid-cooled systems.

Design of the SINAMICS S120 Liquid-Cooled units

SINAMICS S120 Liquid-Cooled units in chassis format are characterized by a high power density and a footprint-optimised design. They come with degree of protection IP00. The electrical power connections for the supply and the DC link are located at the top of the units and the motor connections at the bottom. The connections for the coolant (inflow and return flow) are also located at the bottom of the units.



SINAMICS S120 Liquid-Cooled chassis units: Examples of a Basic Line Module and a Motor Module

SINAMICS S120 Liquid-Cooled chassis units in the higher output power range (Basic Line Modules in frame sizes FBL and GBL and Motor Modules in frame sizes HXL and JXL) have an aluminium heat sink, through which the coolant directly flows. So the best heat transfer between heat sink and coolant is achieved. However, the aluminium heat sink places high demands on the cooling circuit and the properties of the coolant.

SINAMICS S120 Liquid-Cooled chassis units in the lower output power range (AC/AC Power Modules in frame sizes FL and GL and Motor Modules in frame sizes FXL and GXL) have a heat sink with an integrated stainless steel heat exchanger. These units place low demands on the cooling circuit and the properties of the coolant.

The heat sink of the most liquid-cooled units is equipped with power unit components on both sides. These include the power semi-conductors of the rectifier and the inverter, the DC link capacitors and the symmetrizing resistors of the DC link. Consequently, the power losses of all the main components are absorbed by the coolant. Only the very small power losses of the electronic boards and the busbars are dissipated into the air. The Control Unit CU320, which is required for the operation of the unit, is not a part of the Power Module.

The functionality of the liquid-cooled units corresponds to that of the corresponding air-cooled units. This includes overload capacity, factory-set pulse frequency, current derating factors for increased pulse frequencies, possibility of parallel connection of up to four identical power units and derating factors for the parallel configuration.

All system components of the air-cooled units are also available for the liquid-cooled variants. These include both, power components such as line and motor-side reactors and filters (with the exception of the line filter according to category C2 and Braking Modules which, due to their cooling principle can only be used in air-cooled units) and the electronic components, such as Communication Boards, Terminal Modules and Sensor Modules.

Fundamental Principles and System Description

Engineering Information

Requirements concerning coolant and cooling circuit

The coolant required for SINAMICS S120 Liquid-Cooled units is either water or a mixture of water and anti-freeze. In the cooling circuit, electro-chemical processes can occur, which lead to corrosion. The occurrence of these processes depends on several factors:

- The type of cooling circuit (open or closed cooling system)
- The materials used in the cooling circuit (metals, plastics, rubber seals and tubes)
- The electro-chemical potentials in the cooling circuit
- The chemical composition of the coolant and other additives (inhibitors, anti-freeze, biozides)

In order to prevent these corrosive, electro-chemical processes, or at least to keep them to a minimum, which will allow problem-free operation of the cooling circuit for many years, the following points must be taken into account.

The cooling circuit should be a closed circuit. For units with an aluminium heat sink, through which the coolant directly flows, a closed cooling circuit is absolutely essential. This is because only a closed circuit can prevent the permanent infiltration of the cooling circuit by reactive oxygen and ensure that there is a permanent and stable, chemical balance in the cooling circuit with aluminium heat sink. For units with heat sinks with an integrated stainless steel heat exchanger a closed cooling circuit is not essential, but recommended. Under certain conditions, for these units also open circuits can be used.

The materials used in the cooling circuit must be coordinated with one another so that they do not corrode as a result of electro-chemical reactions. If units with an aluminium heat sink are used, mixed installations made up of aluminium, copper, brass and iron should be avoided or, at least, limited. The use of plastics containing halogens (PVC pipes and seals) should also be avoided. Recommended cooling circuits are closed cooling circuits with pipes made of high-alloy steel (V2A or V4A) or, alternatively, with pipes made of ABS plastics. For the connections of the liquid-cooled units to the pipes EPDM hoses should be used. Seals must be chloride, graphite and carbon-free.

The electrical potentials in the cooling circuit must be designed in such a way that no differences between the electrical potentials of the individual components of the cooling circuit can occur. The rules stated in the section "EMC-compliant installation for optimized equipotential bonding in the drive system" also apply here, whereby in liquid-cooled systems not only all electrical components, such as converters and motors, must be fully incorporated in the equipotential bonding, but also non-electrical components of the cooling circuit, such as pipes, pumps and heat exchangers. As SINAMICS S120 Liquid-Cooled units are designed for potential-free operation, the grounding of the units must be done with the largest possible cross-section.

The chemical composition of the coolant for SINAMICS S120 Liquid-Cooled units must be as follows:

Units with aluminium heat sinks, through which the coolant directly flows:

- a) Deionised water, i.e. water with reduced electrical conductivity (5.....10 S/cm), such as "battery water" with 0.2 % – 0.25 % Nalco inhibitor 00GE056 or with 20 % - 45 % Antifrogen N anti-freeze, or
- b) Filtered drinking/urban water with 20 % - 45 % Antifrogen N anti-freeze, or
- c) Drinking or urban water of the quality specified below:
 - pH value 5.5 to 8.0
 - Chloride ions < 40 ppm
 - Sulphate ions < 50 ppm
 - Nitrate ions < 50 ppm
 - Dissolved solids < 340 ppm
 - Total hardness < 170 ppm
 - Electrical conductivity < 500 µS/cm
 - Size of entrained particles < 0.1 mm

In addition 0.2 % – 0.25 % Nalco inhibitor 00GE056 or 20 % – 45 % Antifrogen N anti-freeze must be used.

Units with heat sinks with an integrated stainless steel heat exchanger:

Drinking or urban water of the quality specified below:

• pH value	6.5 to 9.5
• Chloride ions	< 250 ppm
• Sulfate ions	< 240 ppm
• Nitrate ions	< 50 ppm
• Dissolved solids	< 340 ppm
• Total hardness	< 170 ppm
• Electrical conductivity	< 2500 $\mu\text{S}/\text{cm}$
• Size of entrained particles	< 0.1 mm

If the chloride content cannot be guaranteed, the coolant must be mixed with water with reduced electrical conductivity.

Inhibitors, anti-freeze, biozides

These additives to the coolant are required under certain conditions.

- Inhibitors delay corrosive electro-chemical processes. Essentially, they must be used if it is not possible to fully meet the requirements regarding the materials in the cooling circuit and the requirements regarding the coolant quality. With SINAMICS S120 Liquid-Cooled units in chassis format, as far as is necessary, Nalco inhibitor 00GE056 must be used in an amount of 0.2 %.
- Anti-freeze prevents the freezing of the coolant in minus temperatures and must always be used if the conditions of use are expected to include frost. Some anti-freeze additives contain inhibitors and have a biozide effect. With SINAMICS S120 Liquid-Cooled units in chassis format, Antifrogen N should be used as anti-freeze, when necessary. The amount of Antifrogen N anti-freeze must always be between 20 % and 45 %. 45% Antifrogen N anti-freeze provides frost protection up to -30°C . With lower concentrations than 20 %, Antifrogen N anti-freeze is corrosive and with higher concentrations than 45 % heat dissipation becomes worst. It must be noted that with the addition of anti-freeze, the kinetic viscosity of the coolant is changed and the pump must be adapted accordingly.
- Biozides prevent corrosion as a result of slimy, corrosive or iron-depositing bacteria. These can occur in both closed cooling circuits with low water hardness and open cooling circuits. Biozides must be selected for the type of bacteria present. Compatibility with inhibitors used together with the biocide must also be checked.

Protection against condensation

With liquid-cooled units, warm air can condense on the cold surfaces of the pipes and the heat sink. This condensation depends on the air humidity and the temperature difference between the ambient air and the coolant. The higher the air humidity, the lower the temperature difference at which the condensation occurs. The water which is produced as a result of condensation can cause corrosion at the surface of the equipment as well as electrical damage. As the SINAMICS units cannot prevent condensation by themselves, it must be prevented using external measures. This can either be an adapted coolant temperature, which ensures that critical temperature differences cannot occur, or a coolant temperature control dependent on the ambient air temperature.

Closed cooling circuit for SINAMICS S120 Liquid-Cooled units

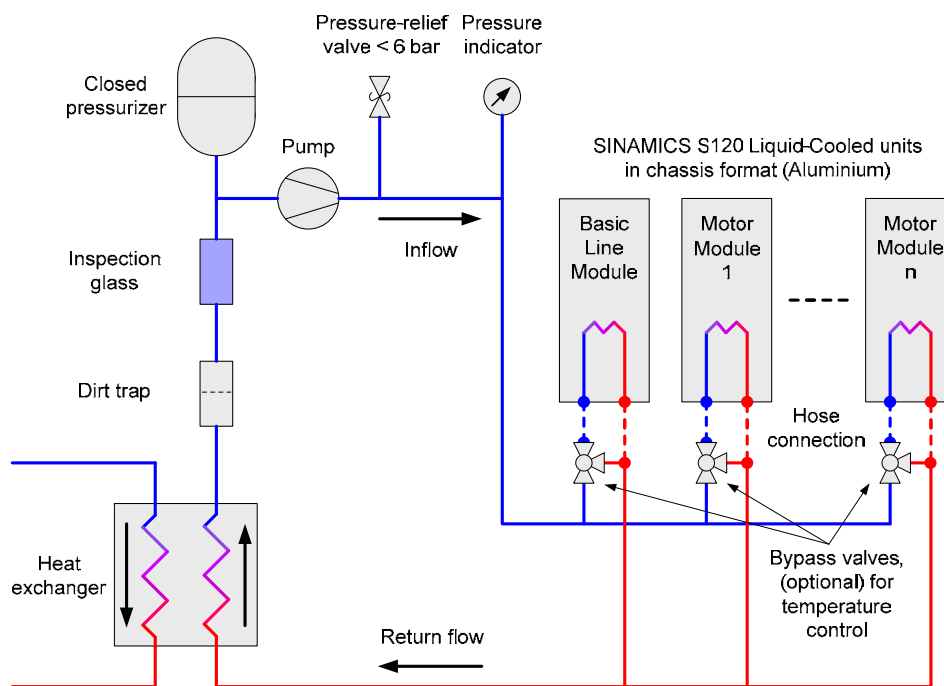
The diagram on the next page shows an example of a typical closed cooling circuit. This cooling circuit is absolutely essential for units with aluminium heat sink, through which the coolant directly flows. It is also highly recommended for units with a heatsink with integrated stainless steel heat exchanger. In the diagram all the important cooling circuit components are shown.

The closed pressurizer ensures a roughly constant pressure in the cooling circuit, even during great temperature variations, and must always be installed on the suction side of the pump. At this side a minimum pressure of 0.3 bar

Fundamental Principles and System Description

Engineering Information

is required. The pump is necessary to circulate the coolant and its flow area should, ideally, be made of stainless steel. The permissible differential pressure of the cooling circuit to atmosphere must not exceed a maximum of 6 bar. This must be ensured by a pressure-relief valve. The pressure indicator works as a visual control of the differential pressure of the cooling circuit to atmosphere. The pressure difference inside the cooling circuit between inflow and return flow, which is produced by the pump, must, on the one hand, be large enough to reach the coolant flow rate required for the cooling of the SINAMICS units. On the other hand, however, the pressure difference inside the cooling circuit must not be unnecessarily large as the risk of equipment damage through cavitation and abrasion is considerably increased by a high coolant flow rate. Therefore, the differential pressure across each heat sink should be between 1.0 bar and a maximum of 2.0 bar. The liquid-cooled units are designed in such a way that a differential pressure of 0.7 bar occurs when the rated coolant flow rate is reached



SINAMICS S120 Liquid-Cooled units in chassis format: Recommendation for a closed cooling circuit

The connecting pipes between the individual components of the cooling circuit should be made of stainless steel or ABS plastics. The seals must be chloride, graphite and carbon-free. For mechanical decoupling the SINAMICS units must be connected to the piping of the cooling system by short, flexible EPDM hoses. Ideally, the heat exchanger, like the piping, should be made of stainless steel. However, if absolutely necessary, copper heat exchangers may be used, as long as the cooling circuit is closed and the correct concentration of inhibitors or anti-freeze is used. Dirt traps retain dissolved solids > 0.1 mm and prevent the blocking of the heat sinks in SINAMICS units. The inspection glass is recommended for diagnosing clouding or discolouration of the coolant, which indicates that corrosion and wear may have been occurred. The bypass valve is required in case a temperature control is required for the protection against condensation.

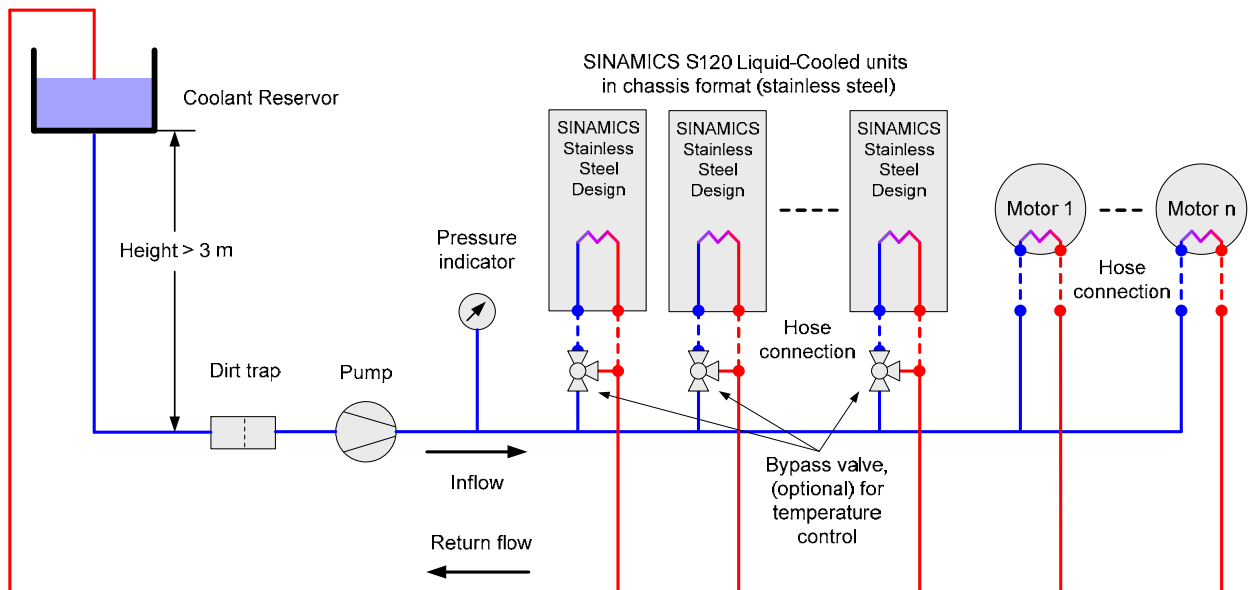
Open cooling circuit for SINAMICS S120 Liquid-Cooled units

The diagram on the next page shows an example of a typical open cooling circuit. This type of cooling circuit must not be used with units with aluminium heat sinks, through which the coolant directly flows, due to high oxygen levels. It can, therefore, only be used with units with integrated stainless steel heat exchangers.

The geodesic height of the coolant reservoir determines the the differential pressure to atmosphere in the cooling circuit and must be at least 3 m, in order that the minimum pressure of 0.3 bar on the suction side of the pump can be reached. The pump circulates the coolant, whose flow area should be made of stainless steel. With regard to the pressure difference between inflow and return flow, the same criteria apply as for closed cooling circuits.

Fundamental Principles and System Description

Engineering Information



SINAMICS S120 Liquid-Cooled units in chassis format: Recommendation for an open cooling circuit

The connecting pipes between the individual components of the cooling circuit should be made of stainless steel or ABS plastics. The seals must be chloride, graphite and carbon-free. For mechanical decoupling, the SINAMICS units and the motors connected to the cooling circuit must be connected to the piping of the cooling system by short, flexible EPDM hoses. The cooling circuit of motors and other units must, if connected to the same cooling circuit as the SINAMICS units, also be made of stainless steel or another incorrodible material. The bypass valve is required in case a temperature control is needed for protection against condensation.

EMC Installation Guideline

■ Introduction

General

EMC stands for “ElectroMagnetic Compatibility” and, according to the EMC Directive, describes “the capability of a device to function satisfactorily in an electromagnetic environment without itself causing intolerable interference for other devices in the environment”.

The growing use of power electronics devices in combination with microelectronics devices in increasingly-complex systems has meant that electromagnetic compatibility has become an extremely important issue when it comes to ensuring that complex systems and plants function without any problems.

For this reason, the question of electromagnetic compatibility must be taken into account as early as the planning phase for devices and systems. This involves, for example, defining EMC zones, establishing which types of cables are to be used and how these are to be routed, as well as providing filters and other interference suppression measures where appropriate.

This chapter is designed to help planning and assembly personnel of OEM customers, cabinet builders, and system integrators to ensure compliance with the regulations of the EMC Directive when SINAMICS drives are used in systems and plants.

The modular concept of SINAMICS allows for a wide range of different device combinations. A description of each individual combination cannot, therefore, be provided here. As such, this section aims to outline some fundamental principles and generally applicable rules that should be taken into account to build up any device combination in such a way that it is “electromagnetically compatible”. To clarify descriptions, some examples for typical applications are provided with explanations at the end of this chapter.

The devices described in this document (SINAMICS G130, G150, S120 Chassis, S120 Cabinet Modules, and S150) are not classified as “devices” in the context of the EMC Directive, but as “components” designed to be integrated in a complete system or plant. To facilitate understanding, however, the generally accepted term “devices” will be used.

EC Directives

EC Directives are published in the Official Journal of the European Union and must be incorporated into national legislation of EU member states, with the aim of facilitating free trade and movement of goods within the European Economic Area. EC Directives published and their implementation as a part of national legislation thus form the basis for legal proceedings within the European Economic Area.

For variable-speed drives, three EC Directives have been published:

- Machinery Directive 98/37/EC
(Legal regulations for machinery in EU member states)
- Low-Voltage Directive 2006/95/EC
(Legal regulations for electrical equipment in EU member states)
- EMC Directive 2004/108/EC
(Legal regulations for electromagnetic compatibility in EU member states)

This section describes the EMC Directive in more detail.

CE marking

The CE marking is a declaration of conformity to all EC Directives to be implemented. Responsibility for attaining the CE marking lies with either the manufacturer or the person/company who launched the product or system. The prerequisite for CE marking is a self-confirmation (or declaration) of the manufacturer indicating that the device in question is conform to all applicable European standards. This declaration (factory certificate, manufacturer's declaration, or declaration of conformity) must only include standards that are listed in the Official Journal of the European Union.

EMC Directive

All electrical and electronic devices and systems that contain electrical or electronic components which can cause electromagnetic interference or whose operation may be affected by such interference must comply with the regulations of the EMC Directive. The SINAMICS devices described in this document fall into this category.

Compliance with the EMC Directive can be verified by the application of the relevant EMC standards, whereby the product standards take precedence over generic standards. In the case of SINAMICS devices, the EMC product standard EN 61800-3 for adjustable speed electrical power drive systems (**Power Drive Systems**, or PDS for short) must be applied. If SINAMICS devices have been integrated in an final product for which a specific EMC product standard exists, the EMC product standard of the final product must be applied.

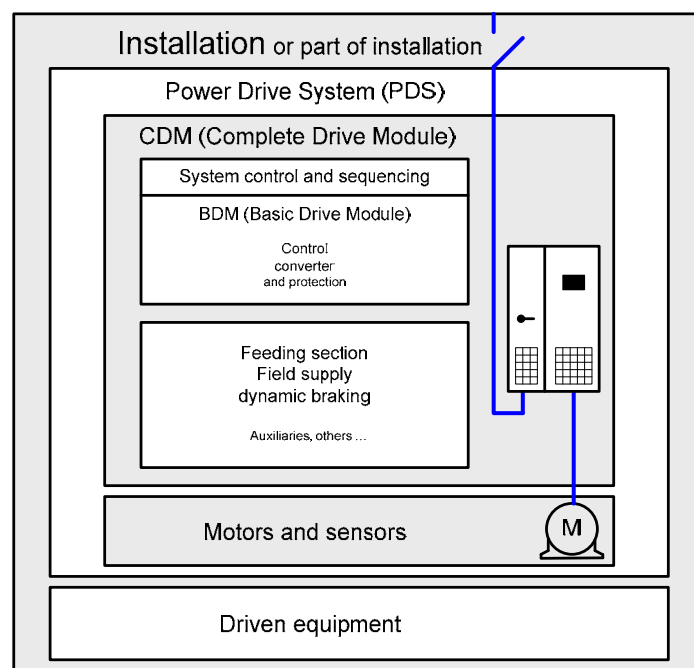
Since SINAMICS devices are viewed as “components” of an overall system or plant (in the same way as transformers, motors, or controllers, for example), the responsibility for applying the CE marking indicating conformity to the EMC Directive does not lie with the manufacturer. The manufacturer of such “components”, however, has a specific duty to provide sufficient information about their electromagnetic characteristics, usage, and installation.

This chapter of the document provides OEM customers, cabinet builders, and system integrators with all the information required to integrate SINAMICS devices in their systems or plants in such a way that the overall systems or plants meet the criteria of the EMC Directive.

This means that the OEM customer or system integrator has the sole and ultimate responsibility for ensuring the EMC of the overall system or plant. Such responsibility cannot be transferred to the suppliers of the “components”.

EMC product standard EN 61800-3

In the case of SINAMICS devices, the EMC product standard EN 61800-3 for adjustable speed electrical power drive systems (**Power Drive Systems**, or PDS for short) applies. This standard does not simply relate to the converter itself, but to a complete, variable-speed drive system which, in addition to the converter, comprises the motor and additional equipment.



Definition of the installation and the drive system (PDS) according to the EMC product standard EN 61800-3

The EMC product standard uses the following terms:

- PDS = Power Drive System (complete drive system comprising converter, motor, and additional equipment)
- CDM = Complete Drive Module (complete converter device, e.g. SINAMICS G150 cabinet unit)
- BDM = Basic Drive Module (e.g. SINAMICS G130 chassis unit)

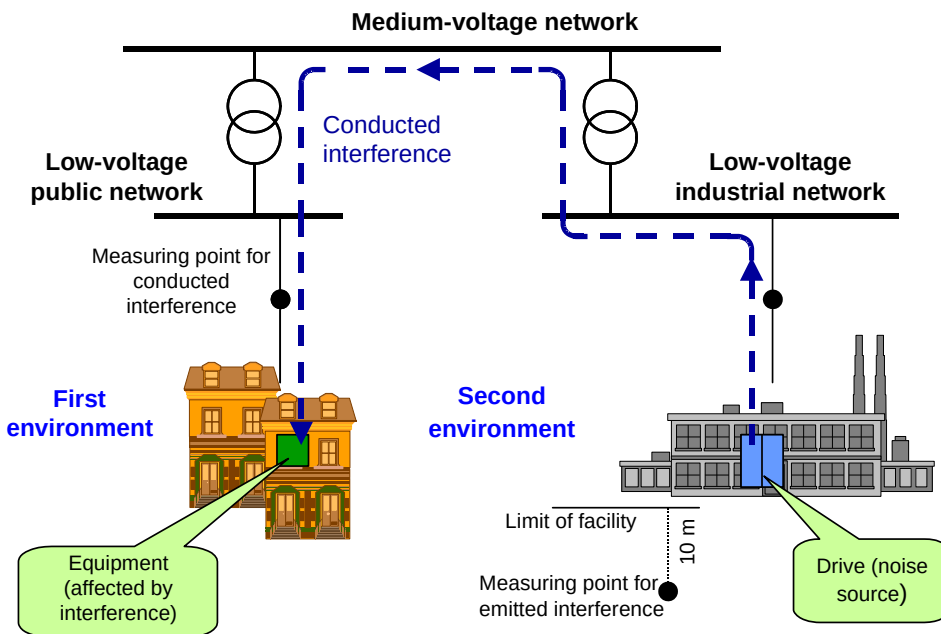
EMC Installation Guideline

Engineering Information

The EMC product standard defines criteria for evaluating operational characteristics in the event of interference, and it defines interference immunity requirements and interference emission limit values depending on the local ambient conditions. With respect to installation sites, a distinction is made between the "first" and "second" environment.

Definition of "first" and "second" environment

- **"First" environment:**
Residential buildings or locations at which the drive system is directly connected to a public low-voltage supply without intermediate transformer.
- **"Second" environment:**
Locations outside residential areas or industrial sites which are supplied from the medium-voltage network via a separate transformer.



"First" and "second" environment as defined by the EMC product standard EN 61800-3

Four different categories are defined in EN 61800-3 depending on the location and the output current of the variable-speed drive.

Definition of categories C1 to C4

- **Category C1:**
Drive systems with rated voltages of < 1000 V for unlimited use in the "first" environment
- **Category C2:**
Fixed-location drive systems with rated voltages of < 1000 V for use in the "second" environment. Use in the "first" environment is possible if the drive system is installed and used by qualified personnel. The warning and installation information supplied by the manufacturer must be observed.
- **Category C3:**
Drive systems with rated voltages of < 1000 V for unlimited use in the "second" environment.
- **Category C4:**
Drive systems with rated voltages of ≥ 1000 V or for rated currents of ≥ 400 A for use in complex systems in the "second" environment.

	Adjustable speed electrical power drive systems PDS			
	C1	C2	C3	C4
Environment	"First" environment (residential, business, and commercial areas)		"Second" environment (industrial areas)	
Voltage or current	< 1000 V			≥ 1000 V or ≥ 400 A
Specialist EMC knowledge required?	No	Installation and commissioning must be carried out by specialist personnel		

Overview of categories C1 to C4 according to the EMC product standard EN 61800-3

In the "first" environment (i.e. residential areas), the permissible interference level is low. As a result, devices designed for use in the "first" environment must exhibit low interference emissions. At the same time, however, they only require a relatively low level of interference immunity.

In the "second" environment (i.e. industrial areas), the permissible interference level is high. Devices designed for use in the "second" environment are allowed to exhibit a relatively high level of interference emissions, but they also require a high level of interference immunity.

Environments for SINAMICS converters

Category C2:

The SINAMICS converters described in this document are designed for use in the "second" environment. Since additional, optional line or EMC filters (RFI suppression filters) can be used, however, SINAMICS G130 and G150 converters as well as the infeeds of the modular system SINAMICS S120 Basic Line Modules can be used in the "first" environment according to category C2 of the EMC product standard EN 61800-3.

Category C3:

The SINAMICS converters described in this document are designed for use in the "second" environment and are equipped with line or EMC filters (RFI suppression filters) as standard, according to category C3 of the EMC product standard EN 61800-3. This applies to SINAMICS G130, G150, and S150 converters as well as to the infeeds for the SINAMICS S120 modular system (Basic Line Modules, Smart Line Modules, and Active Line Modules including the associated Active Interface Modules in Chassis and Cabinet Modules format).

Category C4:

SINAMICS converters can also be used in non-grounded (IT) supply systems. In this case, the line filter integrated as standard according to category C3 must be deactivated by removing the metal bracket connecting the filter capacitors with the housing (for more information, see the operating instructions for the relevant devices). If this is not removed, fault tripping can occur in the converter or the filter may be overloaded or even destroyed if a fault occurs. When the line filters integrated as standard are deactivated, the SINAMICS converters only comply with category C4. This is expressly permitted by the EMC product standard 61800-3 for IT supply systems in complex systems. In such cases, plant manufacturers and plant operators (plant owners) must agree upon an EMC Plan, that is, customized, system-specific measures to ensure compliance with EMC requirements.

Fundamental principles of EMC

Definition of EMC

Electromagnetic compatibility depends on two characteristics of the device in question: Its **interference emissions** and **interference immunity**. Electrical devices can be divided into interference sources (transmitters) and potentially susceptible equipment (receivers). Electromagnetic compatibility is ensured when the existing sources of interference do not adversely affect potentially susceptible equipment. A device can also be both a source of interference (e.g. a converter power unit) and potentially susceptible equipment (e.g. a converter control unit).

EMC Installation Guideline

Engineering Information

Interference emissions and interference immunity

Interference emissions

The interference emission is a type of interference emitted from the frequency converter to the environment.

High-frequency interference emissions from frequency converters are regulated by the EMC product standard EN 61800-3, which defines limit values for:

- High-frequency conducted interference at the supply system connection point (radio interference voltages)
- High-frequency electromagnetically-radiated interference (interference radiation)

The defined limit values depend on the ambient conditions ("first" or "second" environment).

Low-frequency interference emissions from frequency converters (normally referred to as harmonic effects on the supply system or supply system perturbation) are regulated by different standards. EN 61000-2-2 is applicable for public low-voltage supply systems, while EN 61000-2-4 is applicable for industrial supply systems. Outside of Europe, reference is often made to IEEE 519. The regulations of the local power supply company must also be observed.

Interference immunity

Interference immunity describes the behavior of frequency converters under the influence of electromagnetic interference, which affects the converter through the environment. Types of interference include:

- High-frequency conducted interference (radio interference voltages)
- High-frequency electromagnetic radiation (interference radiation)

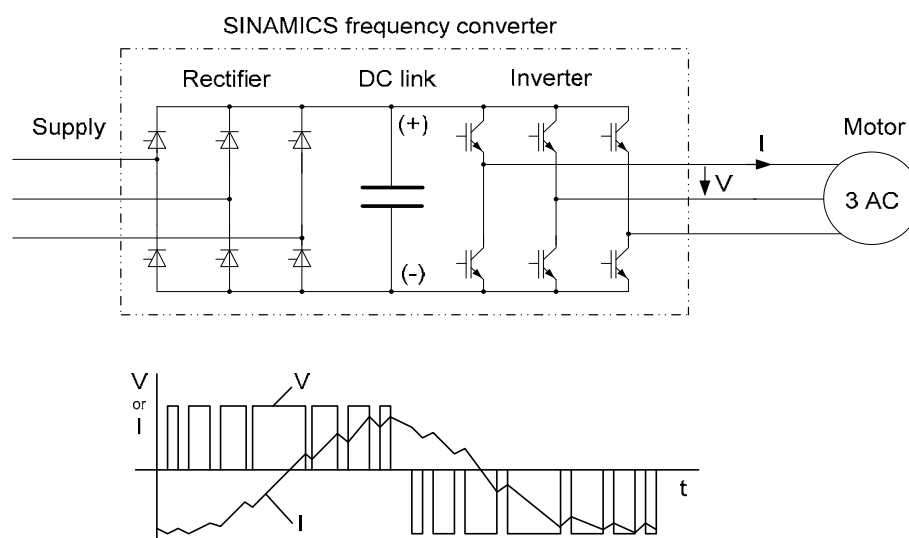
The requirements and criteria for evaluating behavior under the influence of these types of interference are also regulated by the EMC product standard EN 61800-3.

The frequency converter and its EMC

The frequency converter as a source of interference

Method of operation of SINAMICS frequency converters

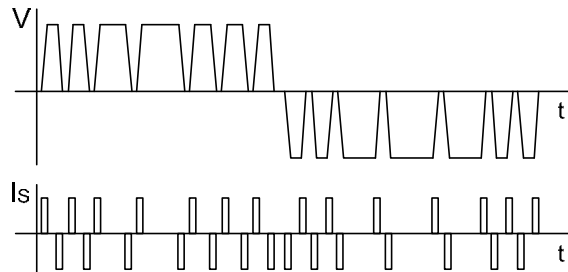
SINAMICS frequency converters comprise a line-side rectifier that supplies a DC link. The inverter connected to the DC link generates an output voltage V (comprising virtually rectangular voltage pulses) from the DC link voltage using the method of pulse width modulation. The smoothing effect of the motor inductance generates a largely sinusoidal motor current I .



Principles of operation of SINAMICS frequency converters and schematic representation of output voltage U and motor current I

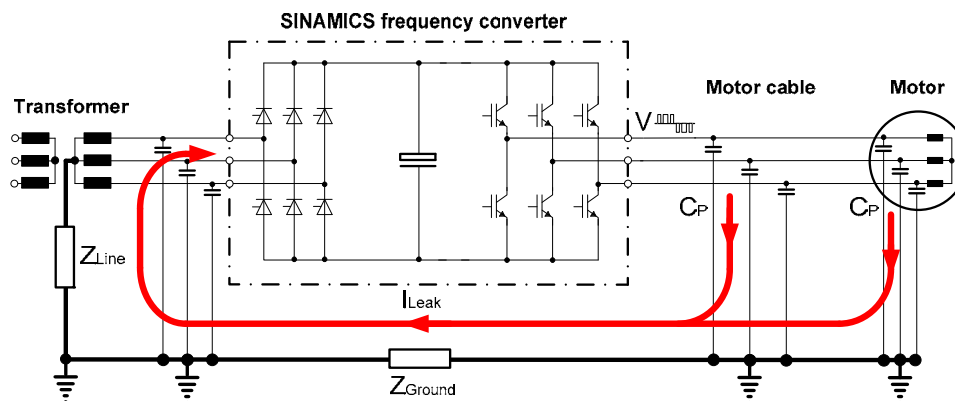
The frequency converter as a high-frequency source of interference

The main source of high-frequency interference is the fast switching of the IGBTs (Insulated Gate Bipolar Transistors) in the motor-side inverter, which results in extremely steep voltage edges. Each voltage edge generates a pulse-shaped leakage or interference current I_l via the parasitic capacitances at the inverter output.



Schematic representation of inverter output voltage V and interference current I_l

The interference current I_l flows from the motor cable and the motor winding to ground via the parasitic capacitances C_P , and must return to its source (the inverter) via a suitable route. The interference current I_l flows back to the inverter via the ground impedance Z_{Ground} and the supply impedance Z_{Line} , whereby the supply impedance Z_{Line} consists of the parallel connection of the transformer impedance (phase to ground) and parasitic capacitances of the supply cable (phase to ground). The interference current itself as well as the interference voltage drops caused by the impedances Z_{Ground} and Z_{Line} can affect other devices connected to the same supply and grounding system.

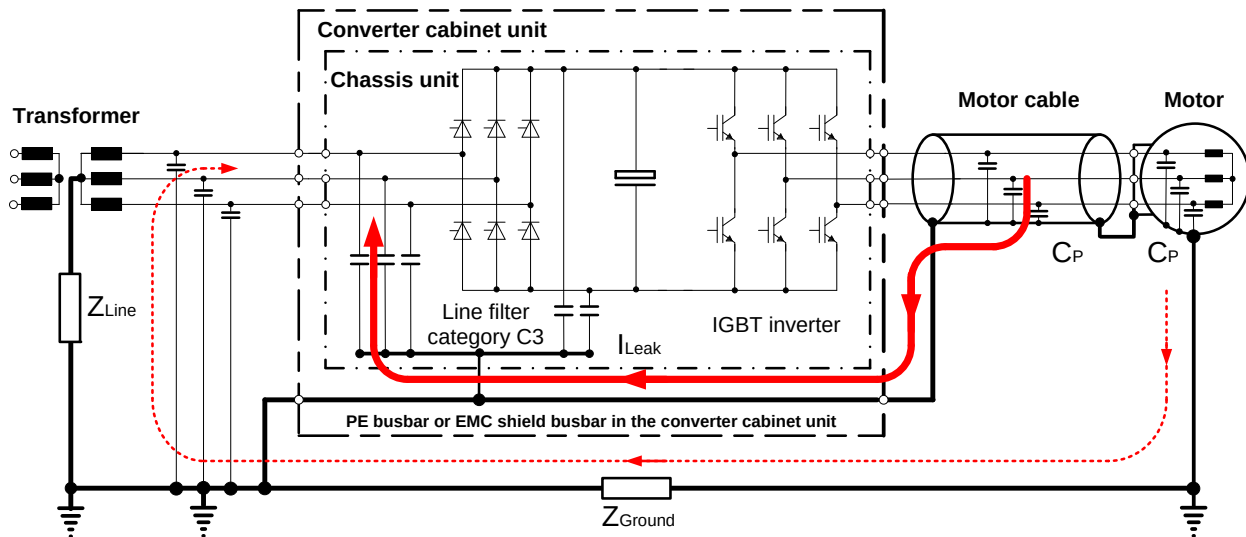


Schematic representation of the generation of the interference current I_l and its route back to the inverter

Measures for reducing high-frequency conducted interference emissions

When unshielded motor cables are used, the interference current I_l flows back to the inverter via cable rack, grounding system, and supply impedance and can generate high interference voltages via impedances Z_{Ground} and Z_{Line} due to its high frequency.

The effect of interference on the grounding and supply system by the interference current I_l can be considerably reduced by leading the high-frequency interference current I_l back to the inverter using a **shielded motor cable** in such a way that the voltage drops via impedances Z_{Ground} and Z_{Line} are minimized. **In combination with the line filter or EMC filter (RFI suppression filter) integrated as standard in SINAMICS devices** (according to category C3 of EMC product standard EN 61800-3), the high-frequency interference current I_l can flow via a low-resistance route back to the inverter within the drive system. This means that most of the interference current I_l flows via the shield of the motor cable, the PE or EMC shield busbar, and the line filter. The standard line filters are provided in SINAMICS G130, G150, and S150 converters as well as in the infeeds of the SINAMICS S120 modular system (Basic Line Modules, Smart Line Modules, and Active Line Modules including the associated Active Interface Modules, in Chassis and Cabinet Modules format). As a result, the grounding and supply system are subject to much lower interference currents and the interference emissions are considerably reduced.



Interference current route when a shielded motor cable is used in combination with an EMC filter in the converter

To achieve the intended reduction in interference, it is essential to install the entire drive system correctly. The installation must be such that the interference current I_l can find a continuous, low-inductance path without interruptions or weak points from the shield of the motor cable to the PE or EMC shield busbar and the line filter back to the inverter.

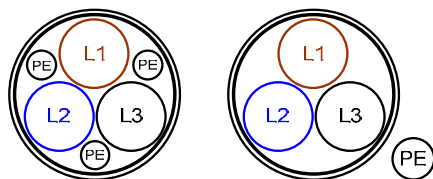
For this reason, the cable used to connect the converter to the motor must be shielded. A symmetrical, three-wire, three-phase cable should be used here.

Shielded cables with symmetrically arranged three-phase conductors L1, L2 and L3 and an integrated, three-wire, symmetrically arranged PE conductor, such as the PROTOFLEX EMV cable, type 2YSLCY-J supplied by Prysmian, are ideal.



Shielded, symmetrical, three-phase cable with three-wire PE conductor

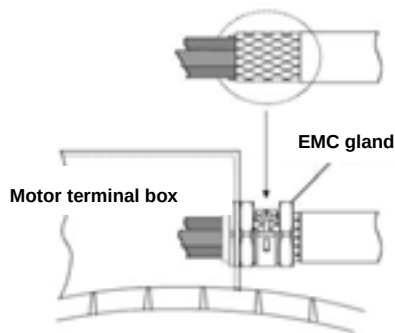
Alternatively, it is also possible to use a shielded cable containing only three-phase conductors L1, L2 and L3 in a symmetrical arrangement. In this case, the PE conductor must be installed separately.



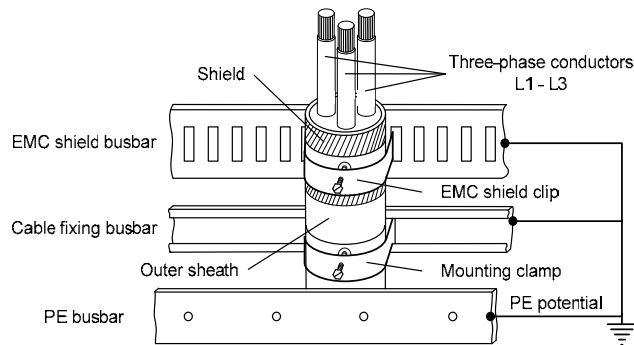
Symmetrical 3-wire, three-phase cables with concentric copper or aluminum shield

Effective shield bonding is achieved if EMC cable glands are used to create a solid 360° contact between the shield and motor terminal box and, at the other side in the converter cabinet, a solid 360° contact with the EMC shield busbar using EMC shield clips. An alternative shield connection to the PE busbar in the converter using only long, braided "pigtaills" is less suitable, particularly if the pigtaills are very long, as this type of shield bond represents a relatively high impedance for high-frequency currents.

Further additional shield bonds between the converter and motor, e.g. in intermediate terminal boxes, must never be created as the shield will then become far less effective in preventing interference currents from spreading beyond the drive system.



Shield bonding to motor terminal box using an EMC gland



Shield bonding to the EMC shield busbar in the converter using an EMC shield clip

Inside the cabinet units the housing of the chassis units equipped with the standard, category C3 line filter must be connected to the PE busbar and the EMC shield busbar with very low inductance. This connection can be established with a large contact area by means of the metal components used in the construction of the cabinet units. The contact surfaces must be bare metal and each contact point must have a minimum cross-section of several cm². This connection can also be established by means of short ground conductors with a larger cross-section ($\geq 95 \text{ mm}^2$). These must be designed to provide low impedance over a wide frequency range (e.g. made of finely stranded, braided round copper wires or finely stranded, braided flat copper strips).

SINAMICS G150 / S150 cabinet units and S120 Cabinet Modules are designed in such a way that low-inductance connections between the housing of the integrated chassis units and the PE busbar and the EMC shield busbar is ensured.

The rules to be followed for connecting chassis units to the PE busbar and the EMC shield busbar are the same as those for connecting optional category C2 line filters to the PE busbar and the EMC shield busbar. The optional category C2 line filters must always be used in combination with line reactors for optimal filtering.

Measures for reducing high-frequency, radiated, electromagnetic interference emissions

In addition to the steep voltage edges at each switching of an IGBT in the inverter, other causes for high-frequency electromagnetic interference are high-frequency, switched-mode power supplies and extremely high-frequency clocked microprocessors in the control units of SINAMICS converters.

To limit this interference radiation, **closed converter cabinets** acting as Faraday cages are required in addition to shielded motor and signal cables, for which optimal shield bonding must be established at both ends.

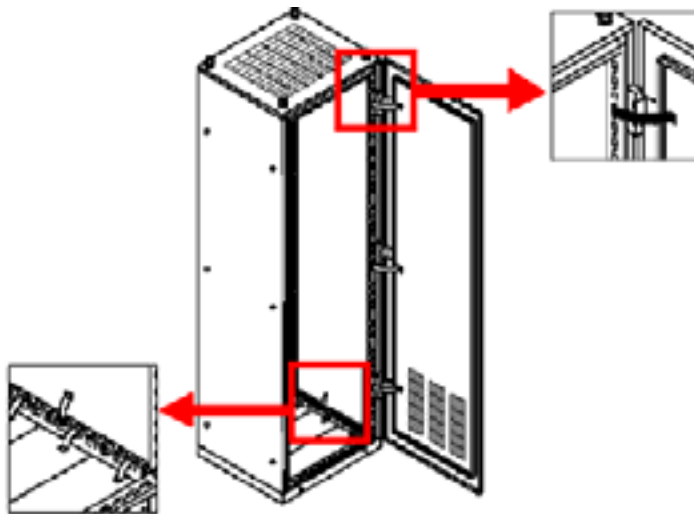
If SINAMICS G130 chassis units and S120 chassis units are integrated in an open cabinet frame, the interference radiation of the devices is not limited to a sufficient degree. To ensure compliance with category C3 of EMC product standard EN 61800-3, the room where the equipment is installed must have a suitable high-frequency shielding that ensures adequate shielding (e.g. installing the open cabinet frames in a container with a metallic closure).

If SINAMICS G130 chassis units and S120 chassis units are installed in standard converter cabinets with coated sheet steel, the interference radiation will fulfill the requirements of category C3 as defined by EMC product standard EN 61800-3 if the following measures are observed:

- All metallic housing components and mounting plates in the converter cabinet must be connected, both to one another and to the cabinet frame, via a large contact area with high electrical conductivity. Large metallic connections or connections established by means of grounding strips with excellent high frequency properties are ideal for this purpose.
- Cabinet covers (e.g. doors, side panels, back walls, roof plates, and floor plates) must also be connected to the cabinet frame with high electrical conductivity, ideally by means of grounding strips with excellent high frequency properties.
- All screwed connections on painted or anodized metallic components must either be equipped with special contact washers that penetrate the non-conductive surface, thereby establishing a metallically conductive contact, or the non-conductive surface between the parts to be connected must be removed prior to assembly to establish a plane metallic connection.
- For EMC reasons, ventilation openings must be kept as small as possible. The fact that satisfactory cabinet ventilation requires certain minimum cross-section dimensions due to the laws of fluid mechanics must be taken into account, however. An appropriate compromise is, therefore, necessary here. For SINAMICS converter cabinets ventilation grids are used with standard opening cross-section sizes of app. 200 mm².

EMC Installation Guideline

Engineering Information



Connection of doors, side walls, back walls, roof plates, and floor plates to the cabinet frame

The SINAMICS G150 and S150 converter cabinet units as well as the Cabinet Modules of the SINAMICS S120 modular cabinet unit system are built at the factory in such a way that they automatically comply with the interference radiation limit values defined in category C3 of the EMC product standard EN 61800-3, when the devices are operated with the cabinet doors closed.

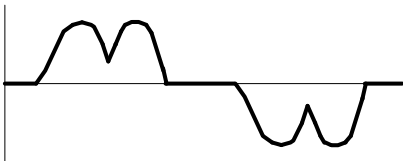
The frequency converter as a low-frequency source of interference

If SINAMICS converters are connected to a supply system with a purely sinusoidal voltage (generator or transformer), the non-linear characteristics of the components in the line-side rectifier circuits cause non-sinusoidal supply system currents to flow, which distorts the voltage at the PCC (Point of Common Coupling). This low-frequency, conducted effect on the line voltage is known as "Harmonic effects on the supply system" or "supply system perturbation".

Measures for reducing low-frequency interference emissions

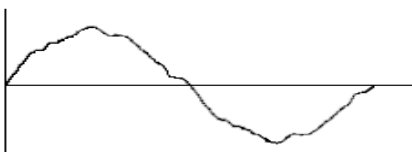
The supply system perturbation caused by SINAMICS converters largely depends on the type of rectifier circuit used. The magnitude of the supply system perturbation can, therefore, be influenced by the selection of the type of rectifier and by additional line side components such as line reactors or Line Harmonics Filters.

The highest level of supply system perturbation is generated by six-pulse rectifier circuits, which are used with SINAMICS G130 and G150 converters as well as with S120 Basic Line Modules and Smart Line Modules.



Typical line current with 6-pulse rectifier circuits

A considerable reduction in supply system perturbation can be achieved by means of Line Harmonics Filters for SINAMICS G130 and G150 converters or by means of 12-pulse rectifier configurations with SINAMICS S120 Basic Line Modules and Smart Line Modules.



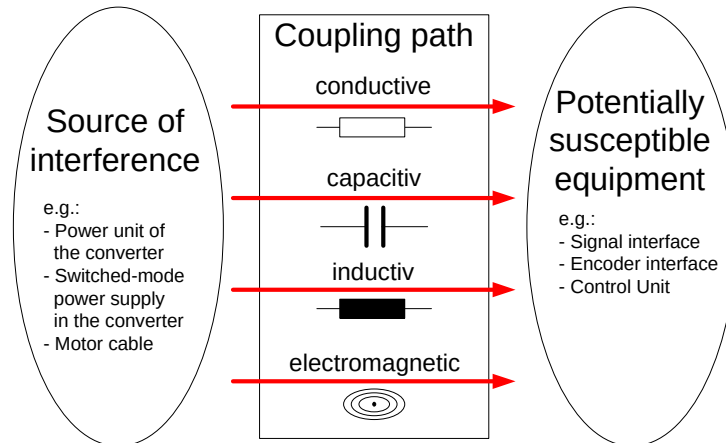
Typical line current of 6-pulse rectifiers with Line Harmonics Filters

The lowest levels of supply system perturbation is generated with active rectifiers, which are used with SINAMICS S150 converters and SINAMICS S120 Active Line Modules. In this case, current and voltage are virtually sinusoidal.

The frequency converter as potentially susceptible equipment

Methods of influence

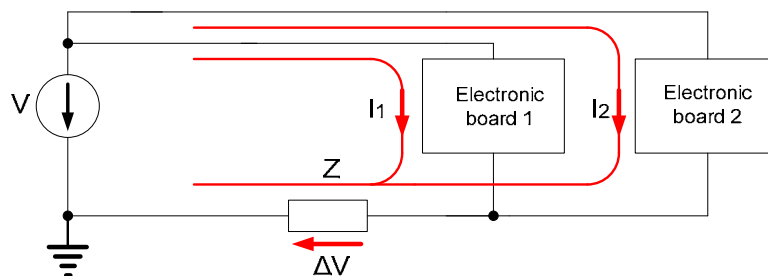
The interference generated from sources of interference can reach potentially susceptible equipment by different types of coupling paths. A distinction is made here between conductive, capacitive, inductive, and electromagnetic interference coupling.



Possible paths between sources of interference and potentially susceptible equipment

Conductive coupling

Conductive coupling is established when several electrical circuits use a common conductor (e.g. a common ground lead or ground connection). Current I_1 of electronic board 1 generates a voltage drop ΔV_1 at impedance Z of the common conductor; which influences the voltage at the terminals of electronic board 2. Conversely, current I_2 of electronic board 2 generates a voltage drop ΔV_2 at impedance Z of the common conductor; which influences the voltage at the terminals of electronic board 1.



Conductive coupling of two electrical circuits by means of the impedance Z of a common conductor

If, for example, the voltage source V is a power supply unit that supplies two electronic boards with a DC voltage of 24 V, and electronic board 1 is a switched-mode power supply with a periodic, pulsating current consumption, and electronic board 2 is a sensitive interface module for analog signal transmission, then electronic board 1 in this scenario would be the source of interference. This disturbs the supply voltage at the terminals of the interface module, which acts as potentially susceptible equipment, via the conductive coupling (i.e. via the voltage drop ΔV at the common impedance Z). This can affect the quality of the analog signal transmission.

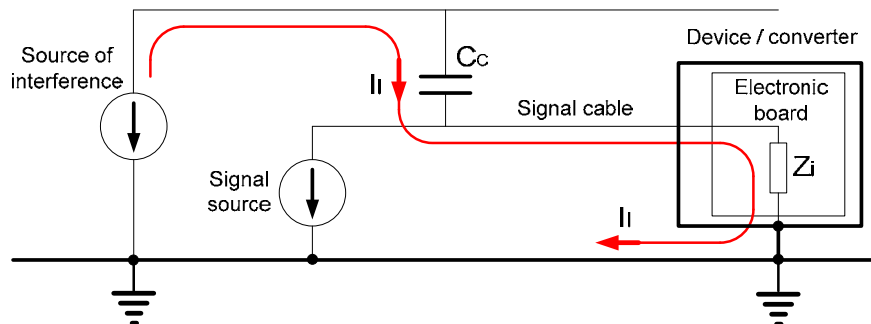
Measures for reducing conductive coupling

- Minimize the length of the common conductor
- Use large cable cross-sections if the common impedance is largely ohmic in character
- Use a separate feed and return line for each electrical circuit

Capacitive coupling

Capacitive coupling occurs between conductors that are isolated against each other and that have different potentials. This difference in potential generates an electrical field between the conductors, known as capacitance C_c . The magnitude of the capacitance C_c depends on the geometry of the conductors and on the distance between the conductors with different potential.

The diagram below shows a source of interference that is coupling an interference current I_i into the potentially susceptible equipment by means of capacitive coupling. The interference current I_i generates a voltage drop at impedance Z_i of the potentially susceptible equipment and, in turn, an interference voltage.



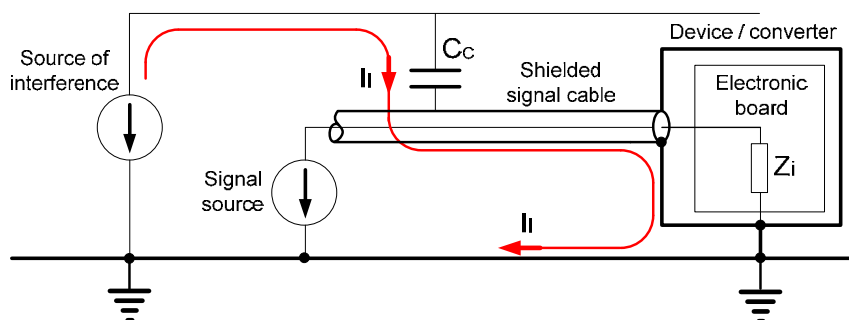
Capacitive coupling of an interference current into a signal cable

If, for example, a motor cable and an unshielded signal cable were routed in parallel close to each other on a long cable rack the small distance between the cables would result in a high coupling capacitance C_c . The motor-side inverter of the frequency converter, which acts as source of interference, couples via the capacitance C_c a pulsating interference current into the signal cable with each switching edge. If this interference current flows via the digital inputs into the Control Unit of the converter, the generated small interference pulses lasting only a few microseconds with an amplitude of only a few volts can affect the microprocessor-based digital control of the converter and can cause the converter to malfunction.

Measures for reducing capacitive coupling

- Maximize the distance between the cable causing the interference and the cable affected by the interference
- Minimize the length of the parallel cable routing
- Use shielded signal cables.

The most effective method is **to ensure systematic separation of power and signal cables in combination with a shielding of the signal cables**. This ensures that the interference current I_i is coupled into the shield and that it flows to ground via shield and housing of the device or converter without affecting the internal electrical circuits.

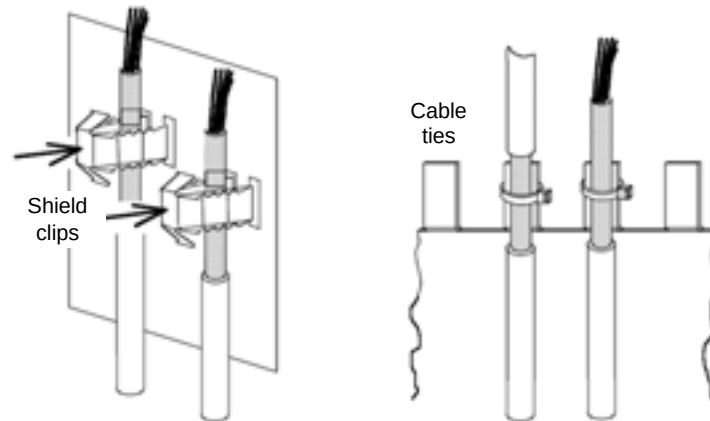


Reducing the interference coupled into the potentially susceptible equipment by using a shielded signal cable

To ensure that the shield is as effective as possible it is necessary to establish a low-inductance shield bonding using a large contact area. When **digital** signal cables are used, shield bonding has to be established at both ends (i.e. at the transmitter side and at the receiver side) using a large contact area. When **analog** signal cables are used, shield bonding at both ends can result in low-frequency interference (hum loops). In this case, shield bonding should only be carried out at one end (i.e. the converter side). The other side of the shield should be grounded by means of a MKT-type capacitor with approximately 10 nF/100 V. When the capacitor is used, this means that the shield is bonded for high frequencies at both ends.

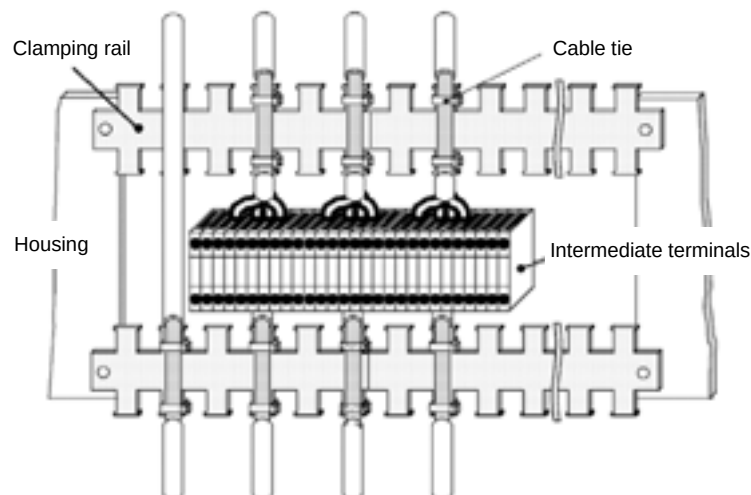
SINAMICS G130 converter chassis units and SINAMICS S120 chassis units as well as SINAMICS G150 and S150 converter cabinet units, and S120 Cabinet Modules offer a range of shield bonding options:

- Each SINAMICS device is supplied with shield clips to ensure an optimum shield connection of the signal cables.
- In addition the shields of the signal cables can also be bonded to comb-shaped shield bonding points by means of cable ties.



Shield bonding options for SINAMICS chassis units and cabinet units

From the EMC point of view, the use of intermediate terminals should be avoided wherever possible because interruptions in the shield reduce its effectiveness. If it is impossible to avoid the use of intermediate terminals in certain cases, however, the signal cable shields must be properly bonded immediately before and after the intermediate terminals on clamping rails. The clamping rails must be connected to the cabinet housing at both ends with excellent electrical conductivity and with a large contact area.



Shield connection of signal cables in the converter cabinet by means of clamping rails when using intermediate terminals

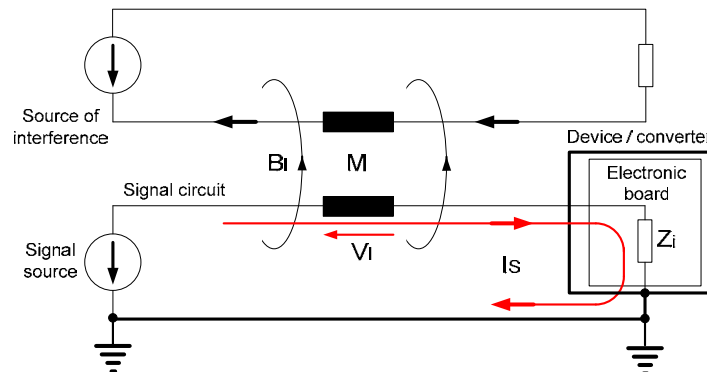
Inductive coupling

Inductive coupling occurs between different current-carrying circuits or between different conductor loops. If an AC current is flowing in one conductor loop, this generates a magnetic alternating field, which penetrates the other conductor loop and induces a voltage in this loop. The magnitude of the inductive coupling can be described in terms of the counterinductance M_K , which depends on the geometry of the conductor loops and on the distance between the conductor loops.

EMC Installation Guideline

Engineering Information

The diagram below shows an electrical circuit fed by a source of interference. This circuit induces an interference voltage V_i into a signal circuit by means of a magnetic interference field B_i . The interference voltage V_i creates an interference current I_i , which generates a voltage drop at impedance Z_i of the potentially susceptible equipment, which can result in a fault.



Inductive coupling of an interference voltage into a signal circuit

If, for example, the source of interference is a braking chopper (i.e. a Braking Module) connected to the converter DC link, then a high, pulsating current flows to the connected braking resistor during braking operation. Due to its magnitude and its high current rate of rise di/dt , this pulsating current induces a pulsating interference voltage in the signal circuit, which results in an pulsating interference current. If this interference current flows, for example, via the digital inputs into the converter interface module malfunctions can occur (e.g. sporadic fault tripping).

Measures for reducing inductive coupling

- Maximize the distance between the conductors / conductor loops
- Keep the area of each conductor loop as small as possible: route the feed and return lines of each circuit in parallel so that they are lying as close to each other as possible, or use twisted cables for the signal cable.
- Use shielded signal cables (in the case of inductive coupling, shield bonding must be ensured at both ends).

Electromagnetic coupling (radiative coupling)

Electromagnetic or radiative coupling is an interference by means of a radiated electromagnetic field. Typical sources of this kind of interference are:

- Cellular radio devices
- Cellular phones
- Devices that operate using spark gaps
(Spark plugs, welding devices, contactors and switches when switching contacts are opened)

Methods for reducing electromagnetic coupling

As the electromagnetic fields are in the high-frequency range, the shielding measures provided below for reducing radiative interference must be implemented in such a way that they are effective even at highest frequencies:

- Use metallic converter cabinets in which individual components (cabinet frame, walls, doors, etc.) are connected to each other with excellent electrical conductivity.
- Use metallic housings for devices and electronic boards, which are connected to each other and to the cabinet frame with excellent electrical conductivity.
- Use shielded cables with finely stranded, braided shields suitable for high frequencies.

■ EMC-compliant installation

The previous section covered the basic principles of EMC of the frequency converter. It covered interference sources and potentially susceptible equipment, the various coupling principles, as well as basic measures for reducing interference.

Based on this, the next section covers all of the most important rules for ensuring that converter cabinets are constructed and drive systems are installed in accordance with the EMC requirements.

Installation examples using typical SINAMICS chassis units and SINAMICS cabinet units will illustrate how these rules can be applied in practice.

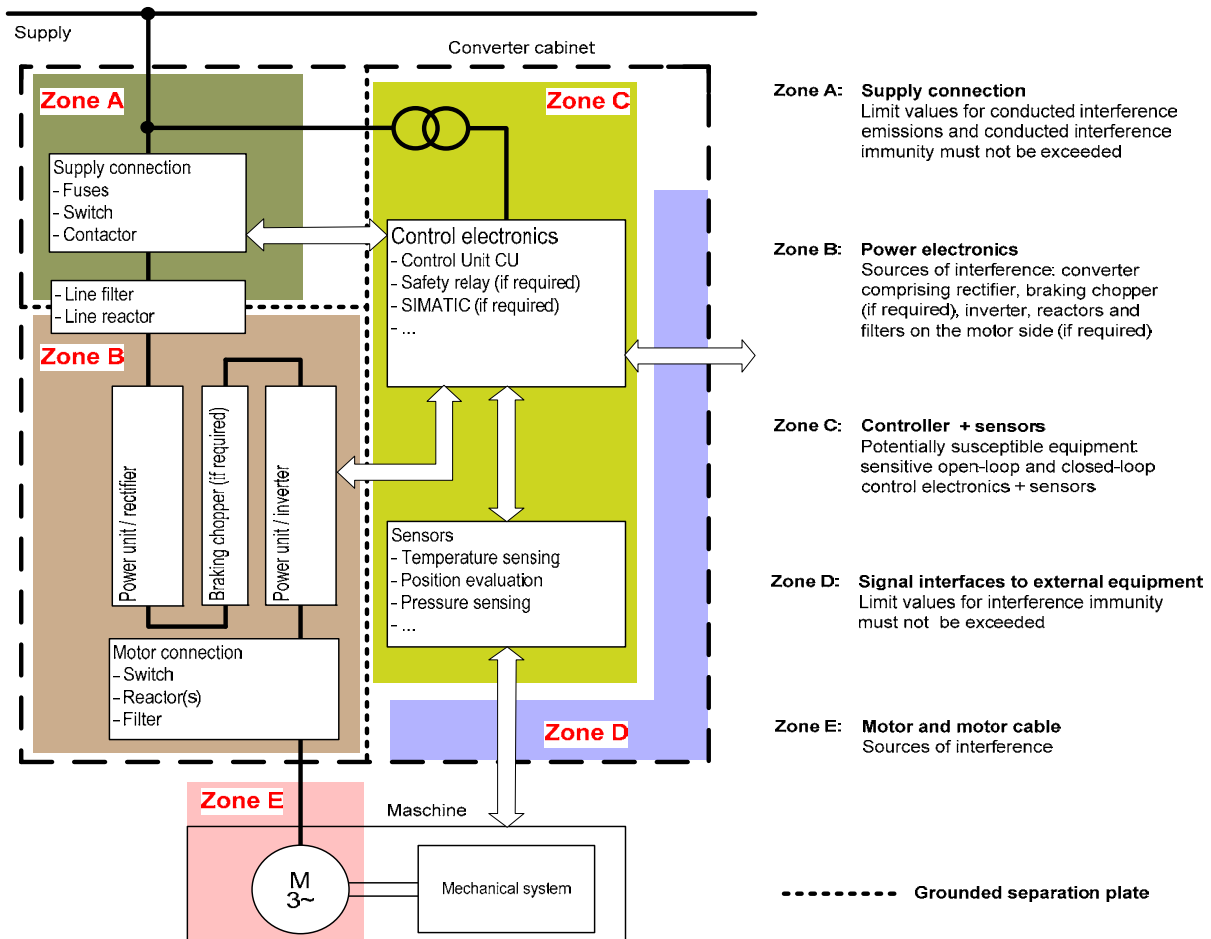
Zone concept within the converter cabinet

The most cost-effective method of implementing interference suppression measures within the converter cabinet is to ensure that interference sources and potentially susceptible equipment are installed separately from each other. This must be taken into account already during the planning phase.

The first step is to determine whether each device used is a potential source of interference or potentially susceptible equipment:

- Typical sources of interference include frequency converters, braking units, switched-mode power supplies, and contactor coils.
- Typical potentially susceptible equipment includes automation devices, encoders and sensors, as well as their evaluation electronics.

Following this, the entire converter cabinet has to be divided into EMC zones and the devices have to be assigned to these zones. The example below illustrates this zone concept in greater detail.



Division of the converter cabinet / drive system into different EMC zones

Inside of each zone, certain requirements apply in terms of interference emissions and interference immunity. The different zones must be electromagnetically decoupled. One method is to ensure that the zones are not positioned directly next to each other (minimum distance app. 25 cm). A better, more compact method, however, is to use separate metallic housings or separation plates with large surface areas. Cables within each zone can be unshielded. Cables connecting different zones must be separated and must not be routed within the same cable harness or cable channel. If necessary, filters and/or coupling modules should be used at the interfaces of the zones. Coupling modules with electrical isolation are an effective means of preventing interference from spreading from one zone to another. All communication and signal cables leaving the converter cabinet must be shielded. For longer, analog signal cables isolating amplifiers should be used. Sufficient space for bonding the cable shields must be provided,

EMC Installation Guideline

Engineering Information

whereby the braided cable shield must be connected to the converter cabinet ground with excellent electrical conductivity and with a large contact area. In this respect, note that the ground potential between the zones must be more or less identical. Differences must be avoided to ensure that impermissible, high compensating currents are kept away from the cable shields.

Converter cabinet structure

- All metallic components of the converter cabinet (side panels, back walls, roof plates, and floor plates) must be connected to the cabinet frame with excellent electrical conductivity, ideally with a large contact area or by means of several point-like screwed connections (i.e. to create a Faraday cage).
- The cabinet doors must be connected to the cabinet frame with excellent electrical conductivity by means of short, finely stranded, braided grounding strips, which are ideally placed at the top, in the middle, and at the bottom of the doors.
- The PE busbar and EMC shield busbar must be connected to the cabinet frame with excellent electrical conductivity with a large contact area.
- All metallic housings of devices and additional components integrated in the cabinet (such as converter chassis, line filter, Control Unit, Terminal Module, or Sensor Module) must be connected to the cabinet frame with excellent electrical conductivity and with a large contact area. The best option here is to mount devices and additional components on a bare metal mounting plate (back plane) with excellent electrical conductivity. This mounting plate must be connected to the cabinet frame and, in particular, to the PE and EMC shield busbars with excellent electrical conductivity and a large contact area.
- All connections should be made so that they are permanent. Screwed connections on painted or anodized metal components must be made either by means of special contact washers, which penetrate the isolating surface and establish a metallically conductive contact, or by removing the isolating surface on the contact points.
- Contactor coils, relays, solenoid valves, and motor holding brakes must have interference suppressors to reduce high-frequency radiation when the contacts are opened (RC elements or varistors for AC current-operated coils, and freewheeling diodes for DC current-operated coils). The interference suppressors must be connected directly on each coil.

Cables inside the converter cabinet

- All power cables of the drive (line supply cables, DC link cables, cables between braking choppers (Braking Modules) and associated braking resistors, as well as motor cables) must be routed separately from signal and data cables. The minimum distance should be approximately 25 cm. Alternatively decoupling in the converter cabinet can be implemented by means of separation plates connected to the mounting plate (back plane) with excellent electrical conductivity.
- Filtered line supply cables with a low level of interference (i.e. line supply cables running between the supply system and the line filter) must be routed separately from non-filtered power cables with a high level of interference (line supply cables between the line filter and the rectifier; DC link cables, cables between braking choppers (Braking Modules) and associated braking resistors; as well as motor cables).
- Signal and data cables, as well as filtered line supply cables, may only cross non-filtered power cables at right angles of 90° to minimize coupled-in interference.
- All cable lengths must be minimized (excessive cable lengths must be avoided).
- All cables must be routed as closely as possible to grounded housing components, such as mounting plates or the cabinet frame. This reduces interference radiation as well as coupled-in interference.
- Signal and data cables, as well as their associated equipotential bonding cables, must always be routed in parallel and with as short a distance as possible.
- When unshielded single-wire cables are used within a zone, the feed and return lines must be either routed in parallel with the minimum possible distance between them, or twisted with one another.
- Spare wires for signal and data cables must be grounded at both ends to create an additional shielding effect.
- Signal and data cables should enter the cabinet only at one point (e.g. from below).

Cables outside the converter cabinet

- All power cables (line supply cables, DC link cables, cables between braking choppers (Braking Modules) and associated braking resistors, as well as motor cables) must be routed separately from signal and data cables. The minimum distance should be approximately 25 cm.
- The power cable between inverter and motor must be shielded. A symmetrical, 3-wire, three-phase cable should be used here. Shielded cables with symmetrical three-phase conductors (L1, L2, and L3) and an integrated, 3-wire, and symmetrically arranged PE conductor are ideal for this purpose.
- The shielded power cable to the motor must be routed separately from the cables to the motor temperature sensors (PTC/KTY) and the cable to the speed encoder, since the latter two are treated as signal cables.
- Signal and data cables must be shielded to minimize coupled-in interference with respect to capacitive, inductive, and radiative coupling.
- Particularly sensitive signal cables, such as setpoint and actual value cables and, in particular, tachometer generator, encoder, and resolver cables must be routed with optimum shield bonding at both ends and without any interruptions of the shield.

Cable shields

- Shielded cables must have finely stranded braided shields. Foil shields are not suitable since they are much less effective.
- Shields must be connected to the grounded housings at both ends with excellent electrical conductivity and a large contact area. Only when this method is used coupled-in interference with respect to capacitive, inductive, and radiative coupling can be minimized.
- Bonding connections for the cable shields should be established, where ever possible, directly behind the cable entry into the cabinet. For power cables the EMC shield busbars should be used. For signal and data cables the shield bonding options provided in the chassis units and cabinet units should be used.
- Cable shields should not be interrupted, wherever possible, by intermediate terminals.
- In the case of both, the power cables and the signal and data cables, the cable shields should be connected by means of suitable EMC shield clips. These must connect the shields to either the EMC shield busbar or the shield bonding options for signal cables with excellent electrical conductivity and a large contact area.
- As plug connectors for shielded data cables (e.g. PROFIBUS cables) only metallic or metallized connector housings should be used.

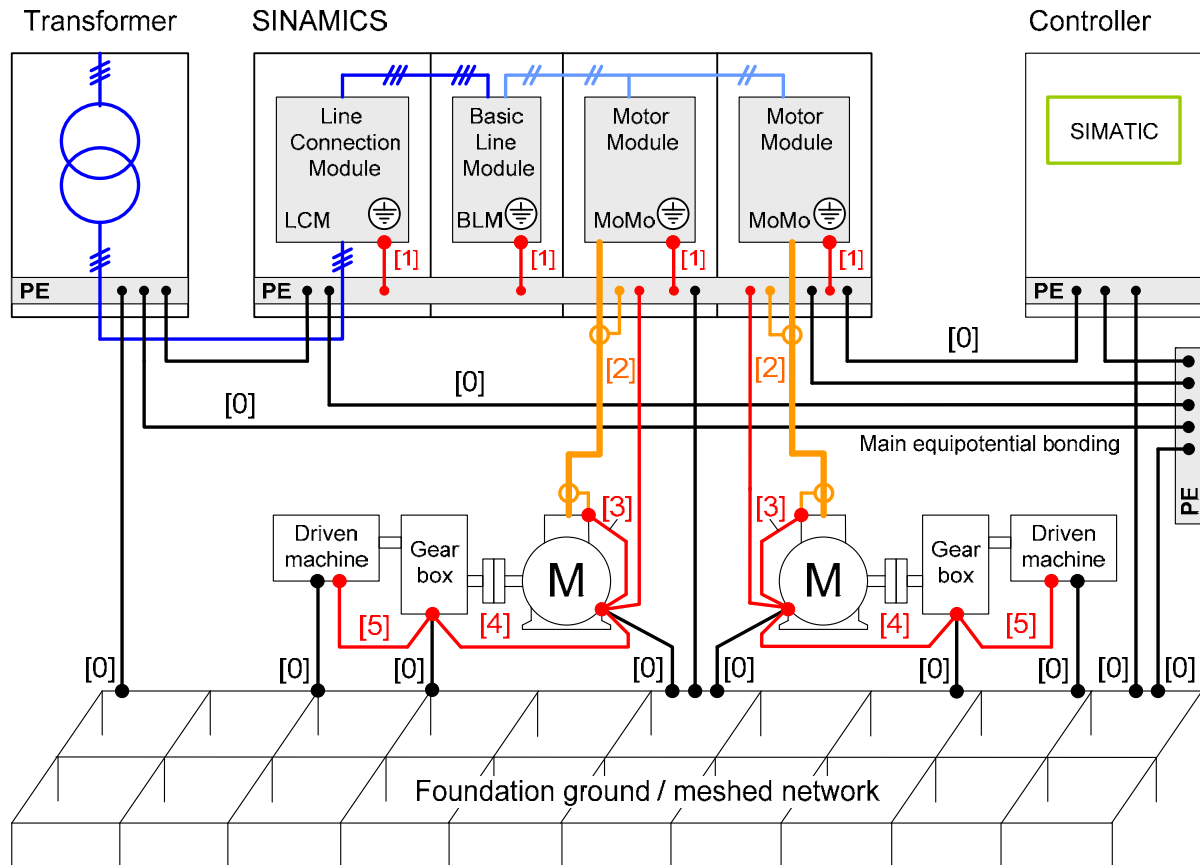
Equipotential bonding in the converter cabinet, in the drive system, and in the plant

- Equipotential bonding within a converter cabinet element has to be established by means of a suitable mounting plate (back plane), to which all metallic housings of the devices and additional components integrated in the cabinet element (such as converter chassis, line filter, Control Unit, Terminal Module, Sensor Module, etc.) are connected. The mounting plate (back plane) has to be connected to the cabinet frame and to the PE or EMC busbar of the cabinet element with excellent electrical conductivity and a large contact area.
- Equipotential bonding between several cabinet elements has to be established by means of a PE busbar which, in the case of larger cabinet units or the S120 Cabinet Modules system, runs through all the cabinet elements. In addition, the frames of the individual cabinet elements must be screwed together multiple times with sufficient electrical conductivity by means of special contact washers. If extremely long rows of cabinets are installed in two groups back to back, the two PE busbars of the cabinet groups must be connected to each other wherever possible.
- Equipotential bonding within the drive system has to be established by connecting all electrical and mechanical drive components (transformer, converter cabinet, motor, gearbox, and driven machine) to the grounding system. These connections are established by means of standard heavy-power PE cables, which do not need to have any special high-frequency properties. In addition to these connections, the inverter (as the source of the high-frequency interference) and all other components in each drive system (motor, gearbox, and driven machine) must be interconnected with respect to the high-frequency point of view. For this purpose cables with good high-frequency properties must be used.

EMC Installation Guideline

Engineering Information

The following diagram illustrates all grounding and high-frequency equipotential bonding measures using the example of a typical installation comprising several SINAMICS S120 Cabinet Modules.



Grounding and high-frequency equipotential bonding measures in the drive system and in the plant

The ground connections shown in black [0] represent the conventional grounding system for the drive components. They are made with standard, heavy-power PE conductors without special high-frequency properties and ensure low frequency equipotential bonding as well as protection against injury.

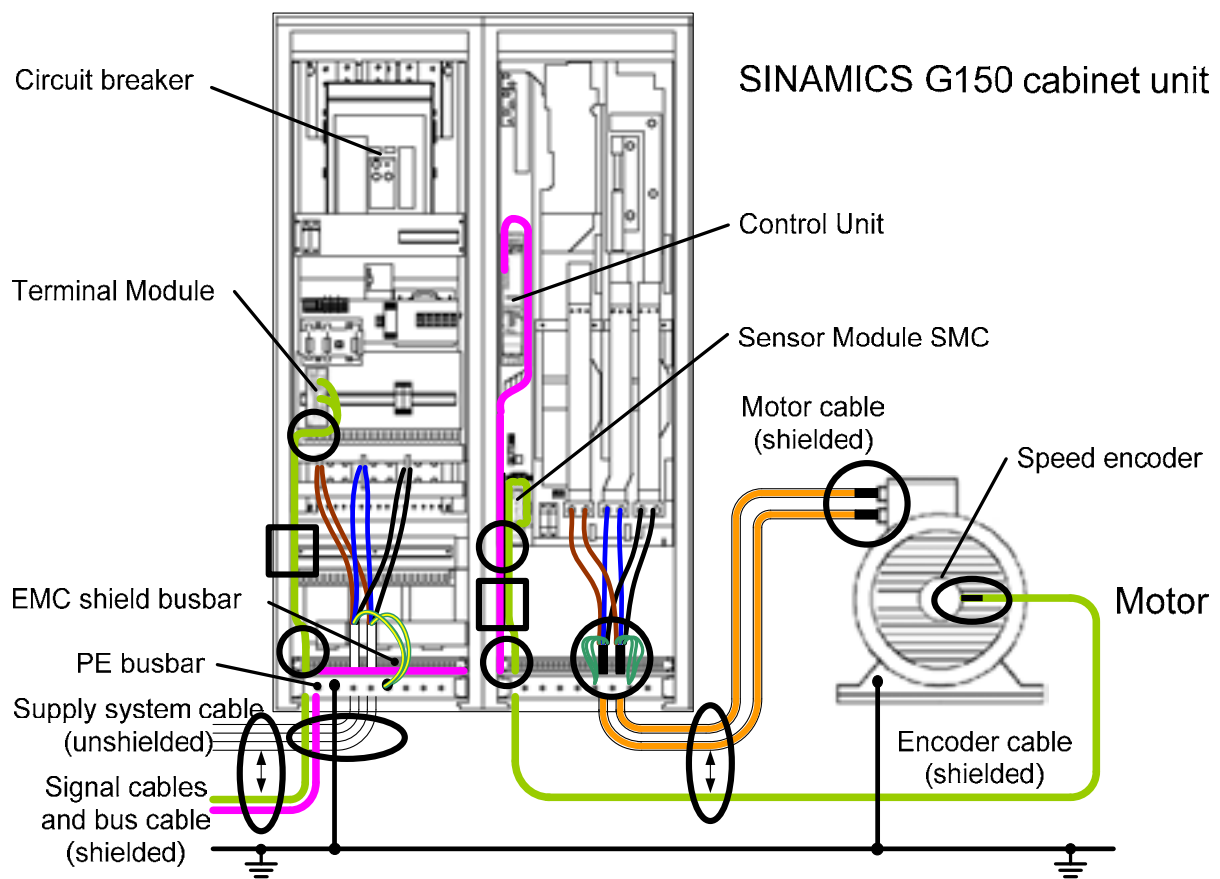
The connections shown in red inside the SINAMICS cabinets [1] provide solid bonding for high-frequency currents between the metal housings of the integrated chassis components and the PE busbar and the EMC shield busbar of the cabinet. These internal connections can be made via a large area using non-isolated metal construction components of the cabinet. In this case, the contact surface must be bare metal and each contact area must have a minimum cross-section of several cm^2 . Alternatively, these connections can be made with short, finely stranded, braided copper wires with a large cross-section ($\geq 95 \text{ mm}^2$).

The shields of the motor cables shown in orange [2] provide high-frequency equipotential bonding between the Motor Modules and the motor terminal boxes. The finely stranded, braided copper cables shown in red can be routed in parallel with the cable shields when cables with poor high-frequency properties are used or in installations with bad grounding systems.

The connections shown in red [3], [4] and [5] provide a solid, high-frequency bonding between the motor housing and the motor terminal box or the gearbox and the driven machine.

Examples for installation

EMC - compliant installation of a SINAMICS G150 converter cabinet unit



Minimum distance between power cables and signal cables: 20 cm to 30 cm



Shield bonding of the motor cable in the converter on the EMC shield busbar using EMC shield clips and connection of the three symmetrical PE conductors on the PE busbar



Shield bonding of the motor cable on the motor terminal box using EMC cable glands



Shield bonding of the signal, bus, and encoder cables on the shield bonding options provided in the converter using EMC shield clips



Shield bonding of the encoder cable on the housing of the speed encoder



Power cables and signal cables cross at an angle of 90°

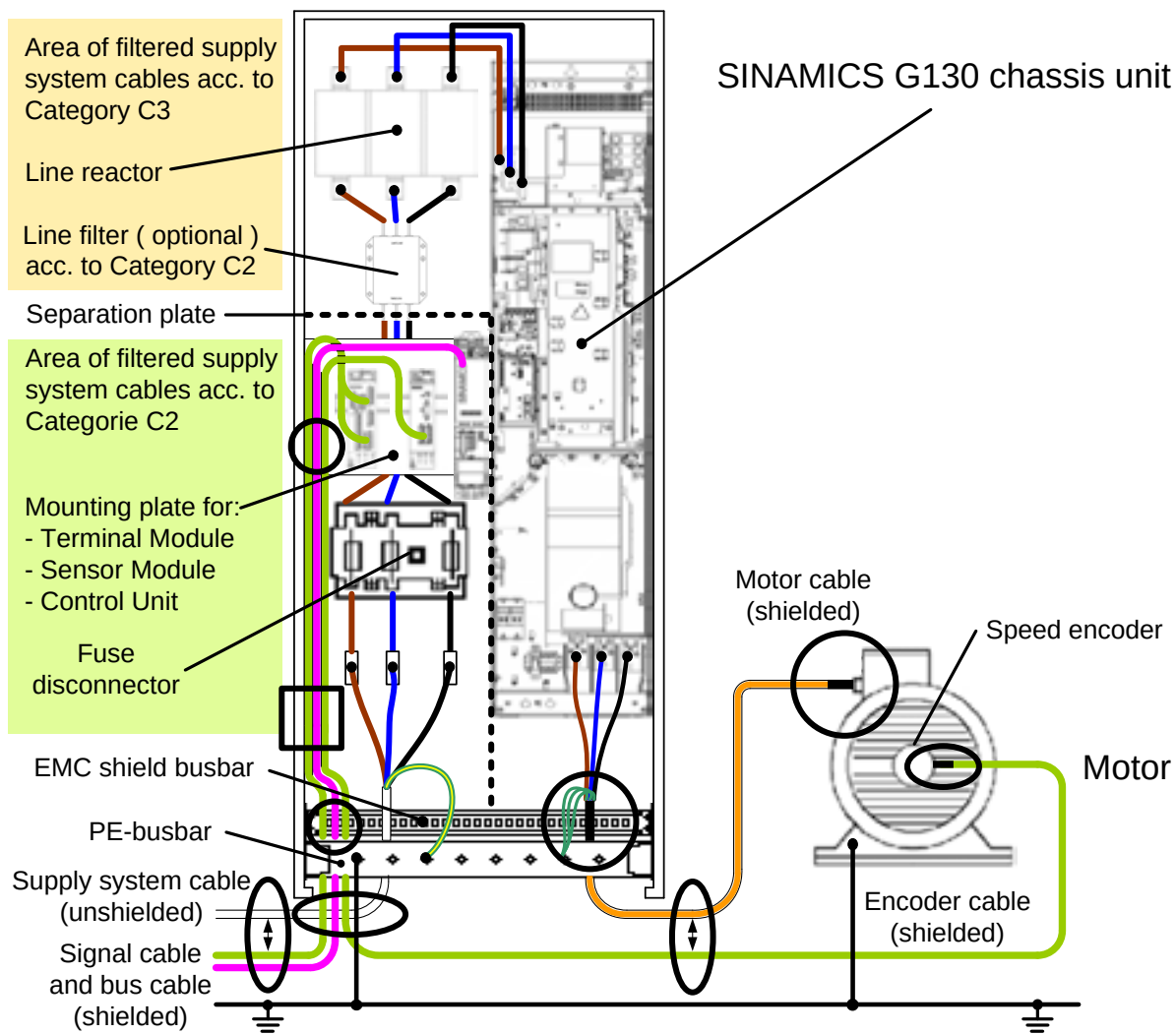


Signal, bus, and encoder cables in the converter must be routed as close as possible to the cabinet frame or on grounded plates at a large distance from the power cables

EMC Installation Guideline

Engineering Information

EMC - compliant construction / installation of a cabinet with a SINAMICS G130 chassis unit



Minimum distance between power cables and signal cables: 20 cm to 30 cm



Shield bonding of the motor cable in the converter on an EMC shield busbar using EMC shield clips and connection of the three symmetrical PE conductors on the PE busbar



Shield bonding of the motor cable on the motor terminal box using EMC cable glands



Shield bonding of the signal, bus, and encoder cables



Shield bonding of the encoder cable on the housing of the speed encoder

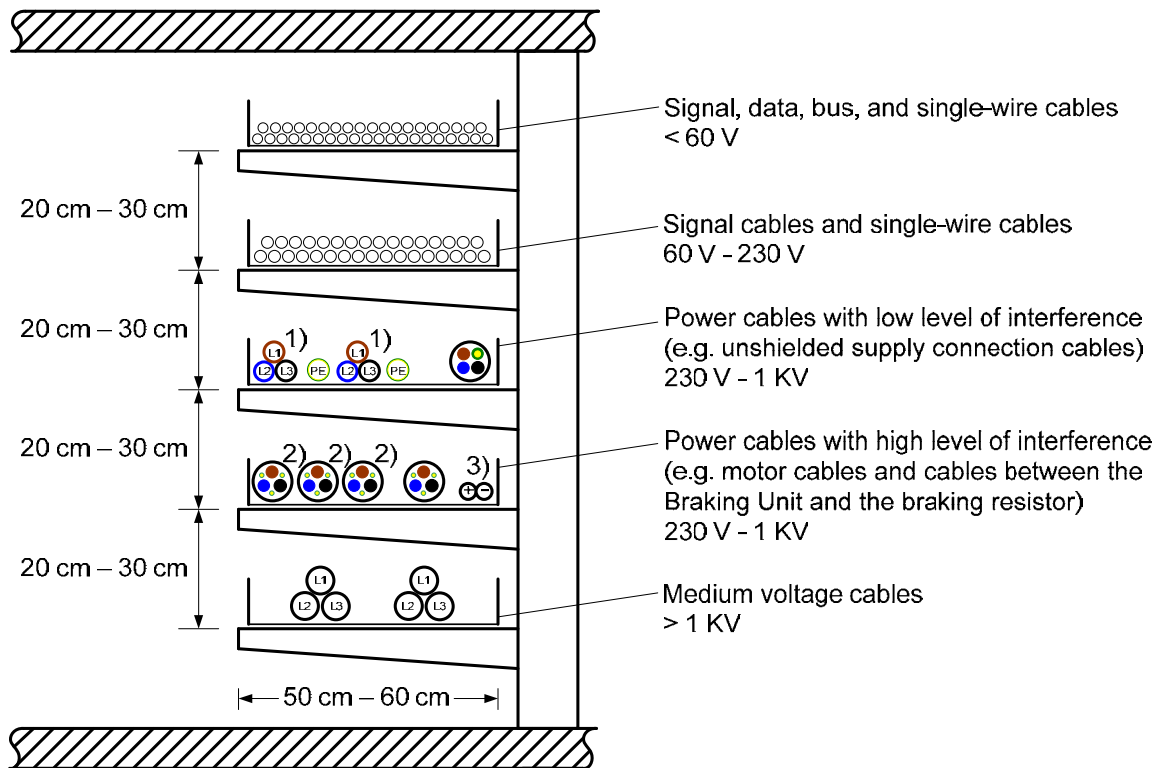


Power cables and signal cables cross at an angle of 90°

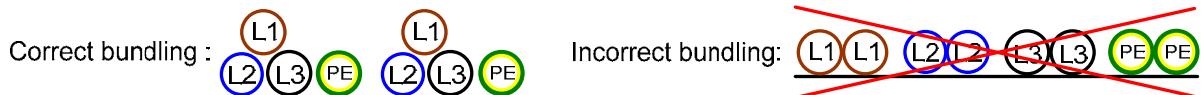


Signal, bus, and encoder cables in the converter must be routed as close as possible to the cabinet frame or on grounded plates at a large distance from the power cables

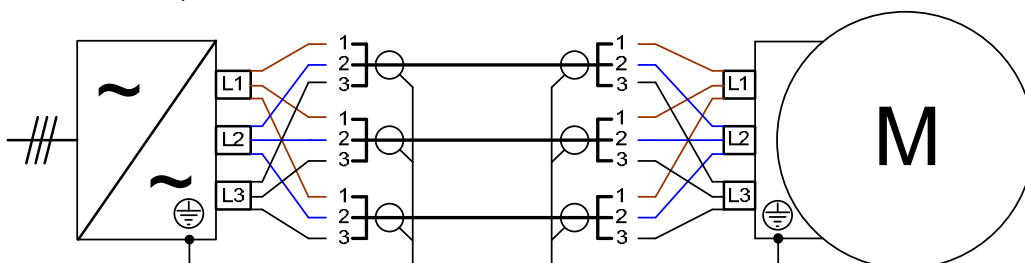
EMC - compliant cable routing on the plant side on cable racks and in cable routes



¹⁾ When single-wire cables (e.g. unshielded supply connection cables) are used in three-phase systems, the three phase conductors (L1, L2, and L3) must be bundled symmetrically to minimize the magnetic leakage fields. This is particularly important when several single-wire cables need to be routed in parallel for each phase of a three-phase system due to high amperages. The illustration below uses an example of a three-phase system with two single-wire cables per phase routed in parallel.



²⁾ When several three-phase motor cables have to be routed in parallel between the converter and the associated motor, it has to be ensured that all three phases of the three-phase system are routed within each motor cable. This minimizes the magnetic leakage fields. The illustration below uses an example of three shielded, three-phase motor cables routed in parallel.



³⁾ When DC cables (DC link cables or connection cables between Braking Modules and the associated braking resistors) are routed, the feed and return lines must be routed in parallel with as little space between them as possible to minimize magnetic leakage fields.

General Engineering Information for SINAMICS

Engineering Information

General Engineering Information for SINAMICS

■ Overview of documentation

A large number of documents on the subject of the SINAMICS equipment range has been published. The following list should provide you with a quick overview and facilitate your search for the correct information source. However the overview includes only those manuals which are relevant to the products discussed in this document.

Please note that only a brief description of the document content can be given here.

Documentation available for converter ranges SINAMICS S120, S150, G130, G150

General	
SINAMICS Function Manual Free function blocks	Description of the firmware function module "Free function blocks"
SINAMICS Commissioning Manual for CANopen	Information about commissioning the CANopen interface with definition of terms
SINAMICS S_G Safety Chassis	Information about safety-integrated for chassis units and cabinet units, Notes for commissioning, function plans, acceptance test and acceptance protocol.
SINAMICS S120	
SINAMICS S120 Getting Started	System description of SINAMICS S120 Booksize; Description of commissioning process using the STARTER tool
SINAMICS S120 Commissioning Manual	Information about commissioning the SINAMICS S120 equipment range using the BOP20 and Starter (without AOP30); Description of commissioning sequence, Explanation of PROFIdrive, PROFIBUS and PROFINET IO, Commissioning of Safety Integrated, Information about diagnostics, Explanation of the fundamentals of the SINAMICS drive system
SINAMICS S120 Function Manual	Description of the fundamental principles and operating modes of the SINAMICS system, Explanation of rectifier types, Description of implemented functions, List of differences between firmware versions
SINAMICS S120 Equipment Manual 1	Description of components which refers to the SINAMICS S120 Booksize system; Control Unit CU320 plus supplementary system components such as option boards and modules, encoder modules, Basic Operator Panel 20
SINAMICS S120 Equipment Manual 2	Description of SINAMICS S120 Booksize power units; Description of units with interfacing information, Description of DRIVE-CLiQ components, Information about cabinet construction and EMC in relation to the Booksize system, Servicing and maintenance information including spare parts list
SINAMICS S120 Equipment Manual 3	Description of SINAMICS S120 chassis power units; Description of units with interfacing information, Information about cabinet construction and EMC in relation to the chassis unit system, Servicing and maintenance information

General Engineering Information for SINAMICS

Engineering Information

SINAMICS S120	
SINAMICS S120 Equipment Manual 4	Description of SINAMICS S120 Booksize Cold Plate power units; Description of units with interfacing information, Description of DRIVE-CLiQ components, Information about cabinet construction and EMC in relation to the Booksize system, Servicing and maintenance information
SINAMICS S120 Equipment Manual 5	Description of SINAMICS S120 Cabinet Modules; Description of units incl. options with interfacing information, Servicing and maintenance information
SINAMICS S120 Equipment Manual 6	Description of SINAMICS S120 AC Drive power units; Description of units with interfacing information, Description of CU310 Control Units and Control Unit Adapter 31, Description of S120 system components, Information about cabinet construction and EMC in relation to the Blocksize system, Servicing and maintenance information including spare parts list
SINAMICS S120 Equipment Manual Chassis LC	Description of liquid-cooled SINAMICS S120 chassis power units; Description of units with interfacing information, Information about construction and EMC in relation to the chassis unit system, Servicing and maintenance information
SINAMICS S List Manual	List of function diagrams, parameters, explanation of faults and alarms for the SINAMICS S system
SINAMICS S150	
SINAMICS S150 Operating Instructions	Description of the SINAMICS S150 system; Description of units with information about mechanical and electrical installation, Commissioning information, Operating instructions, Explanation of functions, Explanation of available diagnostic tools, Servicing and maintenance information
SINAMICS S150 FP	Selected function diagrams in simplified representation with specification of default settings for SINAMICS S150
SINAMICS S150 SU	Overview diagrams of cabinet and component wiring as well as the SINAMICS S150 interfaces
SINAMICS S List Manual	List of function diagrams, parameters, explanation of faults and alarms for the SINAMICS S system
SINAMICS S150 Checklist	Checklist for mechanical and electrical installation as a support document for installation and commissioning
SINAMICS G150 / S150 Pump functions	Description of the macros included in the drives firmware for pump functions

General Engineering Information for SINAMICS

Engineering Information

SINAMICS G130	
SINAMICS G130 AOP30	Description of the Advanced Operator Panel AOP30 in relation to SINAMICS G130
SINAMICS G130 Operating Instructions	Description of the SINAMICS G130 system; Description of units with information about mechanical and electrical installation, Commissioning information, Operating instructions, Explanation of functions, Explanation of available diagnostic tools, Servicing and maintenance information.
SINAMICS G130 BOP20	Description of the Basic Operator panel BOP20
SINAMICS G130 Braking Modules	Description of the Braking Module with information about mechanical and electrical installation
SINAMICS G130 dv/dt Filters	Description of the dv/dt filters with information about mechanical and electrical installation
SINAMICS G130 FP	Selected function diagrams in simplified representation with specification of default settings for SINAMICS G130
SINAMICS G130 Motor Reactors	Description of motor reactors with information about mechanical and electrical installation
SINAMICS G130 Line Reactors	Description of line reactors with information about mechanical and electrical installation
SINAMICS G130 Line Filters	Description of line filters with information about mechanical and electrical installation
SINAMICS G130 Cabinet Design and EMC	Information about cabinet construction and EMC in relation to the SINAMICS G130 unit
SINAMICS LHF	Description of Line Harmonics Filters; description of units with interfacing information
SINAMICS G List Manual	List of function diagrams, parameters, explanation of faults and alarms for the SINAMICS G system
SINAMICS G130 Sine-wave Filters	Description of sine-wave filters with information about mechanical and electrical installation
SINAMICS G150	
SINAMICS G150 Operating Instructions SINAMICS G150 NAFTA Operating Instructions	Description of the SINAMICS G150 system; Description of units with information about mechanical and electrical installation, Commissioning information, Operating instructions, Explanation of functions, Explanation of available diagnostic tools, Servicing and maintenance information.
SINAMICS G150 FP	Selected function diagrams in simplified representation with specification of default settings for SINAMICS G150
SINAMICS G150 SU	Overview diagrams of cabinet and component wiring as well as the SINAMICS G150 interfaces
SINAMICS LHF	Description of Line Harmonics Filters; Description of units with interfacing information
SINAMICS G List Manual	List of function diagrams, parameters, explanation of faults and alarms for the SINAMICS G system
SINAMICS G150 Checklist	Checklist for mechanical and electrical installation as a support document for installation and commissioning
SINAMICS G150 / S150 pump functions	Description of the macros included in the drives firmware for pump functions

General Engineering Information for SINAMICS

Engineering Information

Please note the document release information. The listed documents relate to specific firmware versions.

The documentation for units of type SINAMICS S120 Cabinet Modules, S150, G130 and G150 is supplied with the equipment. Documentation for S120 Booksize units and chassis units must be ordered separately or can be downloaded from the Internet.

Other documentation relating to components used in the equipment which are supplied by third parties might also be supplied with units in cabinet format.

■ Safety-integrated, drive-integrated safety functions

Safe Torque Off (previously known as “Safe Standstill”) and Safe Stop 1

General

The **Safe Torque Off** function (abbreviated to STO) is a mechanism for preventing the drive from unexpectedly starting in compliance with EN60204-1 Section 5.4. Safe Torque Off enables stop category 0 to be implemented in compliance with EN 60204-1 (“Uncontrolled Stop”) with regard to the switching off of the energy supply to the drive components of the machines.

Advantage: With STO motor-side contactors as additional switch-off paths are no longer required.

The **Safe Stop 1** safety function (SS1) is a supplement to the Safe Torque Off function. With this function, it is possible to implement stop category 1 in compliance with EN 60204-1. When Safe Stop 1 is activated, the drive decelerates according to the fast stop ramp (OFF3) and then switches over into the Safe Torque Off mode.

These safety functions are part of the SINAMICS “Safety-Integrated” philosophy and are standard features of the SINAMICS units S120 Booksize, S120 Chassis and Cabinet Modules, G130, G150 and S150. Both safety functions are integrated in each drive unit. Thus no additional higher-level control is required.

Operating principle

The functions Safe Torque Off and Safe Stop 1 are activated by two separate, but mutually dependent signals. These signals act on monitoring channels (signal switch-off paths, data cross-comparison) which are stored separately in the firmware in both the Control Unit and the Motor Module. The two signals must be switched simultaneously. This structure makes it possible to implement a two-channel function for maximum reliability and safety. The function uses digital inputs (DI0-DI7) on the Control Unit and terminals labeled “EP – Enable Pulses” on the power unit. STO and SS1 must be activated by parameter settings as the terminals will not work before.

When the function is selected, the drive unit is in a “safe state”. The switching on inhibited function prevents the drive unit from being restarted. The pulse suppression mechanism integrated in the Motor Modules is a prerequisite for this function. This works by turning off the gating pulses to the power transistors (IGBTs).

When the function is selected, each monitoring channel triggers safe pulse suppression via its switch-off signal path. When a fault is detected in one of the switch-off signal paths, the STO function is also activated and restarting is “locked out” so that the motor cannot start accidentally.

Both functions are implemented individually for each drive axis within a Control Unit (“axial” function). In this way, each drive can be controlled separately when multiple motors are configured for each CU. Functional groups can also be created.

To fulfill the requirements of EN 954-1 regarding early error detection, the two switch-off signal paths must be tested at least once within a defined time to ensure that they are functioning properly. For this purpose, forced dormant error detection must be triggered manually by the user or automatically. Once this time has elapsed, an alarm is created and remains present until forced dormant error detection is carried out. This alarm does not affect machine operation. A self-test is also initiated and the time interval restarted with every normal selection. Depending on the operating state of the machine, therefore, the message might not be visible.

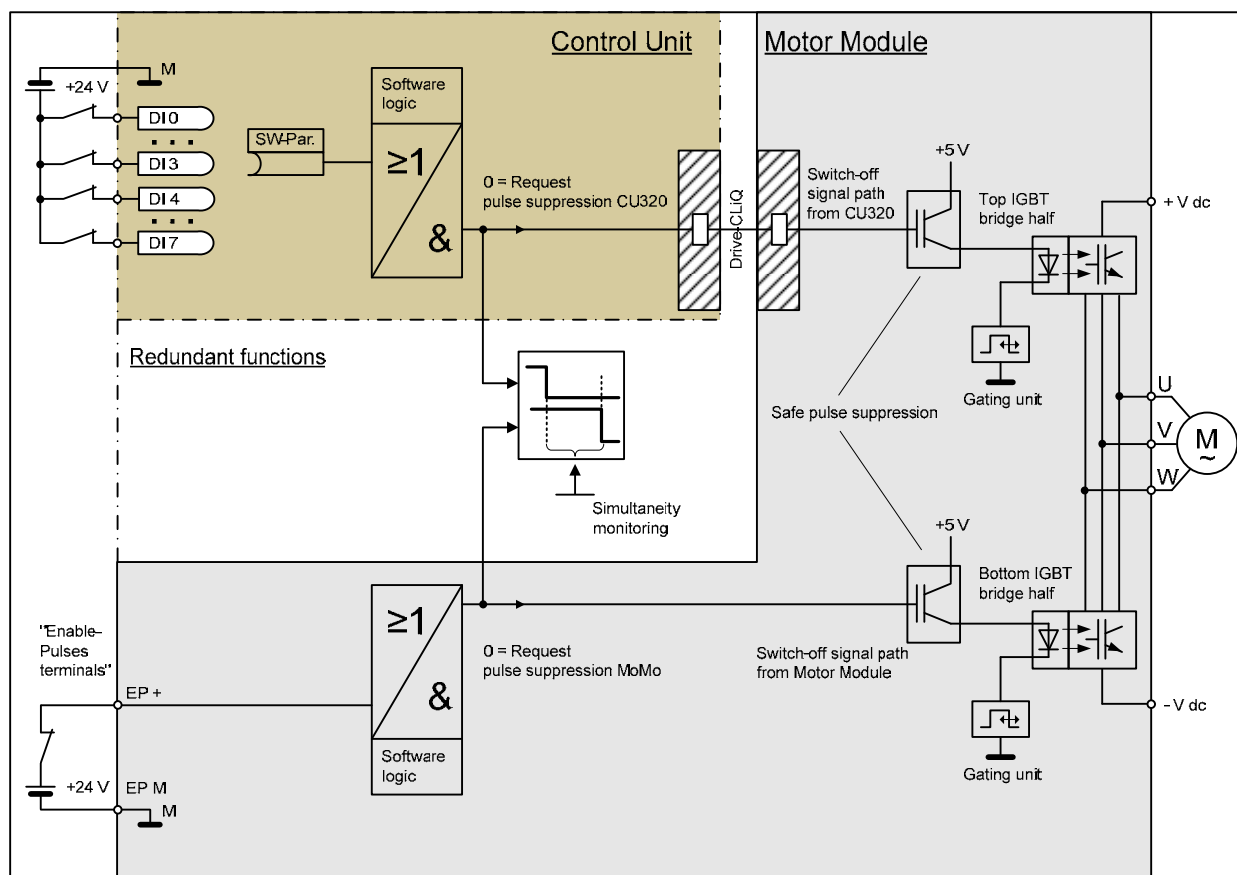
The following boundary conditions should be taken in account when activating the safety functions:

- Simultaneous activation / deactivation at Control Unit and power unit is required
- Control with DC 24V is required
- According to EN 61800-5-1 and UL 508, at the control terminals only the connection of protective extra low voltage (PELV) is permissible
- DC supply cables up to a length of 30 m are permissible
- Unshielded signal cables up to a length of 30 m are permissible without additional circuitry for surge voltage protection. For longer cable lengths, shielded cables must be used or a suitable circuitry for surge voltage protection must be implemented.
- The components must be protected against conductive pollution, e.g. through being installed in a cabinet with degree of protection IP54B in compliance with EN 60529. On the precondition that conductive pollution cannot occur, also lower degree of protection than IP54B can be chosen for the cabinet.

General Engineering Information for SINAMICS

Engineering Information

In the following diagram the operation principles of both safety functions are shown.



Wiring and operating principles of the Safe Torque Off and Safe Stop 1 function

At the various types of SINAMICS components the inputs of the safety functions have different terminal markings. These are shown in the following table:

Component	1st switch-off signal path	2nd switch-off signal path
Control Unit CU320	X122.1...4 / X132.1...4 (on CU320) digital inputs 0 to 7	(see Motor Modules / Power Modules)
S120 Single Motor Module Booksize (also S120 Cabinet Module of type Booksize Cabinet Kits)	(see CU320)	X21.3 and X21.4 (at Motor Module)
S120 Single Motor Module Chassis S120 Cabinet Module without the Booksize Cabinet Kits, G130, G150, S150,	(see CU320)	X41.1 and X41.2 (at CIB board)
S120 Double Motor Module Booksize	(see CU320)	X21.3 and X21.4 (Motor connection X1) X22.3 und X22.4 (Motor connection X2) (at Motor Module)
S120 Liquid Cooled, Single Motor Module Chassis	(see CU320)	X9.7 and X9.8
S120 Power Module Blocksize with CUA31	(see CU320)	X210.3 and X210.4 (at CUA31)
S120 Power Module Blocksize with CU310	X121.1...4 (at CU310) digital inputs 0 to 3	X120.7 and X120.8 (at CU310)
S120 Power Module Chassis with CU310	X121.1...4 (at CU310) digital inputs 0 to 3	X41.1 and X41.2 (at CIB board)

For further information regarding the terminals please refer to the equipment manuals.

Connections at the Power Units for safety functions

General Engineering Information for SINAMICS

Engineering Information

Acceptance test

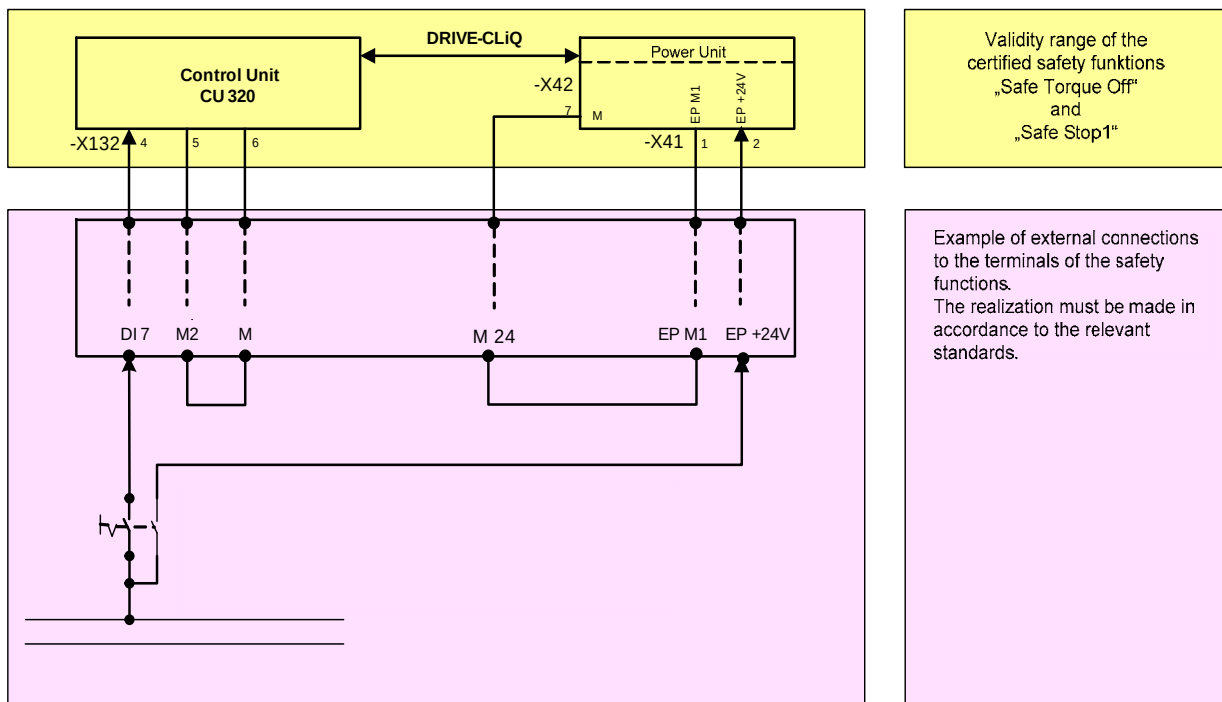
The machine manufacturer must carry out an acceptance test for the activated Safety Integrated functions (SI functions) on the machine. This also applies to the STO and SS1 functions. During the acceptance test, all the limit values entered for the enabled function must be exceeded to check and verify that the functions are working properly.

Each SI function must be tested and the results documented and signed in the acceptance certificate by an authorized person. Authorized in this sense refers to a person who has the necessary technical training and knowledge of the safety functions and is authorized by the machine manufacturer to carry out the test. The acceptance certificate must be stored in the machine logbook.

Certificate

The Safe Torque Off and Safety Stop 1 functions are approved by an accredited body, in accordance with the machine directive 98/37/EC, EN 60204-1 and category 3 of the EN 954-1 resp. ISO/FDIS 13849-1:2006, and also in accordance with IEC 61508 SIL 2 as well as with performance level d of the ISO/FDIS 13849-1. The certificate always refers to specific versions of hardware and firmware.

It is important to note that the certificate refers only to those components listed in the table on the previous page, starting at the input terminals of the safety-integrated function. Additional circuitries inside and outside the cabinets are not included.



Validity range of the certificate

For standard cabinet units G150, S150 and S120 Cabinet Modules option K82 is available, which consists of the complete cable wiring inside the cabinet for all connections required in accordance with certified standards. Further information can be found in the section “Option K82” of the chapter “Modular Cabinet Unit System SINAMICS S120 Cabinet Modules”.

According to IEC 61508, IEC 62061 and ISO 13849-1 it is required to quantify the probability of failures for safety functions in form of a PFH value (Probability of Failure per Hour). The PFH value of a safety function depends on the safety concept of the drive unit, its hardware configuration and on the PFH values of additional components, which are required for the safety function. For SINAMICS units PFH values are provided in dependency on the hardware configuration (number of units, number of sensors, etc.). Thereby no difference is made between the individual integrated safety functions.

A list of certified components and firmware versions as well as a list of the PFH values is available on request from your local Siemens partners.

Functional safety

The Safe Torque Off function prevents the connected motor from starting accidentally from standstill or, in other words, ensures the torque-free state of a rotating drive. A rotating axis loses its ability to brake.

When an electrical installation breaks down or stops, or when it needs to be serviced, repaired or cleaned, it must be completely isolated from the power supply via the main circuit breaker.

The STO function does not isolate the installation from the supply system. It does not therefore provide any protection against "electric shocks"!

Asynchronous motors cannot turn, even when more than one fault occurs.

In applications with synchronous motors, e.g. 1FT6 and 1FK6, it should be noted that limited movement can occur for physical reasons when 2 faults occur in particular constellations.

Description of potential fault: Simultaneous breakdown of one power transistor in the upper inverter bridge and another offset in the lower bridge ("positive arm" and "negative arm").

Maximum residual movement:

Synchronous rotary motors:
$$\alpha_{\max} = \frac{360^\circ}{\text{Pole number of motor}}$$
 e.g.: 1FT6, 6-pole motor; $\alpha_{\max} = 60^\circ$

In the case of synchronous linear motors, the maximum movement corresponds to the pole width.

In order to assess the potential hazard posed by critical residual movements, the machine manufacturer must perform a safety evaluation.

With respect to permanent-magnet synchronous motors such as the 1FW4 torque motor, please note that the motor terminals are under power when the rotor is turning (integrated permanent magnets). If the motors are driven passively, voltage is induced in the motor even when the STO or SS1 functions are activated.

Separate protective mechanisms are recommended in such cases.

Safe Brake Control

General

The Safe Brake Control (SBC) function is designed to activate standstill brakes, which operate according to the holding-current principle (e.g. motor standstill brakes). SINAMICS S120 Motor Modules in the Booksize format have a corresponding connection. In order to use this function with S120 Power Modules in Blocksize format, a Safe Brake Relay must be installed.

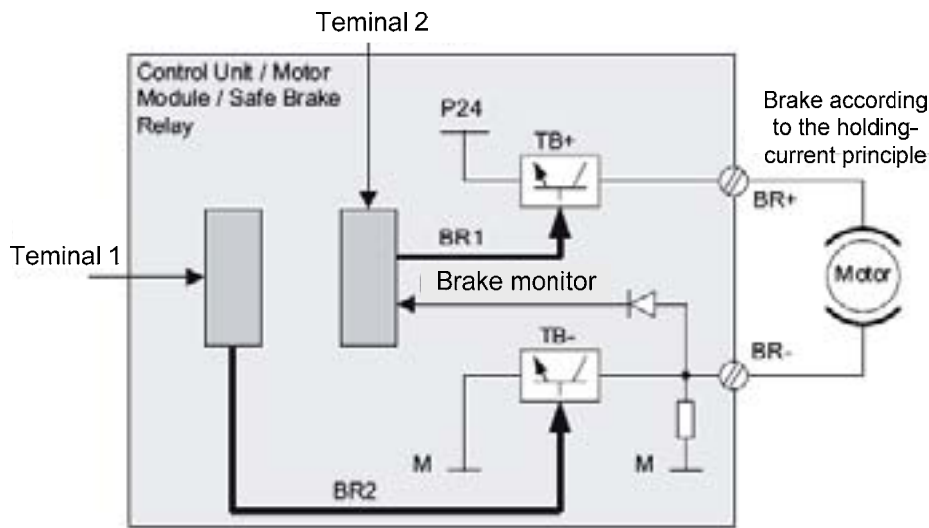
Operating principle

The brake is controlled by the Control Unit. There exist two signal paths for the closing of the brake. The command for opening or closing the brake is transferred from the Control Unit via the DRIVE-CLiQ connection to the Motor Module or the Power Module. The Motor Module or the Safe Brake Relay of the Power Module then acts and activates the outputs for the brake accordingly.

For the Safe Brake Control function, the Motor Module takes over the control function and ensures that if the Control Unit fails, the holding current of the brake is interrupted and the brake is closed. A malfunction of one of the two switches (TB+ and TB-, see diagram below) will only be recognized by the brake diagnosis, if a change of status occurs i.e. when opening or closing the brake. When a fault is recognized by either the Motor Module or the Control Unit, the holding current of the brake will be interrupted and thus a safe status will be achieved.

General Engineering Information for SINAMICS

Engineering Information



Two-channel brake control at SINAMICS S120 Booksize units and Blocksize units

The activation of the brake via the brake connection on the Motor Module or the Safe Brake Relay is realized in a safe way using two independent channels.

The function Safe Brake Control is not available with SINAMICS S120 chassis units and cabinet units.

Certification

The function Safe Brake Control is certified for SINAMICS S120 Booksize units by an accredited body, according to EN 954-1 resp. ISO/FDIS 13849-1:2006 category 3 and according to DIN EN 61508 SIL 2 as well as performance level d of ISO/FDIS 13849-1. The certificate always refers to specific versions of hardware and firmware.

According to IEC 61508, IEC 62061 and ISO 13849-1 it is required to quantify the probability of failures for safety functions in form of a PFH value (Probability of Failure per Hour). The PFH value of a safety function depends on the safety concept of the drive unit, its hardware configuration and on the PFH values of additional components, which are required for the safety function. For SINAMICS units PFH values are provided in dependency on the hardware configuration (number of units, number of sensors, etc.). Thereby no difference is made between the individual integrated safety functions.

A list of certified components and firmware versions as well as a list of the PFH values is available on request from your local Siemens partners.

■ Precharging intervals of the DC link

SINAMICS Booksize units

The precharging intervals of the DC-link for Line Modules in Booksize format can be calculated using the following formula

$$\text{No. of precharging operations within 8 min.} = \frac{\text{max. permissible DC - link capacitance infeed module in } \mu\text{F}}{\Sigma \text{ DC - link capacitance of configured drive group in } \mu\text{F}}$$

SINAMICS chassis units

For Line Modules in chassis format, the maximum permissible DC link precharging interval is 3 minutes. This applies irrespective of whether the unit is a SINAMICS G or S type.

■ Operator Panel

The SINAMICS range includes two operator panels for unit variants S120 (Booksize, Chassis, Cabinet Modules), S150, G130 and G150. The Basic Operator Panel is designed to meet simpler requirements while the Advanced Operator Panel offers a wider scope of functions.

Basic Operator Panel (BOP20)

The optional Basic Operator Panel BOP20 that can be plugged into any CU320 Control Unit can be used to acknowledge faults, set parameters and read diagnostic information (e.g. warnings and error messages).

The Basic Operator Panel BOP20 has a backlit two-line display area and 6 keys.



Key assignment:

- **ON/OFF**
- **Functions**
- **Parameters**
- **Setpoint increase / decrease**

View of the Basic Operator Panel 20

The integrated plug connector to the rear of the Basic Operator Panel BOP20 supplies its power and enables communication with the CU320 Control Unit. It cannot be sited at a distance from the Control Unit or installed remotely and connected via a cable.

Advanced Operator Panel (AOP30)

The Advanced Operator Panel AOP30 is a comfortable optional input/output device. In contrast to the BOP20, this panel offers commissioning and diagnostic functionality in addition to the functions required in normal operation. The panel features a multi-line graphic display on which a wide range of help functions can be called.

General Engineering Information for SINAMICS

Engineering Information



Key assignment:

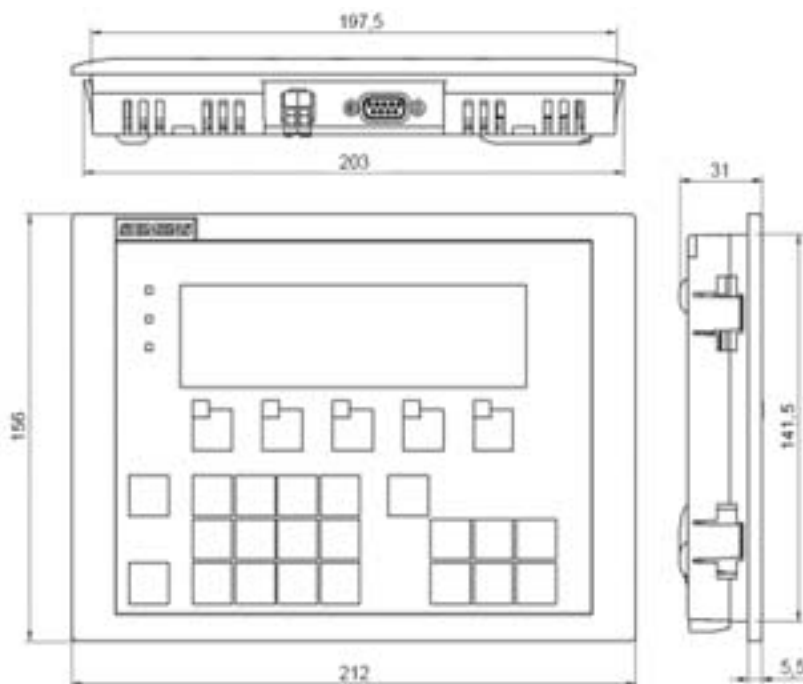
- Functions
- Menu
- Operating / Parameterizing lock
- Numerical keypad
- Local / Remote switchover
- ON/OFF
- Clockwise / Counter-clockwise switchover
- Jog
- Setpoint increase / decrease

View of the Advanced Operator Panel 30

The AOP30 communicates with the SINAMICS / CU320 Control Unit via a serial interface (RS232) with PPI protocol. The interface is a point-to-point connection. During communication, the AOP30 is the master and the connected unit is the slave.

The AOP30 supports configuration of multiple motors on one Control Unit. Both the messages and parameters of all connected units are accessible at all times.

The AOP30 is an operator panel with a graphic display and a touch-sensitive keypad. The device can be installed in a cabinet door (thickness: between 2 mm and 4 mm).



Features

- Display with green backlighting, resolution: 240 x 64 pixels
- 26-key touch-sensitive keypad
- Connection for a 24 V DC power supply
- RS232 interface
- Time and date memory powered by internal battery backup
- 4 LEDs indicate the operating status of the drive unit:
 - RUN green
 - ALARM amber
 - FAULT red
 - LOCAL/REMOTE green

Dimensions of the Advanced Operator Panel 30

Cabinet construction and air conditioning

The modular concept of SINAMICS chassis units allows for a wide range of different device combinations. A description of each individual combination cannot, therefore, be provided here. This section simply aims to provide fundamental principles and general rules designed to ensure that special device combinations are properly configured.

The various local regulations and standards must also be observed. You are advised to carefully observe the information provided in the safety instructions, which can be found in the manuals and the documents accompanying the components supplied.

Directives and standards

The table below provides a list of the most important directives and standards, which must be observed to ensure that installation is carried out correctly, safely, and in compliance with EMC requirements.

Directive	Description
2006/95/EC	Council Directive on the harmonization of the laws of Member States relating to electrical equipment designed for use within certain voltage limits. Low Voltage Directive
98/37/EC	Council Directive on the harmonization of the laws of the Member States relating to machinery. Machinery Directive
2004/108/EC	Council Directive on the harmonization of the laws of the Member States relating to electromagnetic compatibility. EMC Directive

European Directives

Standard	Description
EN ISO 12100-1	Safety of machinery Basic concepts, general principles for design Part 1: Basic terminology, methodology
EN ISO 12100-2	Safety of machinery Basic concepts, general principles for design Part 2: Technical principles
EN 954-1	Safety of machinery Safety-related parts of control systems Part 1: General principles for design
EN 1037	Safety of machinery Prevention of unexpected start-up
EN 60204-1	Safety of machinery Electrical equipment of machines Part 1: General requirements
EN 60439-1	Low-voltage switchgear and controlgear assemblies Part 1: Type-tested and partially type-tested assemblies
EN 60529	Degrees of protection provided by enclosures (IP code)
EN 61508-1	Functional safety of electrical/electronic/programmable electronic safety-related systems Part 1: General requirements
EN 61800-3	Adjustable speed electrical power drive systems Part 3: EMC requirements and specific test methods
EN 61800-5-1	Adjustable speed electrical power drive systems Part 5: Safety requirements/Main section 1:Electrical, thermal and energy

European standards

Standard	Description
UL 508C	Power Conversion Equipment
CSA C22.2 No. 14	Industrial Control Equipment

North American standards

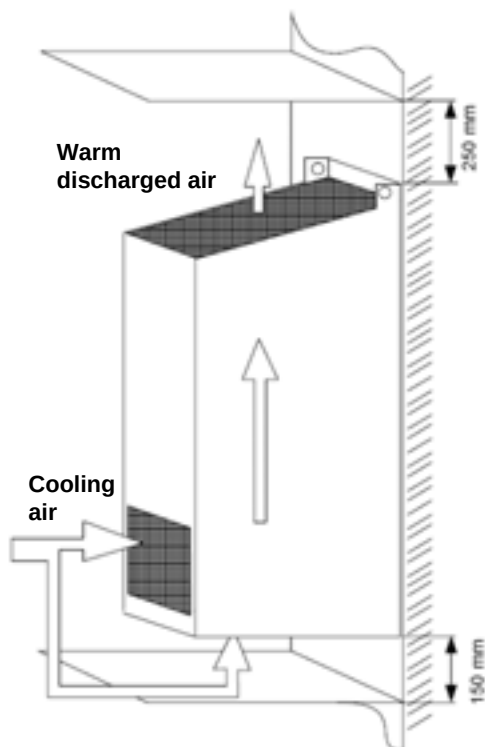
General Engineering Information for SINAMICS

Engineering Information

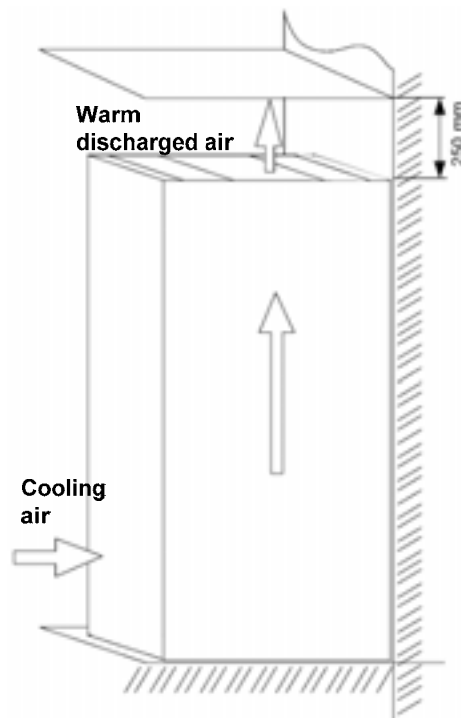
Cabinet air conditioning

SINAMICS chassis units are forced-ventilated by integrated fans. To ensure an adequate air supply, suitable openings for the inlet air (e.g. ventilation slots in the cabinet door) and outlet air (e.g. by means of a special hood) must be provided.

The power unit design must be taken into account. For optimized cooling, components that are subjected to thermal stresses are arranged along an air duct. The cooling air must flow through this duct vertically from bottom (cooler region) to top (region heated by operation). It is essential to note this air-flow direction. It must also be ensured that the warm air can escape at the top.



Air-flow guidance for S120 Active Interface Module, frame sizes FI, GI



Air-flow guidance for S120 Active Interface Module, frame sizes HI, JI

Ventilation concept for chassis power unit S120 Active Interface Module

Sufficient clearances must be designed into the cabinet layout to guarantee effective cooling. It is absolutely essential to observe the ventilation clearances specified in the following table. The measurements refer to the external edges of the relevant units. It should also be taken into account that the clearances do not refer to a closed cabinet, but to conditions in the immediate external environment.

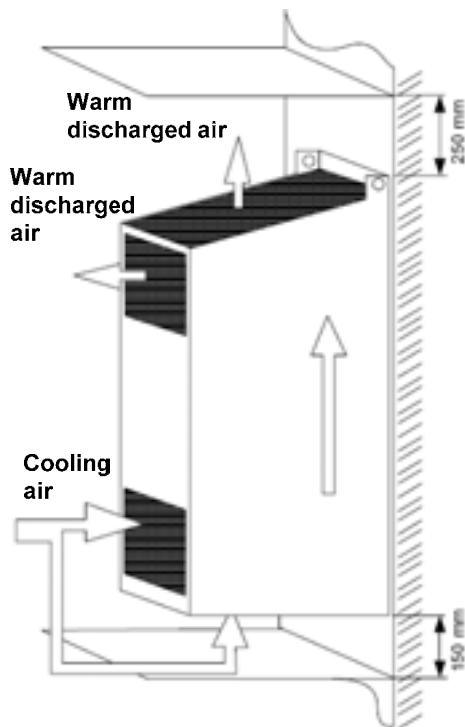
For further information, please refer to the relevant equipment manuals.

General Engineering Information for SINAMICS

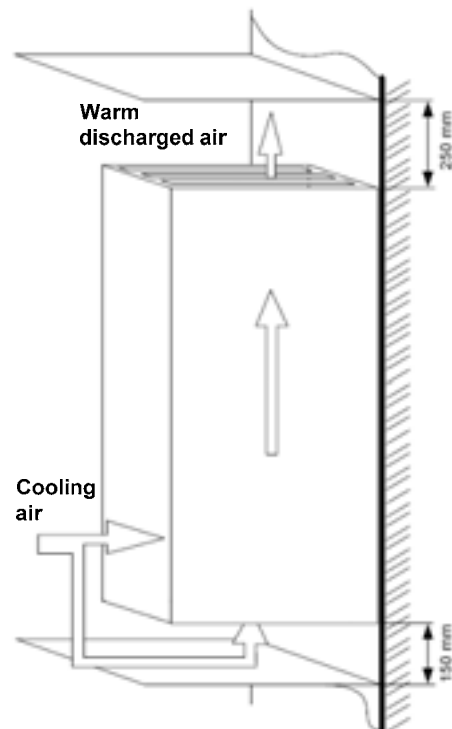
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Component	Frame size	Clearance front ¹⁾ [mm]	Clearance top [mm]	Clearance bottom [mm]
S120 Chassis				
Basic Line Module	FB, GB	40	250	150
Smart Line Module	GX, HX, JX	40	250	150
Active Interface Module	FI	40	250	150
Active Interface Module	GI	50	250	150
Active Interface Module	HI, JI	40	250	0
Active Line Module	FX, GX, HX, JX	40	250	150
Motor Module	FX, GX, HX, JX	40	250	150
G130				
Power Module	FX	40	250	150
Power Module	GX	50	250	150
Power Module	HX, JX	40	250	150

¹⁾ The clearances refer to the area around the ventilation slots on the front cover.



Air-flow guidance for S120 Smart Line Module, Active Line Module, Motor Module, frame sizes FX, GX, G130 frame size FX, GX



Air-flow guidance for S120 Active Interface Module, Active Line Module, Motor Module, frame sizes HX, JX, Basic Line Module, frame sizes FB, GB, G130 frame size HX

Ventilation concept for chassis power units

The cooling air is drawn in at the bottom of the power units. The warm outlet air must be dissipated via the top cover/hood or via side openings in the cabinet at the level of the top of the device. No items of equipment which could impede the flow of air may be mounted above the air outlet openings in the power blocks of a power unit.

General Engineering Information for SINAMICS

Engineering Information

Cooling air requirement and sizes of cabinet openings

The cooling air required by power units is determined by their frame size and output and also depends on the number and size of the fans installed. One fan is provided for each power block. The required cooling air must be made available through openings of the correct size in the cabinet. The correct sizes of opening must be provided for inlet air and outlet air.

The specified opening sizes comprise several small openings. To ensure that pressure loss is kept to a minimum and that the flow resistance does not become too great, the cross-sectional area of each opening must be at least 280 mm² (e.g. 7 mm x 40 mm).

The table below specifies the relevant data. The opening sizes specified in the table refer in each case to one device. If more than one unit is installed in a cabinet, the size of the opening increases accordingly. If the required openings in the cabinet cannot be made, the units must be distributed among several cabinets which are segregated by means of partitions.

With degrees of protection higher than IP20 and if a hood is used, an "active" hood may have to be used. An "active" hood contains fans that blow the air current forwards. Apart from the air outlet, the hood is otherwise closed.

When choosing an "active" hood, you must ensure that the fans are sufficiently powerful to prevent air from accumulating in the cabinet. If air accumulates, the cooling capacity is reduced. This can overheat and destroy the equipment. The cooling capacity of the fans should at least correspond to the device fan data.

To ensure long-term operation of the equipment, measures must be taken to prevent the ingress of dirt and dust. Wire lattices (wire cloth DIN 4189-St-vzk-1x0.28) or filter mats (min. filter class G2) must be used for this purpose. The choice of filter mats depends on the required degree of protection and the ambient conditions. If cabinets are installed in an environment containing fine dust particles or oil vapors, micro-filter mats must be used to prevent the devices from becoming contaminated.

If dirt filters are used, the specified opening sizes and filter areas must be increased.

If the filter mats are heavily contaminated, the volume of air drawn in is reduced due to the increased flow resistance. This can cause the fans integrated in the devices to overload, or it could cause the devices themselves to overheat and become damaged. In order to avoid this, short filter change intervals should be applied.

To ensure adequate ventilation of the equipment, the minimum opening sizes and air-flow rates specified in the following table must be observed.

Component	Rated power	Cooling air requirement [m³/s]	Minimum size of opening in cabinet	
			Inlet opening [m²]	Outlet opening [m²]
S120 Chassis				
Basic Line Module				
▪ Frame size FB	200-400 kW at 400 V; 250-560 kW at 690 V	0.17	0.1	0.1
▪ Frame size GB	560-710 kW at 400 V; 900-1100 kW at 690 V	0.36	0.16	0.16
Smart Line Module				
▪ Frame size GX	250-355 kW at 400 V; 450 kW at 690 V	0.36	0.16	0.16
▪ Frame size HX	500 kW at 400 V; 710 kW at 690 V	0.78	0.28	0.28
▪ Frame size JX	630-800 kW at 400 V; 1000-1400 kW at 690 V	1.08	0.4	0.4
Active Interface Module				
▪ Frame size FI	132-160 kW at 400 V	0.24	0.1	0.1
▪ Frame size GI	235-300 kW at 400 V	0.47	0.2	0.2
▪ Frame sizes HI/JI	380-900 kW at 400 V; 560-1400 kW at 690 V	0.4	0.16	0.16

General Engineering Information for SINAMICS

Engineering Information

Component	Rated power	Cooling air requirement	Minimum size of opening in cabinet	
		[m³/s]	Inlet opening [m²]	Outlet opening [m²]
Active Line Module				
▪ Frame size FX	132 kW at 400 V	0.17	0.1	0.1
	160 kW at 400 V;	0.23	0.1	0.1
▪ Frame size GX	235-300 kW at 400 V	0.36	0.16	0.16
▪ Frame size HX	380-500 kW at 400 V;	0.78	0.28	0.28
	560 kW at 690 V			
▪ Frame size JX	630-900 kW at 400 V;	1.1	0.4	0.4
	800-1400 kW at 690 V			
Motor Module				
▪ Frame size FX	110 kW at 400 V;	0.17	0.1	0.1
	132 kW at 400 V;		0.1	0.1
	75-132 kW at 690 V		0.1	0.1
▪ Frame size GX	160-250 kW at 400 V;	0.36	0.16	0.16
	160-315 kW at 690 V			
▪ Frame size HX	315-450 kW at 400 V;	0.78	0.28	0.28
	400-560 kW at 690 V			
▪ Frame size JX	560-800 kW at 400 V;	1.1	0.4	0.4
	710-1200 kW at 690 V	1.48	0.55	0.55
G130				
Power Module				
▪ Frame size FX	110-132 kW at 400 V; 75-132 kW at 690 V	0.17	0.1	0.1
▪ Frame size GX	160-315 kW at 400 V;	0.36	0.16	0.16
	110-200 kW at 500 V; 160-315 kW at 690 V			
▪ Frame size HX	315-450 kW at 400 V;	0.78	0.28	0.28
	315-400 kW at 500 V; 400-560 kW at 690 V			
▪ Frame size JX	560 kW at 400 V;	1.48	0.55	0.55
	500-560 kW at 500 V; 710-800 kW at 690 V			

Cooling air requirement and cabinet opening sizes for SINAMICS chassis units

Partitioning

The devices must not be operated with an "air short-circuit", since this can damage the equipment or cause it to fail. The suction caused by the fan leads to underpressure at the ventilation openings in the cabinet doors. This depends on the strength of the air flow and the effective cross-section of the openings.

The air, which blows out of the top of the device, accumulates under the top cover / hood resulting in overpressure.

The pressure difference between the overpressure at the top of the cabinet and the underpressure at the bottom can create an internal air flow from top to bottom (air short-circuit). This can vary in strength depending on the cross-section of the doors and cover openings and the air flow of the fan.

Due to the flow of air within the cabinet, the fan of the device draws in pre-heated air. This causes a significant temperature rise in the components and the fan of the device does not function effectively.

These problems can be prevented only by partitioning the cabinet. Partitions must be installed in such a way that no air can flow along the outer sides on the top and the bottom of the devices. In particular, air must be prevented from flowing from the top (warm outlet air) to the bottom (cold cooling air). Suitable plates can be used as partitions, for example, which must reach up to the side panels or cabinet doors. A partition must be set up in such a way that the

General Engineering Information for SINAMICS

Engineering Information

outgoing air is not forced into the free space between cabinet frame. Partitions must be installed for all degrees of protection higher than IP20.

The cabinets adjacent to the converter cabinets must also be taken in account when partitions are installed.

Changing the power block on chassis power units

An installation fixture which facilitates replacement of the chassis power blocks is available as an option. It is designed to simplify mounting and dismounting of the blocks.

It serves as an installation aid which is placed in front of and secured to the module. The telescopic rails allow the withdrawable device to be adjusted according to the height at which the power blocks are installed. Once the mechanical and electrical connections have been removed, the power block can be removed from the module, whereby the power block is guided and supported by the guide rails on the withdrawable devices. The power block can then be lifted off the rail.



Installation device for chassis power blocks

■ Replacement of SIMOVERT P and SIMOVERT A converter ranges by SINAMICS

General

The converters of the SIMOVERT P and SIMOVERT A ranges that were in production up till about 1995 are reaching the end of their life cycle and the spare parts supply is becoming increasingly problematic. As a result, more and more of them are being replaced by the new SINAMICS converters.

However, the series 1LA6 and 1LA1 motors fed by the converters are often not replaced at the same time.

In contrast to the older range of converters, the SINAMICS converters are equipped with modern, fast-switching IGBTs in the motor-side inverter. The consequences for the older 1LA6 and 1LA1 motors driven by these new converters are

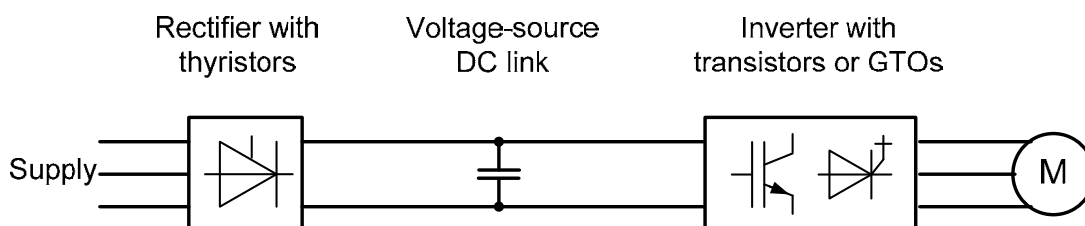
- higher voltage stress on the motor winding,
- higher bearing currents in the motor bearings.

When SINAMICS converters are combined with old motors of the 1LA6 or 1LA1 range, therefore, a number of points need to be considered if the motors are to be protected against damage in operation on SINAMICS units.

Replacement of converters in SIMOVERT P 6SE35/36 and 6SC36/37 ranges by SINAMICS

Properties of the SIMOVERT P converter

Like the new SINAMICS units, SINAMICS P converters are PWM converters with a voltage-source DC link. The motor-side inverter on models of type 6SE35/36 for line supply voltages of ≤ 500 V is equipped with transistors and of type 6SC36/37 for line supply voltages of 600 V to 690 V with GTOs (Gate Turn-Off Thyristors).



Drive with SIMOVERT P 6SE35/36 or 6SC36/37 voltage-source DC link converter

The voltage rate of rise and the pulse frequencies for SIMOVERT P converters are relatively low.

- Transistorized frequency converter 6SE35/36: $dv/dt = 1 \text{ kV}/\mu\text{s}$ to $3 \text{ kV}/\mu\text{s}$, Pulse frequency $f_p = 1 \text{ kHz}$
- GTO converter 6SC36/37: $dv/dt \approx 200 \text{ V}/\mu\text{s}$, Pulse frequency $f_p = 500 \text{ Hz}$

The voltage stress on the motor winding and the bearing currents in the motor bearings are therefore significantly lower in drives with a SIMOVERT P converter than in systems operating on a SINAMICS converter with IGBTs in the inverter.

Properties of 1LA6 and 1LA1 motors operating on SIMOVERT P converters

- The motors feature high-leakage rotor designs (special model for SIMOVERT P: With frame size 315L and higher on 1LA6 motors and generally on 1LA1 motors).
- The insulation system on 1LA6 motors is comparable to the standard insulation on modern motors, while the insulation system on 1LA1 motors is comparable to the special insulation on modern motors designed for converter-fed operation at 690 V (see chapter "Motors").
- 1LA6 motors have no insulated bearing at the non-drive end. Due to their bigger frame size, 1LA1 motors do have an insulated bearing at the non-drive end.

General Engineering Information for SINAMICS

Engineering Information

Replacement of SIMOVERT P converters by SINAMICS

As SIMOVERT P converters and SINAMICS converters are both designed as voltage-source, DC link converters and the matching motors feature relatively high-leakage models of rotor, it is generally easy to replace a SIMOVERT P with a SINAMICS unit. However, the following aspects need to be taken into account:

- SIMOVERT P converters are existing as a standard version for 1Q operation and as an NGP version for 4Q operation (line-side converter for rectifier/regenerative operation). This must be taken into account to ensure correct selection of the SINAMICS unit for 1Q or 4Q operation.
- For the output power range of 1LA1 motors typically parallel connections of converters are used. However, 1LA1 motors for operation on SIMOVERT P converters do not have electrically isolated winding systems and this must be taken into account in the selection of the appropriate parallel connections of SINAMICS converters. For further details, e.g. minimum cable lengths to the motor or maximum attainable output voltage without pulse-edge modulation, please refer to the section "Parallel connections of converters" of the chapter "Fundamental Principles and System Description".
- SIMOVERT P converters operate on lower pulse frequencies than the newer SINAMICS devices. When a SIMOVERT P unit is replaced by a SINAMICS, therefore, the stray losses in the motor and the motor noise caused by the converter supply are slightly lower.

It is also important to note the potential problems affecting the motors:

- Voltage stress on the motor winding
- Bearing currents in the motor bearings.

Solutions to counter these problems are available. For example, motor reactors or motor filters can be installed at the SINAMICS converter output, or the motor can be retrofitted with an insulated bearing in an approved service workshop.

1. Measures recommended when replacing a 6SE35/36 transistorized frequency converter for a line supply voltage of ≤ 500 V

1.1 Operation with 1LA6 motors:

- Use a motor reactor on the SINAMICS converter to reduce the voltage rate of rise dv/dt and retrofit an insulated bearing to the non-drive end of the motor ¹⁾
- or
- Use a dv/dt filter plus VPL on the SINAMICS converter, but do not modify the motor

1.2 Operation with 1LA1 motors:

- No measures required

2. Measures recommended when replacing a 6SC36/37 GTO converter for a line supply voltage of 600 V to 690 V

2.1 Operation with 1LA6 motors:

- Use a dv/dt filter plus VPL on the SINAMICS converter, but do not modify the motor

2.2 Operation with 1LA1 motors:

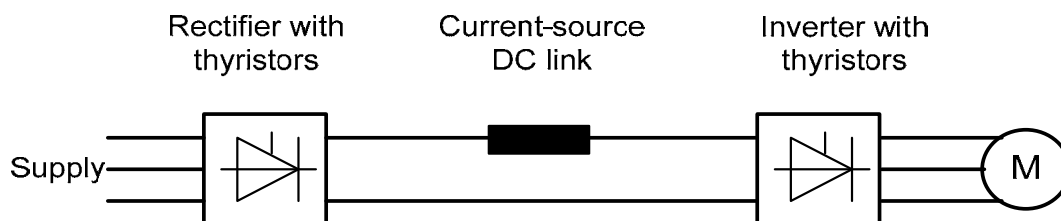
- No measures required

¹⁾ **Notice!** If the motor is retrofitted with an insulated non-drive end bearing and also has a speed encoder, the encoder must also be insulated or replaced by an encoder with insulated bearings.

Replacement of converters in SIMOVERT A 6SC23 range by SINAMICS

Properties of the SIMOVERT A converter

SIMOVERT A converters are current-source DC link converters and therefore capable of 4Q operation without modification or upgrading. Both the rectifier and the motor-side inverter are equipped with normal thyristors on 6SC23 devices.



Drive with SIMOVERT A 6SC23 current-source DC link converter

The voltage rate of rise at the inverter output is very significantly lower than on PWM converters with IGBTs. As a result, the voltage stress on the motor winding and the bearing currents in the motor bearings are very low.

Since line and motor currents have a very high harmonic content on drives with current-source DC link converters, high-power-output converters are usually operating as a 12-pulse configuration at both the line and the motor side. In this instance, the motor-side inverter consists of a parallel connection which supplies a 12-pulse motor with two separate windings mutually out of phase by 30 °el.

Properties of 1LA6 and 1LA1 motors operating on SIMOVERT A converters

- The motors feature low-leakage rotor designs (special model for SIMOVERT A: With frame size 315L and higher on 1LA6 motors and generally on 1LA1 motors).
- 1LA1 motors can be designed with a 6-pulse winding with a phase displacement of 0 °el., or a 12-pulse winding with a phase displacement of 30 °el.
- The insulation system on 1LA6 motors is comparable to the standard insulation on modern motors, while the insulation system on 1LA1 motors is comparable to the special insulation on modern motors designed for converter-fed operation at 690 V (see chapter "Motors").
- 1LA6 motors have no insulated bearing at the non-drive end. Due to their bigger frame size, 1LA1 motors do have an insulated bearing at the non-drive end.

Replacement of SIMOVERT A converters by SINAMICS

It is not always possible to replace SIMOVERT A current-source DC link converters with voltage-source DC link converters from the SINAMICS range. It is essential to analyze the existing drive constellation exactly for the following reasons:

- The special motor models for SIMOVERT A (frame size 315L and higher with 1LA6 series and 1LA1 series in general) are low-leakage, whereas PWM converters with a voltage-source DC link like SINAMICS require high-leakage motors. The current spikes in the motor increase significantly in low-leakage motors operating on SINAMICS converters. This carries the risk of tripping on over current in the event of dynamic peak loads. For this reason, a SIMOVERT A converter used to supply motor models specially designed for use with SIMOVERT A should be replaced by SINAMICS only for drive applications without substantial load peaks. However, if the drive motors are basic models of 1LA6 up to frame size 315M, the issue of current spikes in the motor should not present a problem.
- 1LA1 motors can be of 6-pulse or 12-pulse design. With the 12-pulse design, the winding systems are mutually out of phase by 30 °el.. This kind of 12-pulse motor can never be operated on a SINAMICS unit, even when the converter is connected in parallel, because motors for SINAMICS cannot have out-of-phase winding systems. For further details, please refer to the section "Parallel connections of converters", in the chapter "Fundamental Principles and System Description".

General Engineering Information for SINAMICS

Engineering Information

- SIMOVERT A converters are generally designed for 4Q operation, i.e. without modification or upgrading. When SINAMICS is chosen as a replacement converter, it is therefore necessary to clarify whether the unit is required to operate in regenerative mode for the application in question so that the correct unit for either 1Q or 4Q mode is selected.
- Due to their pulse width modulation technique, converters like SINAMICS generate higher noise levels in the motor than SIMOVERT A units. An increase in motor noise of about 5 dB(A) to 7 dB(A) must therefore be expected when a SIMOVERT A converter is replaced by a SINAMICS converter.

It is also important to note the potential problems affecting the motors:

- Voltage stress on the motor winding
- Bearing currents in the motor bearings.

Solutions to counter these problems are available. For example, motor reactors or motor filters can be installed at the SINAMICS converter output, or the motor can be retrofitted with an insulated bearing in an approved service workshop.

1. Measures recommended when replacing a 6SC23 SIMOVERT A converter for a line supply voltage of 500 V

1.1 Operation with 1LA6 motors:

- Use a motor reactor on the SINAMICS converter to reduce the voltage rate of rise dv/dt and retrofit an insulated bearing to the non-drive end of the motor ¹⁾
- or
- Use a dv/dt filter plus VPL on the SINAMICS converter, but do not modify the motor

1.2 Operation with 1LA1 motors with 6-pulse winding:

- No measures required

2. Measures recommended when replacing a 6SC23 SIMOVERT A converter for a line supply voltage of 690 V

2.1 Operation with 1LA6 motors:

- Use a dv/dt filter plus VPL on the SINAMICS converter, but do not modify the motor

2.2 Operation with 1LA1 motors with 6-pulse winding:

- No measures required

¹⁾ **Notice!** If the motor is retrofitted with an insulated non-drive end bearing and also has a speed encoder, the encoder must also be insulated or replaced by an encoder with insulated bearings.

Converter Chassis Units SINAMICS G130

General information

The SINAMICS G130 Chassis are AC/AC converters for medium to high-output single drives that can be combined very flexibly with the associated system components and integrated into customer-specific cabinets or directly into machines.

They are designed for applications with less stringent requirements in terms of control quality and feature a simple, 6 - pulse rectifier, i.e. they are not capable of regenerative operation.

SINAMICS G130 are available for the line supply voltages and outputs listed in the table below:

Line supply voltage	Converter output
380 V – 480 V 3AC	110 kW – 560 kW at 400 V
500 V – 600 V 3AC	110 kW – 560 kW at 500 V
660 V – 690 V 3AC	75 kW – 800 kW at 690 V

Line supply voltages and output power ranges of SINAMICS G130 chassis units

SINAMICS G130 Chassis comprise two independent components:

- Power Module
- Control Unit

The Power Module includes the following components:

- 6-pulse rectifier for 1Q operation
- DC link capacitors
- motor-side IGBT inverter
- gating and monitoring electronics
- DC link precharging circuit
- fan with appropriate voltage supply

Power Module and Control Unit can be assembled close together or mounted at separate locations. At Power Modules with lower power ratings, the Control Unit can be mounted externally on the left side-panel and at Power Modules with higher power ratings, installation inside the Power Module itself is possible.

The Power Modules are supplied with a DRIVE-CLiQ cable for communication with the Control Unit and a cable for the 24 V supply to the Control Unit. With these, the installation of the Control Unit on either the side of the Power Module or within it is possible. If Power Module and Control Unit are at separate locations, the cables should be ordered in the appropriate lengths.

The Control Unit is available in the "CU Kit" which is a simpler ordering option. This kit comprises the Control Unit, the Compact Flash Card and a product documentation CD.

Predefined interfaces – either via the terminal block or PROFIBUS – make it much easier to commission and control the drive. The interfaces of the CU320 Control Unit can be supplemented with additional modules, such as the TB30 Terminal Board or the TM31 Terminal Module.

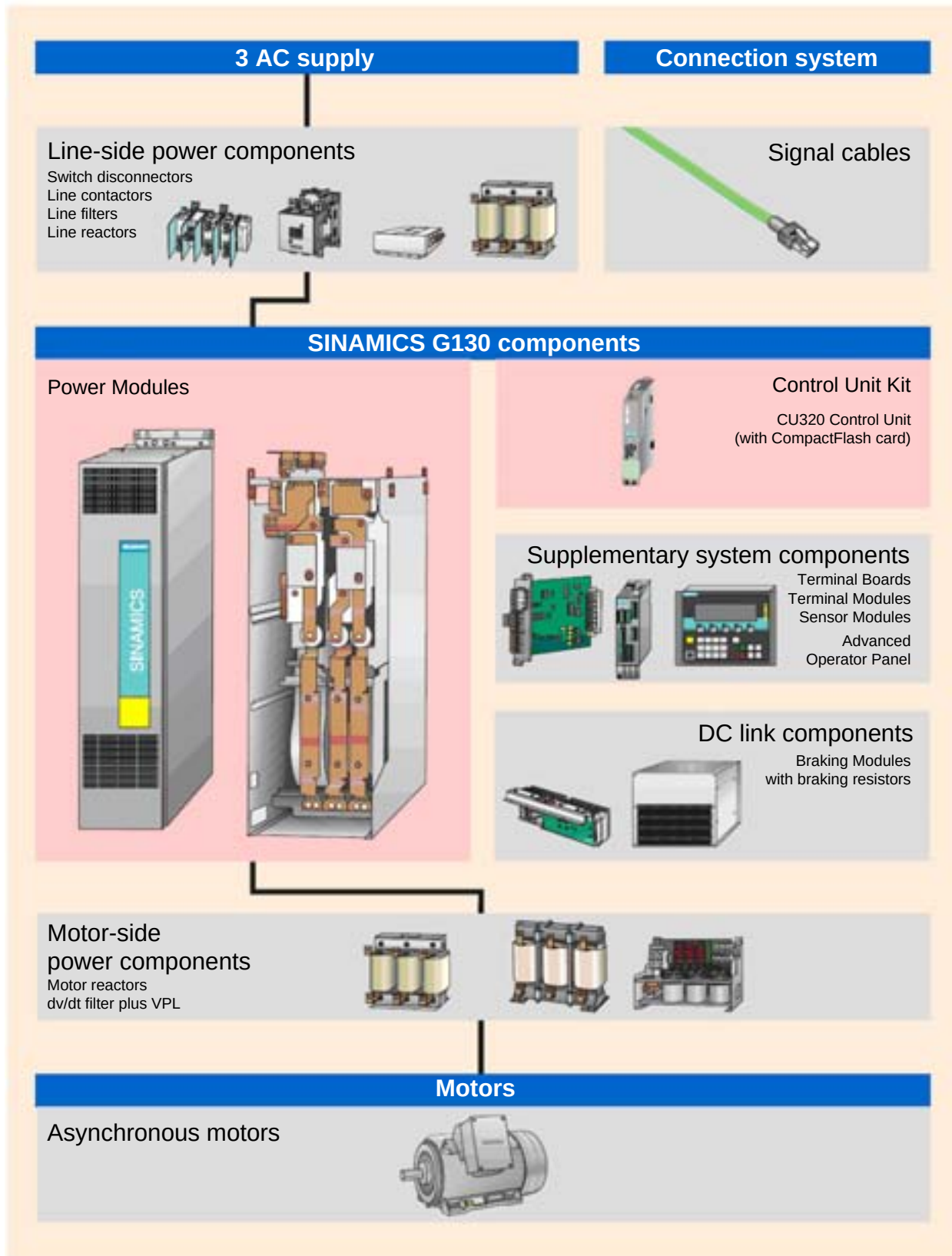
It is advisable to use the internal auxiliary power supply of the Power Module as the 24 V source for the Control Unit.

If further customer interfaces are needed to communicate with the drive, it might be necessary to provide an external 24 V supply.

The drive system can be tailored optimally to meet the relevant requirements with numerous additional components such as line fuses, line reactors, braking units, motor reactors and motor filters.

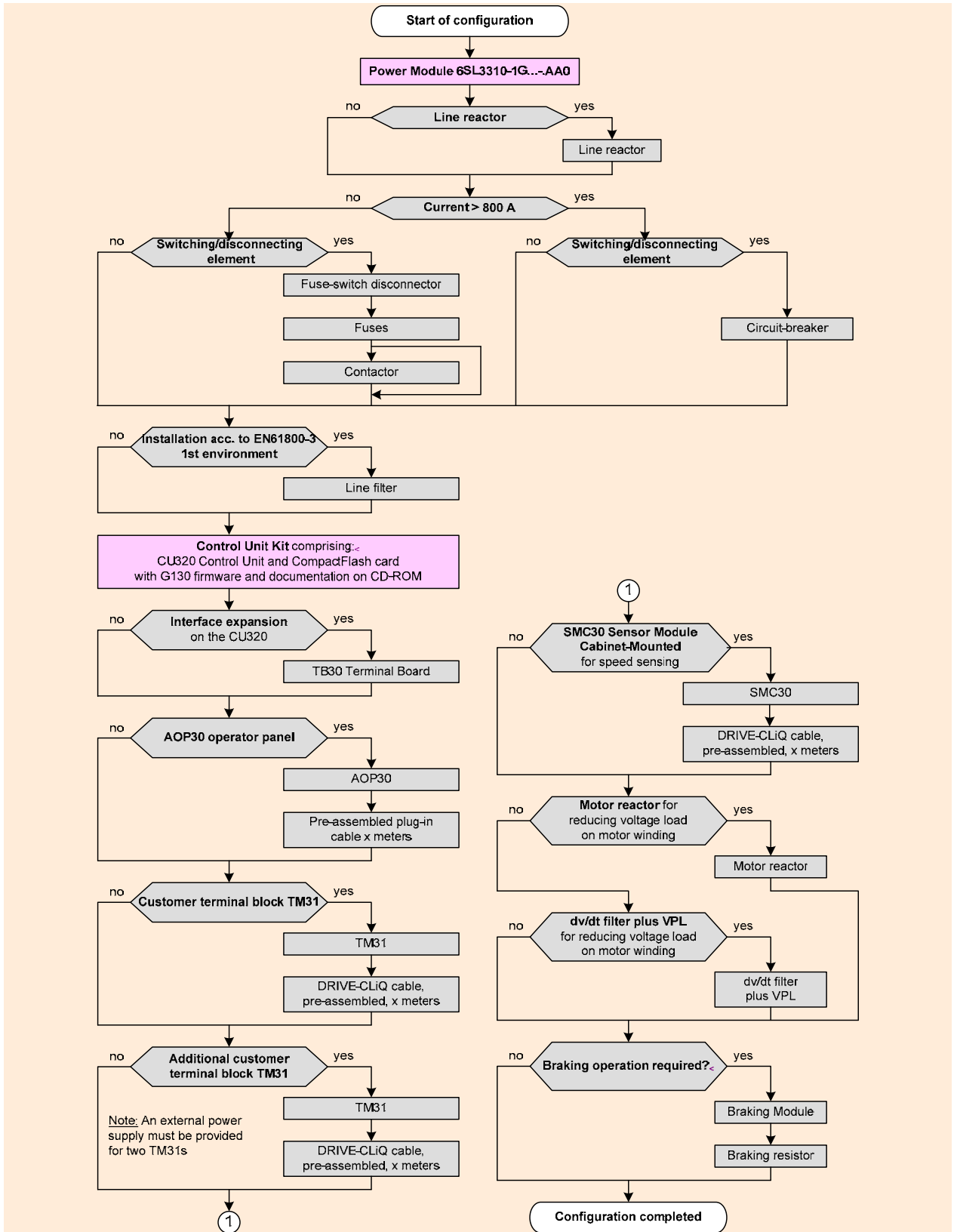
SINAMICS G130

Engineering Information



System components for SINAMICS G130 chassis units

Configuring sequence for a drive system with SINAMICS G130 chassis units



Flowchart for selecting the components of a drive system with SINAMICS G130 chassis units

Rated data of converters for drives with low demands on control performance

Main applications

SINAMICS G130 Chassis are primarily intended for applications which require a lower standard of dynamic response and control accuracy and are usually operated in sensorless vector control mode.

They are basically not capable of regenerative operation. For applications where the drive operates in regenerative mode for brief periods, it is possible either to activate the $V_{dc\ max}$ controller or install braking units.

Where the application requires a higher standard of control, i.e. where the control accuracy is more important than the dynamic response, SINAMICS G130 Chassis can be equipped with an SMC30 speed encoder interface which enables them to operate with TTL/HTL incremental encoders.

Line supply voltages

SINAMICS G130 Chassis are available for the following line supply voltages:

- 380 V – 480 V 3AC
- 500 V – 600 V 3AC
- 660 V – 690 V 3AC

The permissible voltage tolerance is $\pm 10\%$ continuously and -15% for brief periods ($< 1\ min$). In the case of line undervoltages within the specified tolerances, the available output power will drop accordingly unless additional power reserves are available to increase the output current.

Usable output currents

The output currents specified in the selection and ordering data can be utilized over the entire frequency or speed setting range, i.e. even at very low output frequencies down to zero speed.

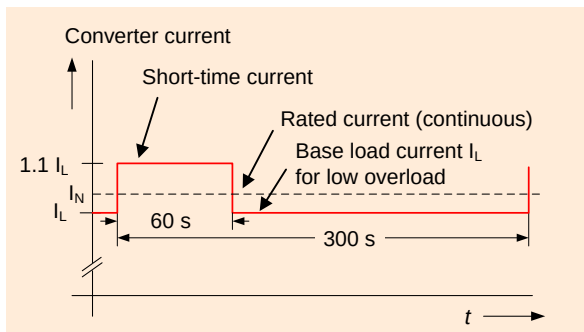
The specified rated output current is the maximum continuous thermally permissible output current. The units have no additional overload capacity when operating at this current.

Overload capability, load duty cycle definitions

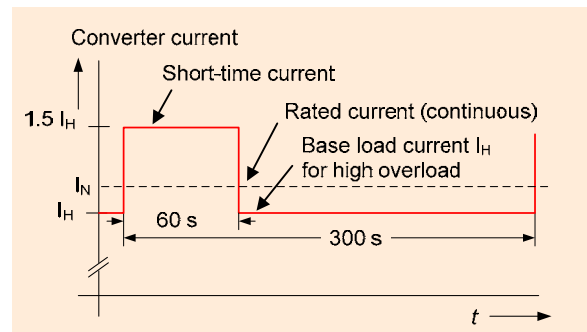
When a drive is required to overcome breakaway torques or is subjected to high surge loads, its configuration must take these factors into account. In such instances, it must be operated on the basis of a base load current which is lower than the rated output current. Sufficient overload reserves are available for this purpose. The load duty cycles for operation with low and high overloads are defined below.

- The base load current I_L for low overload is based on a load duty cycle of 110% for 60 s or 150% for 10 s.
- The base load current I_H for a high overload is based on a load duty cycle of 150% for 60 s or 160% for 10 s.

These overload values apply on condition that the converter is operated at its base load current before and after the period of overload on the basis of a load duty cycle duration of 300 s in each case.



Load duty cycle definition for low overload



Load duty cycle definition for high overload

Overload and overtemperature protection

SINAMICS G130 Chassis are equipped with effective overload and overtemperature protection mechanisms which protect them against thermal overloading.

Sensors at various locations in the converter (inlet air, control electronics, rectifier heatsink, inverter heatsink) measure the relevant temperatures and feed them into the so-called "Thermal model". This continuously calculates the temperature at critical positions on power components. In this way the converter is effectively protected against thermal overloads, whether they are caused by excessive current or high ambient temperatures. The so-called "I²t" monitoring circuit checks the level of utilization of the motor-side inverter. If the level of inverter utilization or the temperature at any point in the converter exceeds the upper tolerance limit, the converter responds by initiating an overload reaction parameterized in the firmware. It is possible to select whether the converter should react to overload by reducing the output frequency and output current or the pulse frequency. Immediate shutdown can also be parameterized.

Maximum output frequencies

With SINAMICS G130 chassis units, the maximum output frequency is limited to 160 Hz resp. 100 Hz due to the pre-set pulse frequency of $f_{Puls} = 2.00 \text{ kHz}$ resp. $f_{Puls} = 1.25 \text{ kHz}$. Higher output frequencies can only be reached by increasing the pulse frequency. Due to the fact that with higher pulse frequency, switching losses in the IGBT inverters on the motor side increase, the output power must be reduced accordingly.

Permissible output current and maximum output frequency as a function of pulse frequency

Output power at 400 V 500 V / 690 V	Rated output current at pulse frequency of		Current derating-factor at pulse frequency of	
	2 kHz	1,25 kHz	4 kHz	2,5 kHz
380 V – 480 V 3AC				
110 kW	210 A	-	82 %	-
132 kW	260 A	-	83 %	-
160 kW	310 A	-	88 %	-
200 kW	380 A	-	87 %	-
250 kW	490 A	-	78 %	-
315 kW	-	605 A	-	72 %
400 kW	-	745 A	-	72 %
450 kW	-	840 A	-	79 %
560 kW	-	985 A	-	87 %
500 V – 600 V 3AC				
110 kW	-	175 A	-	87 %
132 kW	-	215 A	-	87 %
160 kW	-	260 A	-	88 %
200 kW	-	330 A	-	82 %
250 kW	-	410 A	-	82 %
315 kW	-	465 A	-	87 %
400 kW	-	575 A	-	85 %
500 kW	-	735 A	-	79 %
560 kW	-	810 A	-	72 %
660 V – 690 V 3AC				
75 kW	-	85 A	-	89 %
90 kW	-	100 A	-	88 %
110 kW	-	120 A	-	88 %
132 kW	-	150 A	-	84 %
160 kW	-	175 A	-	87 %
200 kW	-	215 A	-	87 %
250 kW	-	260 A	-	88 %
315 kW	-	330 A	-	82 %
400 kW	-	410 A	-	82 %
450 kW	-	465 A	-	87 %
560 kW	-	575 A	-	85 %
710 kW	-	735 A	-	79 %
800 kW	-	810 A	-	72 %

SINAMICS G130: Permissible output current as a function of pulse frequency

SINAMICS G130

Engineering Information

Pulse frequency	Maximum attainable output frequency
1.25 kHz	100 Hz
2.00 kHz	160 Hz
2.50 kHz	200 Hz
≥ 4.00 kHz	300 Hz

Maximum attainable output frequency as a function of pulse frequency

Current derating as a function of installation altitude/ambient temperature

If the SINAMICS G130 converters are operated at an installation altitude of >2000 m above sea level, the maximum permissible output current can be calculated using the following tables. The specified values already include a permitted correction between installation altitude and ambient temperature (incoming air temperature at the inlet to the Power Module).

Installation altitude above sea level m	Current derating at an ambient temperature (inlet air temperature) of						
	20 °C	25 °C	30 °C	35 °C	40 °C	45 °C	50 °C
0 ... 2000	100 %					95.0 %	87.0 %
... 2500						96.3 %	91.4 %
... 3000	96.7 %			96.2 %	92.5 %	87.9 %	80.5 %
... 3500				92.3 %	88.8 %	84.3 %	77.3 %
... 4000	97.8 %	92.7 %	88.4 %	85.0 %	80.8 %	74.0 %	

Current derating as a function of the ambient temperature (inlet air temperature) and installation altitude

To obtain these values, the air flow rate stipulated in the technical data tables must be provided. Particular attention must be paid to ensuring that no thermal short circuits occur either outside or inside the cabinet. The top of the cabinet must be designed such that heated outlet air can exit.

Voltage derating as a function of installation altitude

In addition to current derating, voltage derating as stipulated in the table below is applicable at installation altitudes of > 2000 m above sea level.

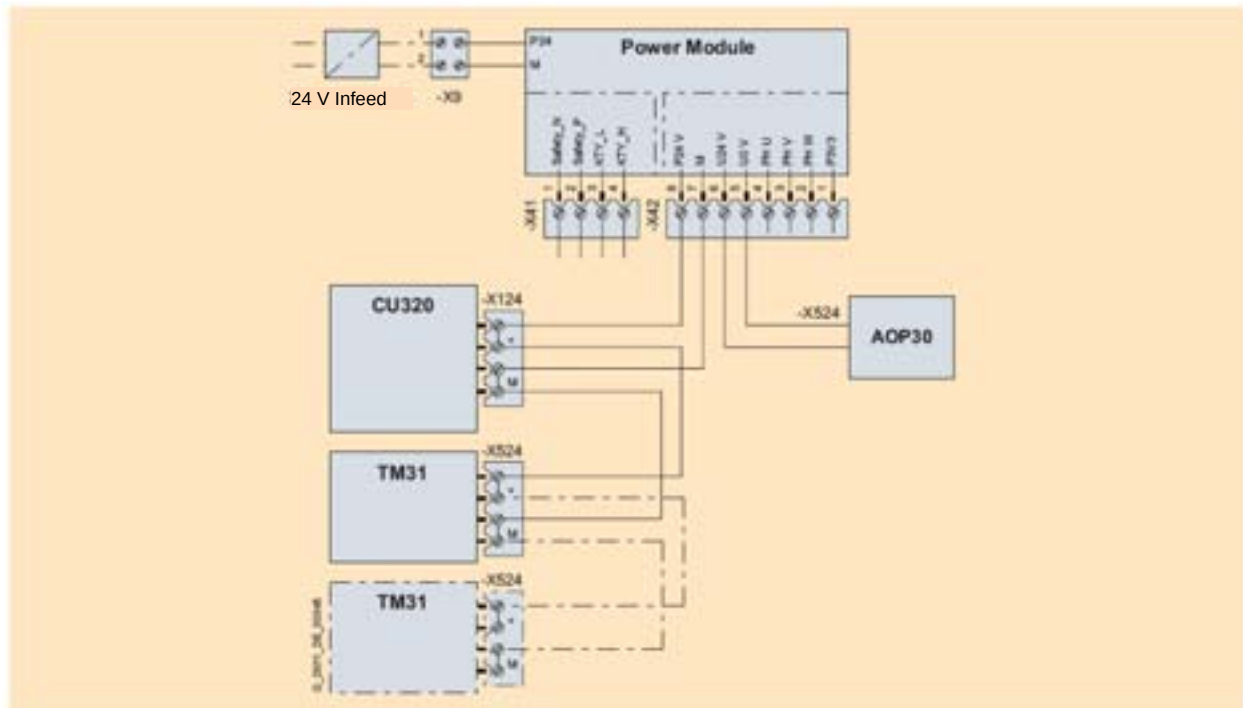
Installation altitude above sea level m	voltage derating at a rated input voltage of												
	380 V	400 V	420 V	440 V	460 V	480 V	500 V	525 V	550 V	575 V	600 V	660 V	690 V
0 ... 2000	100 %						100 %					100 %	
... 2250												96 %	
... 2500	98 %		94 %										
... 2750	98 %		94 %	90 %									
... 3000	95 %		91 %	88 %									
... 3250	97 %		93 %	89 %	85 %	98 %		89 %	85 %				
... 3500	98 %	93 %	89 %	85 %	82 %	98 %		94 %	85 %	82 %			
... 3750	95 %	91 %	87 %	83 %	79 %	98 %		95 %	91 %	-	-		
... 4000	96 %	92 %	87 %	83 %	80 %	76 %	95 %		91 %	87 %	-	-	

Voltage derating as a function of installation altitude

Incorporating different loads into the 24 V supply

The SINAMICS G130 Chassis consists of the Power Module and a CU320 Control Unit which requires a 24 V supply. In addition to the Control Unit, it may also be necessary to supply a further one or two TM31 Terminal Modules which are installed to expand the number of digital and analog inputs/outputs and/or an AOP30 operator panel.

The following diagram shows how different loads are incorporated into the 24 V supply of the Power Module.



Incorporating different loads into the 24 V supply of the Power Module

The internal auxiliary power supply of the Power Module is provided by the DC link of the power unit and supplies the following maximum currents at its output terminals when no external 24 V supply is connected at terminal X9:

Terminal block	Max. output current	Comment
-X42 Pin 5 and 6	350 mA	Sufficient to supply the AOP30 with < 200 mA
-X42 Pin 7 and 8	2000 mA	Current demand of the CU320 Control Unit is approximately 800 mA, ignoring the assignment of the slot and the Control Unit's digital outputs. Current demand of the TM31 Terminal Module is approximately 500 mA, ignoring the digital outputs.

Maximum output currents of the internal auxiliary supply of the Power Module

If the connected loads require more power than the table values, an external 24 V supply must be connected to terminal X9 (e.g. SITOP Power).

An external 24 V supply will also be required if the internal auxiliary power supply needs to remain active even when the power unit is disconnected from the mains so that auxiliary power can no longer be provided by the DC link. This applies, for example, if a main contactor is used and the communication link to the converter must remain intact even when the main contactor is open.

■ Factory settings (defaults) of customer interface on SINAMICS G130

The following factory settings are provided to simplify configuring of the customer interface and commissioning. The interfaces can also be assigned as required at any time.

1. The converter is controlled via the PROFIBUS interface which is integrated as standard. The digital inputs and outputs on the Control Unit are used to incorporate external alarm and/or error messages and control signals.

Terminal block on CU320		
-X122	Factory setting	Comment
DI0	Not assigned	
DI1	Not assigned	
DI2	Not assigned	
DI3	Acknowledge fault	
M1		
M1		
<u>DI/DO8</u>	Inverter enable (Run)	
<u>DI/DO9</u>	No fault	
M (GND)		
<u>DI/DO10</u>	P24	Factory-set as output
<u>DI/DO11</u>	External alarm ¹⁾	Low active
M (GND)		
-X132		
DI4	OFF 2 ¹⁾	
DI5	OFF 3 ¹⁾	Ramp-down along quick-stop ramp, only of relevance in conjunction with the Braking Module
DI6	External fault ¹⁾	
DI7	Not assigned	
M (GND)		
<u>DI/DO12</u>	Error message acknowledgement, Braking Module	Output is used (factory-set) in conjunction with the Braking Module
<u>DI/DO13</u>	P24	Factory-set as output
M (GND)		
<u>DI/DO14</u>	P24	Factory-set as output
<u>DI/DO15</u>	P24	Factory-set as output
M (GND)		

The factory settings of the bidirectional inputs/outputs are underscored.

¹⁾ A jumper should be inserted here if these inputs are not used.

2. The converter is controlled exclusively via the standard digital inputs/outputs on the Control Unit.

Terminal block on CU320		
-X122	Factory setting	Comment
DI0	ON/OFF 1	
DI1	Increase setpoint/fixed setpoint 0	Parameters can be set in the firmware to determine whether operation is via motorized digital potentiometer or fixed setpoint.
DI2	Decrease setpoint/fixed setpoint 1	
DI3	Acknowledge fault	
M1		
M1		
<u>DI/DO8</u>	Inverter enable (Run)	
<u>DI/DO9</u>	No fault	
M (GND)		
<u>DI/DO10</u>	P24	Factory-set as output
<u>DI/DO11</u>	External alarm ¹⁾	Low active
M (GND)		
-X132		
DI4	OFF 2 ¹⁾	Immediate pulse disable, motor coasts to standstill
DI5	OFF 3 ¹⁾	Ramp-down along quick-stop ramp, only of relevance in conjunction with the Braking Module
DI6	External fault 1 ¹⁾	
DI7	Not assigned	
M (GND)		
<u>DI/DO12</u>	Error message acknowledgement, Braking Module	Output is used (reserved) in conjunction with the Braking Module
<u>DI/DO13</u>	P24	Factory-set as output
M (GND)		
<u>DI/DO14</u>	P24	Factory-set as output
<u>DI/DO15</u>	P24	Factory-set as output
M (GND)		

The factory settings of the bidirectional inputs/outputs are underscored.

¹⁾ A jumper must be inserted here if these inputs are not used

3. The converter is controlled via the PROFIBUS interface which is integrated as standard. The digital inputs and outputs on the Control Unit as well as the optional customer interface TM31 are used to incorporate external alarm and/or error messages and control signals.

Terminal block on CU320		
-X122	Factory setting	Comment
DI0	Not assigned	
DI1	Not assigned	
DI2	Not assigned	
DI3	Not assigned	
M1		
M1		
<u>DI/DO8</u>	Not assigned	Factory-set as output
<u>DI/DO9</u>	Not assigned	Factory-set as output
M (GND)		
<u>DI/DO10</u>	Not assigned	Factory-set as output
<u>DI/DO11</u>	Not assigned	Factory-set as output
M (GND)		
-X132		
DI4	Not assigned	
DI5	Not assigned	
DI6	Not assigned	
DI7	Not assigned	
M (GND)		
<u>DI/DO12</u>	Error message acknowledgement, Braking Module	Output is used (reserved) in conjunction with the Braking Module
<u>DI/DO13</u>	Not assigned	Factory-set as output
M (GND)		
<u>DI/DO14</u>	Not assigned	Factory-set as output
<u>DI/DO15</u>	Not assigned	Factory-set as output
M (GND)		

The factory settings of the bidirectional inputs/outputs are underscored.

Terminal block on TM31		
	Factory setting	Comment
-X520	Optocoupler inputs connected to common potential	
DI0	Not assigned	
DI1	Not assigned	
DI2	Not assigned	
DI3	Acknowledge fault	
-X530	Optocoupler inputs connected to common potential	
DI4	OFF 2 ¹⁾	Immediate pulse disable, motor coasts to standstill
DI5	OFF 3 ¹⁾	Ramp-down along quick-stop ramp, only of relevance in conjunction with the Braking Module
DI6	External fault ¹⁾	
DI7	Not assigned	

¹⁾ A jumper must be inserted here if these inputs are not used

Terminal block on TM31		
	Factory setting	Comment
-X541	Bidirectional inputs/outputs	
<u>DI/DO8</u>	Message: Ready to start	
<u>DI/DO9</u>	Not assigned	Factory-set as input
<u>DI/DO10</u>	Not assigned	Factory-set as input
<u>DI/DO11</u>	External alarm ¹⁾	Factory-set as input
-X542	Relay outputs (changeover contact)	
DO0	Inverter enable (Run)	
DO1	Checkback signal No converter fault	
-X521	Analog inputs, differential	
AI0+	Not assigned	
AI0-		
AI1+	Not assigned	
AI1-		
-X522	Analog outputs	
AO 0V+		The factory setting for the outputs is 0 to 10 V.
AO 0V-	Analog output, actual speed value	
AO 0C+		
AO 1V+		The factory setting for the outputs is 0 to 10 V.
AO 1V-	Analog output, actual motor current value	
AO 1C+		
-X522	Thermistor protection	
+Temp		Input for KTY84 temperature sensor or PTC thermistor
-Temp		

The factory settings of the bidirectional inputs/outputs are underscored.

4. The converter is controlled exclusively via the digital inputs/outputs or analog inputs/outputs on the optional TM31 customer interface.

Terminal block on CU320		
-X122	Factory setting	Comment
DI0	Not assigned	
DI1	Not assigned	
DI2	Not assigned	
DI3	Not assigned	
M1		
M1		
DI/DO8	Not assigned	Factory-set as output
DI/DO9	Not assigned	Factory-set as output
M (GND)		
DI/DO10	Not assigned	Factory-set as output
DI/DO11	Not assigned	Factory-set as output
M (GND)		
-X132		
DI4	Not assigned	
DI5	Not assigned	
DI6	Not assigned	
DI7	Not assigned	
M (GND)		
DI/DO12	Error message acknowledgement, Braking Module	Output is used (reserved) in conjunction with the Braking Module
DI/DO13	Not assigned	Factory-set as output
M (GND)		
DI/DO14	Not assigned	Factory-set as output
DI/DO15	Not assigned	Factory-set as output
M (GND)		

The factory settings of the bidirectional inputs/outputs are underscored.

Terminal block on TM31		
	Factory setting	Comment
-X520	Optocoupler inputs connected to common potential	
DI0	ON/OFF 1	
DI1	Increase setpoint/fixed setpoint 0	Parameters can be set in the firmware to determine whether operation is via motorized digital potentiometer or fixed setpoint
DI2	Decrease setpoint/fixed setpoint 1	
DI3	Acknowledge fault	
-X530	Optocoupler inputs connected to common potential	
DI4	OFF 2 ¹⁾	Immediate pulse disable, motor coasts to standstill
DI5	OFF 3 ¹⁾	Ramp-down along quick-stop ramp, only of relevance in conjunction with the Braking Module
DI6	External fault ¹⁾	
DI7		
-X541	Bidirectional inputs/outputs	
DI/DO8	Message: Ready to start	
DI/DO9	Not assigned	Factory-set as input

¹⁾ A jumper must be inserted here if these inputs are not used

Terminal block on TM31		
	Factory setting	Comment
<u>DI/DO10</u>	Not assigned	Factory-set as input
<u>DI/DO11</u>	External alarm ¹⁾	Factory-set as input
-X542	Relay outputs (changeover contact)	
DO 0	Inverter enable (Run)	
DO 1	Checkback signal No converter fault	
-X521	Analog inputs, differential	
<u>AI0+</u>	Analog input for setting speed setpoint	The factory setting for the inputs is 10 V.
<u>AI0-</u>		
<u>AI1+</u>	Analog input reserved	The factory setting for the inputs is 10 V.
<u>AI1-</u>		
-X522	Analog outputs	
<u>AO 0V+</u>		The factory setting for the outputs is 0 to 10 V.
<u>AO 0V-</u>	Analog output, actual speed value	
<u>AO 0C+</u>		
<u>AO 1V+</u>		The factory setting for the outputs is 0 to 10 V.
<u>AO 1V-</u>	Analog output, actual motor current value	
<u>AO 1C+</u>		
-X522	Thermistor protection	
+Temp		Input for KTY84 temperature sensor or PTC thermistor
-Temp		

The factory settings of the bidirectional inputs/outputs are underscored.

- The converter is controlled and operated exclusively via the optional AOP30.
The digital inputs and outputs on the CU320 or TM31 are not used for this purpose.

Line-side components

Line fuses

The combined fuses (3NE1., class gS) for line and semiconductor protection are recommended to protect the converter. These fuses are specially adapted to provide protection for the input rectifier's semiconductors.

- Superfast
- Adapted to the overload characteristic of the semiconductor
- Low arc voltage
- Improved current limiting (lower let-through values)

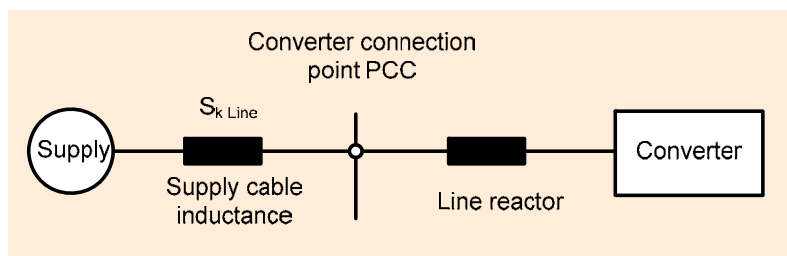
Line reactors

A line reactor must be installed whenever

- the converters are connected to a line supply system with high short-circuit power, i.e. with low line supply inductance
- more than one converter is connected to the same point of common coupling (PCC)
- the converters are equipped with line filters for RFI suppression
- the converters are equipped with Line Harmonics Filter for reducing harmonic effects on the supply.

The line reactor smoothes the current drawn by the converter and thus reduces harmonic components in the line current and thus the thermal load on the rectifier and DC link capacitors of the converter. The harmonic effects on the supply are also reduced, i.e. both the harmonic currents and harmonic voltages in the power supply are attenuated.

Line reactors can be dispensed with only if the supply cable inductance is sufficiently high or the relative short-circuit power RSC^{*)} correspondingly low.



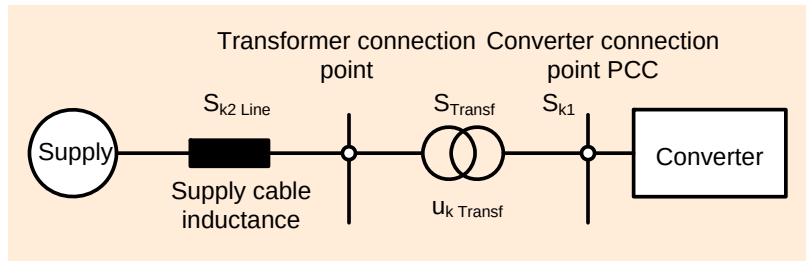
The following values apply to SINAMICS G130 Chassis:

Converter output SINAMICS G130	Line reactor can be omitted with an RSC of	Line reactor is required with an RSC of
< 200 kW	≤ 43	> 43
200 kW - 500 kW	≤ 33	> 33
> 500 kW	≤ 20	> 20

As the configuration of the supply system for operating individual converters is often not known in practice, i.e. the short-circuit power at the PCC of the converter is not certain, it is advisable to connect a line reactor on the line side of the converter in cases of doubt.

^{*)} RSC=Relative Short-Circuit power:
Ratio of the short-circuit power $S_{k \text{ Line}}$ at the PCC to the fundamental frequency apparent power $S_{\text{Converter}}$ of the connected converter).

A line reactor can only be dispensed with when the RSC value for relative short-circuit power is less than stated in the above table. This applies, for example, if the converter is connected to the supply via a transformer with specially adapted rating and none of the other reasons stated above for using a line reactor is valid.



In this case, the short-circuit power S_{k1} at the PCC of the converter is approximately

$$S_{k1} = \frac{S_{Transf}}{u_{kTransf} + \frac{S_{Transf}}{S_{k2Line}}}$$

Abbreviation	Meaning
S_{Transf}	Rated power of the transformer
$u_{kTransf}$	Relative short-circuit power of the transformer
S_{k2Line}	Short-circuit power of the higher-level voltage

Line reactors must always be provided if more than one converter is connected to the same point of common coupling. In this case, the reactors perform two functions, i.e. they smooth the line current and decouple the rectifiers at the line side. This decoupling is essential in ensuring fault-free operation of the rectifier circuit. For this reason, each converter must be provided with its own line reactor, i.e. it is not permissible for more than one converter to be connected to the same line reactor.

A line reactor must also be installed for any converter that is to be equipped with a line filter for RFI suppression or with a Line Harmonics Filter (LHF) for reducing harmonic effects on the supply. This is because filters of this type cannot be 100% effective without a line reactor.

Line filters

SINAMICS G130 Chassis are equipped as standard with an integrated line filter for limiting radio frequency interference emissions in accordance with EMC product standard EN 61800-3, category C3 (applications in industrial areas or in the "second" environment).

An optional line filter is also available which renders the units suitable for category C2 applications in accordance with product standard EN 61800-3 (installation in residential areas or in the "first" environment).

To ensure that the converters comply with the tolerance limits defined for the above categories, it is absolutely essential that the relevant installation guidelines are followed. The efficiency of the filters as regards grounding and shielding can be guaranteed only if the drive is properly installed.

Line filters can be used only on converters that are connected to grounded supply systems (TN or TT). On converters connected to non-grounded systems (IT supply systems), the standard integrated line filter must be isolated from PE potential. This can be done simply by removing a metal clip on the filter when the drive is commissioned (see operating instructions). It is not permissible to use the optional line filter in non-grounded systems to achieve compliance with the tolerance limits defined for category C2 by EMC product standard EN 61800-3.

For further details about line filters, please refer to the section "Line filters" of the chapter "Fundamental Principles and System Description".

Components at the DC link

Braking units

Braking units are used when regenerative energy occurs occasionally and briefly, for example when the brake is applied to the drive (emergency stop). Braking units comprise a Braking Module and a braking resistor, which must be fitted externally.

Braking units with a continuous braking power of 25 kW (P_{20} power 100 kW) or 50 kW (P_{20} power 200 kW) are available for SINAMICS G130 chassis units. Higher braking powers can be obtained for larger converters by connecting braking units in parallel (on request).

If the braking units are used at ambient temperatures $> 40^{\circ}\text{C}$ and installation altitudes $> 2000\text{ m}$, the derating factors for current and output power listed for the Power Units also apply here.

A thermal contact, which can be integrated into the converter's alarm and shutdown sequence, is installed in the braking resistor for monitoring.

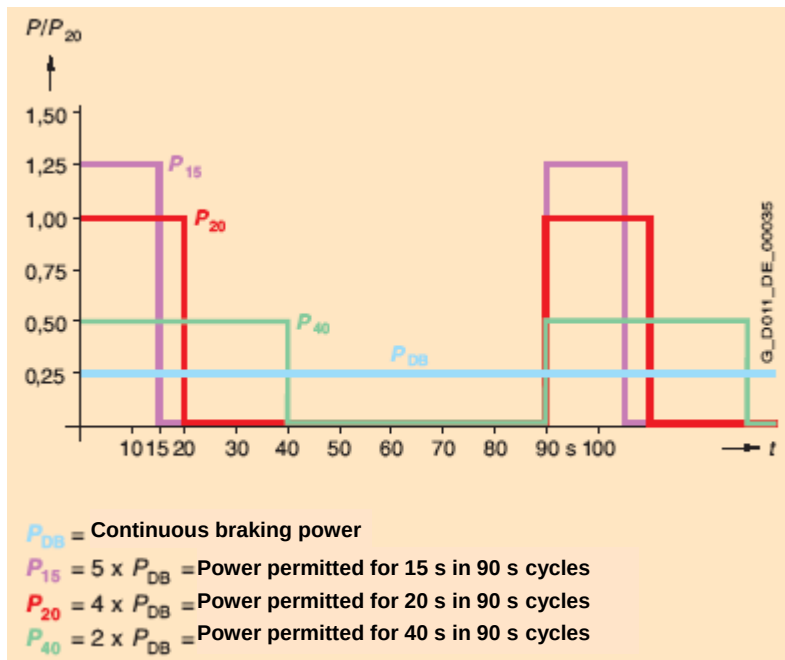
SINAMICS G130 chassis units	Matching Braking Modules					Max. current
	Rated power (continuous braking power) P_{DB}	Power P_{40}	Power P_{20}	Peak power P_{15}	Braking resistor R_B	
380 V – 480 V 3AC						
110 kW - 132 kW	25 kW	50 kW	100 kW	125 kW	4.4 Ω ±7.5 %	189 A
160 kW - 560 kW	50 kW	100 kW	200 kW	250 kW	2.2 Ω ±7.5 %	378 A
500 V – 600 V 3AC						
110 kW - 560 kW	50 kW	100 kW	200 kW	250 kW	3.4 Ω ±7.5 %	306 A
660 V – 690 V 3AC						
75 kW - 132 kW	25 kW	50 kW	100 kW	125 kW	9.8 Ω ±7.5 %	127 A
160 kW - 800 kW	50 kW	100 kW	200 kW	250 kW	4.9 Ω ±7.5 %	255 A

Braking Modules and braking resistors available for SINAMICS G130 chassis units

How to calculate the required braking units and braking resistors

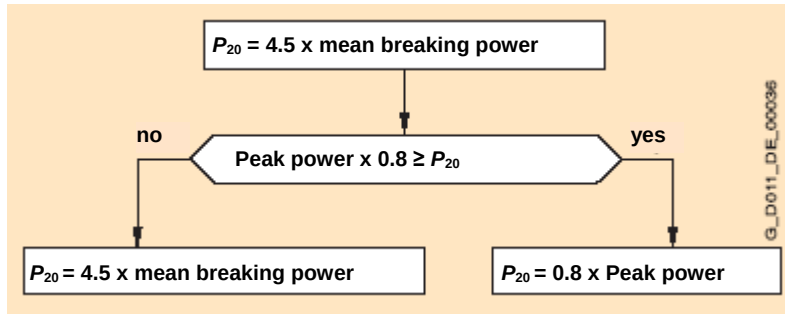
- For periodic load duty cycles with a cycle duration of $\leq 90\text{ s}$, the average value of the braking power within this load duty cycle needs to be calculated. The respective period is used as the time base.
- For periodic load duty cycles with a cycle duration of $> 90\text{ s}$ or for sporadic braking operations, a time interval of 90 s in which the highest average value occurs must be selected. The 90 s period must be applied as the time base.

Apart from the average braking power, the required peak braking power must also be taken into account when braking units are selected (Braking Module and braking resistors). The diagrams and tables below illustrate the correlations.



Load duty cycle diagram and power definitions

Calculation of the P_{20} power



The ON/OFF states of the Braking Module are controlled by a 2-point controller. To reduce the voltage stress on the motor and converter, the response threshold at which the braking unit is activated and the DC link voltage generated during braking can be reduced. For example, the DC link voltage for the converters in the voltage range 380 V to 480 V can be reduced from 774 V to 673 V. This also reduces the attainable peak power. In this case, a factor of 1.06 should be applied instead of 0.8.

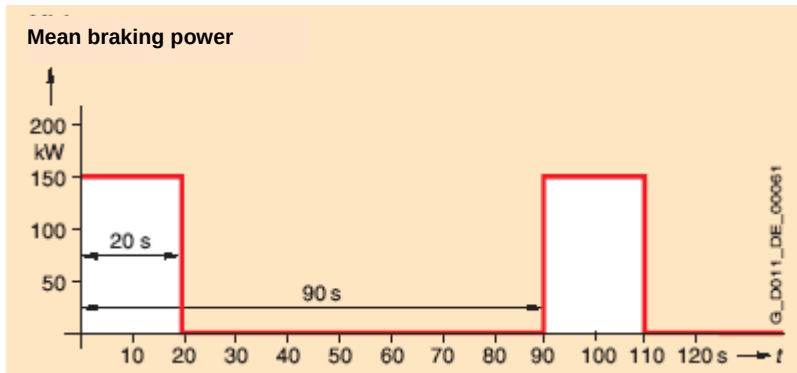
The response thresholds are shown in the following table.

Line supply voltage	Braking unit response threshold
380 V – 480 V 3AC	774 V or 673 V
500 V – 600 V 3AC	967 V or 841 V
660 V – 690 V 3AC	1158 V or 1070 V

Response thresholds of braking units

Example:

In the following example, we will calculate the rating of the Braking Module and braking resistor for a 450 kW Power Module.



The mean braking power is calculated as follows:

$$\text{Mean braking power} = 150 \text{ kW} \times 20 \text{ s} / 90 \text{ s} = 33.3 \text{ kW}$$

$$P_{20} = 4.5 \times 33.3 \text{ kW} = 150 \text{ kW}$$

$$\text{Peak power} = 0.8 \times 150 \text{ kW} = 120 \text{ kW}$$

Result:

The mean braking power is the determining factor in choosing the correct rating of Braking Module and braking resistor, i.e., a braking unit of $\geq 150 \text{ kW}$ must be provided.

The braking unit with 50 kW ($P_{20} = 200 \text{ kW}$) must be selected.

When the response threshold is reduced, the required braking power P_{20} is calculated as follows:

$$\text{Mean braking power} = 150 \text{ kW} \times 20 \text{ s} / 90 \text{ s} = 33.3 \text{ kW}$$

$$P_{20} = 4.5 \times 33.3 \text{ kW} = 150 \text{ kW}$$

$$\text{Peak power} = 1.06 \times 150 \text{ kW} = 159 \text{ kW}$$

Result:

The peak power requirement is the determining factor in choosing the correct rating of Braking Module and braking resistor, i.e., a braking unit of $\geq 159 \text{ kW}$ must be provided.

The braking unit with 50 kW ($P_{20} = 200 \text{ kW}$) must be selected.

■ Load-side components and cables

Motor reactor

The fast switching of the IGBTs in the inverter causes high voltage rate of rise dv/dt at the inverter output. If long motor cables are used, these voltage gradients increase the current load on the converter output due to capacitive charge/discharge currents. The length of cable which may be connected is therefore limited.

The high voltage rate of rise and the resulting voltage spikes at the motor terminals, increase the voltage stress at the motor winding in comparison to direct line operation. In conjunction with the connected cable capacitances, the motor reactors reduce the capacitive charge/discharge currents in the motor cables and, as a function of the motor cable length, limit the voltage rate of rise dv/dt and the voltage spikes V_{PP} at the motor terminals.

For a more detailed description, please refer to the section "Motor reactors" of the chapter "Fundamental Principles and System Description".

dv/dt filter plus VPL

The dv/dt filter plus VPL consists of two components, the dv/dt reactor and the voltage limiting network (Voltage Peak Limiter), which limits voltage spikes and returns the energy back to the DC link.

The dv/dt filter plus VPL must be used for motors for which the withstand voltage of the insulation system is unknown or insufficient. Motors in the 1LA and 1LG ranges require this type of filter only when they are connected to a supply voltage exceeding 500 V +10 % and no special insulation is used on the motor.

The dv/dt filter plus VPL limits the voltage rate of rise to values $< 500 \text{ V}/\mu\text{s}$ and the typical voltage spikes at the motor to the values below:

- V_{PP} (typically) $< 1000 \text{ V}$ for $V_{Line} < 575 \text{ V}$
- V_{PP} (typically) $< 1250 \text{ V}$ for $660 \text{ V} < V_{Line} < 690 \text{ V}$

For a more detailed description, please refer to the section "dv/dt filters plus VPL" of the chapter "Fundamental Principles and System Description".

Sine-wave filter

Sine-wave filters are LC low-pass filters and constitute the most sophisticated filter solution. They are significantly more effective than dv/dt filters plus VPL in reducing the voltage rate of rise dv/dt and peak voltages V_{PP} , but operation with sine-wave filters imposes substantial restrictions in terms of the possible pulse frequency settings and voltage and current utilization of the motor-side inverter (voltage and current derating).

For a more detailed description and for the derating data, please refer to the section "Sine-wave filters" of the chapter "Fundamental Principles and System Description".

Maximum connectable motor cable lengths

The table shows the maximum connectable motor cable lengths. The values apply to the motor cable types recommended in the table as well as to other types of cable.

Line supply voltage		Output power at 400 V / 500 V / 690 V	Maximum permissible motor cable length	
			Shielded cable e.g. Protodur NYCWY	Unshielded cable e.g. Protodur NYY
Without reactor or filter				
380 V – 480 V 3AC	110 kW - 560 kW	300 m	450 m	
500 V – 600 V 3AC	110 kW - 560 kW	300 m	450 m	
660 V – 690 V 3AC	75 kW - 800 kW	300 m	450 m	
With one motor reactor				
380 V – 480 V 3AC	110 kW - 560 kW	300 m	450 m	
500 V – 600 V 3AC	110 kW - 560 kW	300 m	450 m	
660 V – 690 V 3AC	75 kW - 800 kW	300 m	450 m	

Permissible motor cable lengths for SINAMICS G130

SINAMICS G130

Engineering Information

Line supply voltage	Output power at 400 V / 500 V / 690 V	Maximum permissible motor cable length	
		Shielded cable e.g. Protodur NYCWY	Unshielded cable e.g. Protodur NYY
With dv/dt filter plus VPL			
380 V – 480 V 3AC	110 kW - 560 kW	300 m	450 m
500 V – 600 V 3AC	110 kW - 560 kW	300 m	450 m
660 V – 690 V 3AC	75 kW - 800 kW	300 m	450 m
With sine-wave filter			
380 V – 480 V 3AC	110 kW - 250 kW	300 m	450 m
500 V – 600 V 3AC	110 kW - 132 kW	300 m	450 m

Permissible motor cable lengths for SINAMICS G130 (continued)

Under certain conditions, the permissible cable lengths can be increased even further through the series connection of two motor reactors. Cable lengths for two motor reactors in series and the corresponding limitations are available on request.

Converter Cabinet Units SINAMICS G150

■ General information

SINAMICS G150 cabinets are ready-to-connect, high-output AC/AC converters in a standard cabinet. An extensive range of electrical and mechanical options means that they can be configured easily to meet individual requirements.

They are designed for applications with less stringent requirements in terms of control quality and feature a simple, 6 - pulse rectifier, i.e. they are not capable of regenerative operation.

SINAMICS G150 cabinets are available for the line supply voltages and outputs listed in the table below:

Line supply voltage	Converter output single converters	Converter output parallel connected converters (version A only)
380 V – 480 V 3AC	110 kW - 560 kW at 400 V	630 kW - 900 kW at 400 V
500 V – 600 V 3AC	110 kW - 560 kW at 500 V	630 kW - 1000 kW at 500 V
660 V – 690 V 3AC	75 kW - 800 kW at 690 V	1000 kW - 1500 kW at 690 V

Line supply voltages and output power ranges of SINAMICS G150 cabinets

There are two versions of the SINAMICS G150 cabinets:

- Version A
is designed to allow installation of all the available line connection components, such as line fuses, main circuit breaker, main contactor, circuit breakers, line filter or motor-side components and additional monitoring equipment. This version is also available in the higher power range with two Power Units connected in parallel.
- Version C
with specially space-optimized design without line-side components. This version can be used, for example, when line connection components are accommodated in a central low-voltage distribution panel (MCC) in the plant.

SINAMICS G150 cabinets are available in a range of cabinet widths, starting at 400 mm and increasing in increments of 200 mm.

The standard model has a degree of protection IP20, but further models with degrees of protection IP21, IP23, IP43 and IP54 are available as options.

SINAMICS G150 cabinets feature as standard the AOP30 Advanced Operator Panel for control, monitoring and commissioning tasks. It is mounted in the cabinet door.

The customer interface on the G150 is provided in the form of a PROFIBUS interface on the CU320 Control Unit and the TM31 Terminal Module which adds a large number of analog and digital inputs/outputs.

The digital inputs and outputs on the CU320 Control Unit are used for internal purposes on G150 cabinets and are not therefore available for use as a customer interface. The TM31 Terminal Module must always be used for this purpose.

■ Rated data of converters for drives with low demands on control performance

Main applications

SINAMICS G150 cabinets are primarily intended for applications which require a lower standard of dynamic response and control accuracy and are usually operated in sensorless vector control mode.

They are basically not capable of regenerative operation. For applications where the drive operates in regenerative mode for brief periods, it is possible either to activate the $V_{dc\ max}$ controller or install braking units (options L61 or L62).

Where the application requires a higher standard of control, i.e. where the control accuracy is more important than the dynamic response, SINAMICS G150 cabinets can be equipped with an SMC30 speed encoder interface which enables them to operate with TTL/HTL incremental encoders (option K50).

Line supply voltages

SINAMICS G150 cabinets are available for the following line supply voltages:

- 380 V – 480 V 3AC
- 500 V – 600 V 3AC
- 660 V – 690 V 3AC

The permissible voltage tolerance is $\pm 10\%$ continuously and -15% for brief periods (< 1 min). In the case of line undervoltages within the specified tolerances, the available output power will drop accordingly unless additional power reserves are available to increase the output current.

Usable output currents

The output currents specified in the selection and ordering data can be utilized over the entire frequency or speed setting range, i.e. even at very low output frequencies down to zero speed.

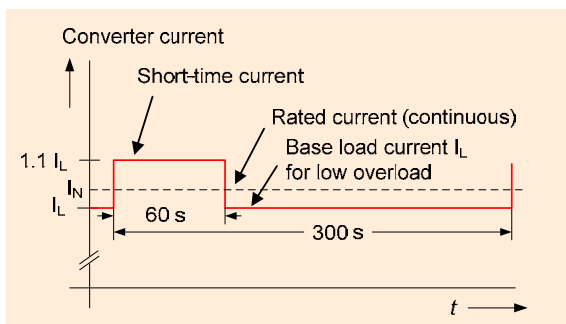
The specified rated output current is the maximum continuous thermally permissible output current. The units have no additional overload capacity when operating at this current.

Overload capability, load duty cycle definitions

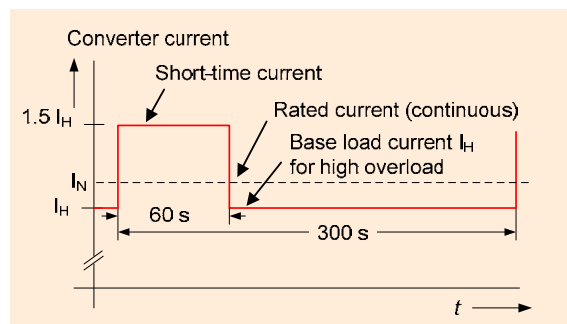
When a drive is required to overcome breakaway torques or is subjected to high surge loads, its configuration must take these factors into account. In such instances, it must be operated on the basis of a base load current which is lower than the rated output current. Overload reserves are available for this purpose. The load duty cycles for operation with low and high overloads are defined below.

- The base load current I_L for low overload is based on a load duty cycle of 110% for 60 s or 150% for 10 s.
- The base load current I_H for a high overload is based on a load duty cycle of 150% for 60 s or 160% for 10 s.

These overload values apply on condition that the converter is operated at its base load current before and after the period of overload on the basis of a load duty cycle duration of 300 s in each case.



Load duty cycle definition for low overload



Load Duty cycle definition for high overload

Overload and overtemperature protection

SINAMICS G150 cabinets are equipped with effective overload and overtemperature protection mechanisms which protect them against thermal overloading.

Sensors at various locations in the converter (inlet air, control electronics, rectifier heatsink, inverter heatsink) measure the relevant temperatures and feed them into the so-called "Thermal model". This continuously calculates the temperature at critical positions on power components. In this way the converter is effectively protected against thermal overloads, whether they are caused by excessive current or high ambient temperatures. The so-called " I^2t " monitoring circuit checks the level of utilization of the motor-side inverter. If the level of inverter utilization or the temperature at any point in the converter exceeds the upper tolerance limit, the converter responds by initiating an overload reaction parameterized in the firmware. It is possible to select whether the converter should react to overload by reducing the output frequency and output current or the pulse frequency. Immediate shutdown can also be parameterized.

Maximum output frequencies

The maximum output frequency for SINAMICS G150 cabinets is limited to either 160 Hz or 100 Hz due to the factory-set pulse frequency of either $f_{\text{pulse}} = 2.00$ kHz or $f_{\text{pulse}} = 1.25$ kHz. Higher output frequencies can be obtained only through an increase in the pulse frequency. As the switching losses in the motor-side IGBT inverter increase in proportion to the pulse frequency, the output current must be reduced accordingly.

Permissible output current and maximum output frequency as a function of pulse frequency

Output power at 400 V 500 V / 690 V	Rated output current at pulse frequency of		Current derating-factor at pulse frequency of	
	2 kHz	1,25 kHz	4 kHz	2,5 kHz
380 V – 480 V 3AC				
110 kW	210 A	-	82 %	-
132 kW	260 A	-	83 %	-
160 kW	310 A	-	88 %	-
200 kW	380 A	-	87 %	-
250 kW	490 A	-	78 %	-
315 kW	-	605 A	-	72 %
400 kW	-	745 A	-	72 %
450 kW	-	840 A	-	79 %
560 kW	-	985 A	-	87 %
630 kW	-	1120 A ¹⁾	-	72 %
710 kW	-	1380 A ¹⁾	-	72 %
900 kW	-	1560 A ¹⁾	-	79 %
500 V – 600 V 3AC				
110 kW	-	175 A	-	87 %
132 kW	-	215 A	-	87 %
160 kW	-	260 A	-	88 %
200 kW	-	330 A	-	82 %
250 kW	-	410 A	-	82 %
315 kW	-	465 A	-	87 %
400 kW	-	575 A	-	85 %
500 kW	-	735 A	-	79 %
560 kW	-	810 A	-	72 %
630 kW	-	860 A ¹⁾	-	87 %
710 kW	-	1070 A ¹⁾	-	85 %
1000 kW	-	1360 A ¹⁾	-	79 %
660 V – 690 V 3AC				
75 kW	-	85 A	-	89 %
90 kW	-	100 A	-	88 %
110 kW	-	120 A	-	88 %
132 kW	-	150 A	-	84 %
160 kW	-	175 A	-	87 %
200 kW	-	215 A	-	87 %
250 kW	-	260 A	-	88 %
315 kW	-	330 A	-	82 %
400 kW	-	410 A	-	82 %
450 kW	-	465 A	-	87 %
560 kW	-	575 A	-	85 %
710 kW	-	735 A	-	79 %
800 kW	-	810 A	-	72 %
1000 kW	-	1070 A ¹⁾	-	85 %
1350 kW	-	1360 A ¹⁾	-	79 %
1500 kW	-	1500 A ¹⁾	-	72 %

¹⁾ G150 parallel converter / the specified currents represent the total current of the two parallel-connected converter units

SINAMICS G150: Permissible output current as a function of pulse frequency

Pulse frequency	Maximum attainable output frequency
1.25 kHz	100 Hz
2.00 kHz	160 Hz
2.50 kHz	200 Hz
≥ 4.00 kHz	300 Hz

Maximum attainable output frequency as a function of pulse frequency

Current derating as a function of installation altitude/ambient temperature

If the converters are operated at an **installation altitude > 2000 m** above sea level, the maximum permissible output current can be calculated using the following tables according to the degree of protection selected for the cabinets. To obtain these values, the air flow rate stipulated in the technical data tables must be provided. The specified values already include a permitted correction between installation altitude and ambient temperature (incoming air temperature at the inlet to the cabinet).

Installation altitude above sea level m	Current derating at an ambient temperature (inlet air temperature) of						
	20 °C	25 °C	30 °C	35 °C	40 °C	45 °C	50 °C
0 ... 2000	100 %					95.0 %	87.0 %
... 2500						96.3 %	91.4 %
... 3000	96.7 %			96.2 %	92.5 %	87.9 %	80.5 %
... 3500				92.3 %	88.8 %	84.3 %	77.3 %
... 4000	97.8 %	92.7 %	88.4 %	85.0 %	80.8 %	74.0 %	

Current derating as a function of ambient temperature (temperature of inlet air) and installation altitude for G150 cabinets with **degree of protection IP20, IP21, IP23 and IP43**

Installation altitude above sea level	Current derating at an ambient temperature (inlet air temperature) of						
	20 °C	25 °C	30 °C	35 °C	40 °C	45 °C	50 °C
0 ... 2000	100 %				95.0 %	87.5 %	80.0 %
... 2500					96.3 %	91.4 %	84.2 %
... 3000	96.7 %		96.2 %	92.5 %	87.9 %	81.0 %	74.1 %
... 3500			92.3 %	88.8 %	84.3 %	77.7 %	71.1 %
... 4000	97.8 %	92.7 %	88.4 %	85.0 %	80.8 %	74.7 %	68.0 %

Current derating as a function of ambient temperature (temperature of inlet air) and installation altitude, for G150 cabinets with **degree of protection IP54**

Voltage derating as a function of installation altitude

In addition to the current derating, a voltage derating as stipulated in the table below is applicable at installation altitudes of > 2000 m above sea level.

Installation altitude above sea level m	voltage derating at a rated input voltage of												
	380 V	400 V	420 V	440 V	460 V	480 V	500 V	525 V	550 V	575 V	600 V	660 V	690 V
0 ... 2000	100 %						100 %					100 %	
... 2250												96 %	
... 2500	98 %		94 %										
... 2750	98 %		94 %	90 %									
... 3000	95 %		91 %	88 %									
... 3250	97 %		93 %	89 %	85 %	98 %		89 %	85 %				
... 3500	98 %	93 %	89 %	85 %	82 %	98 %		94 %	85 %	82 %			
... 3750	95 %	91 %	87 %	83 %	79 %	98 %		95 %	91 %	-	-		
... 4000	96 %	92 %	87 %	83 %	80 %	76 %	95 %		91 %	87 %	-	-	

Voltage derating as a function of installation altitude

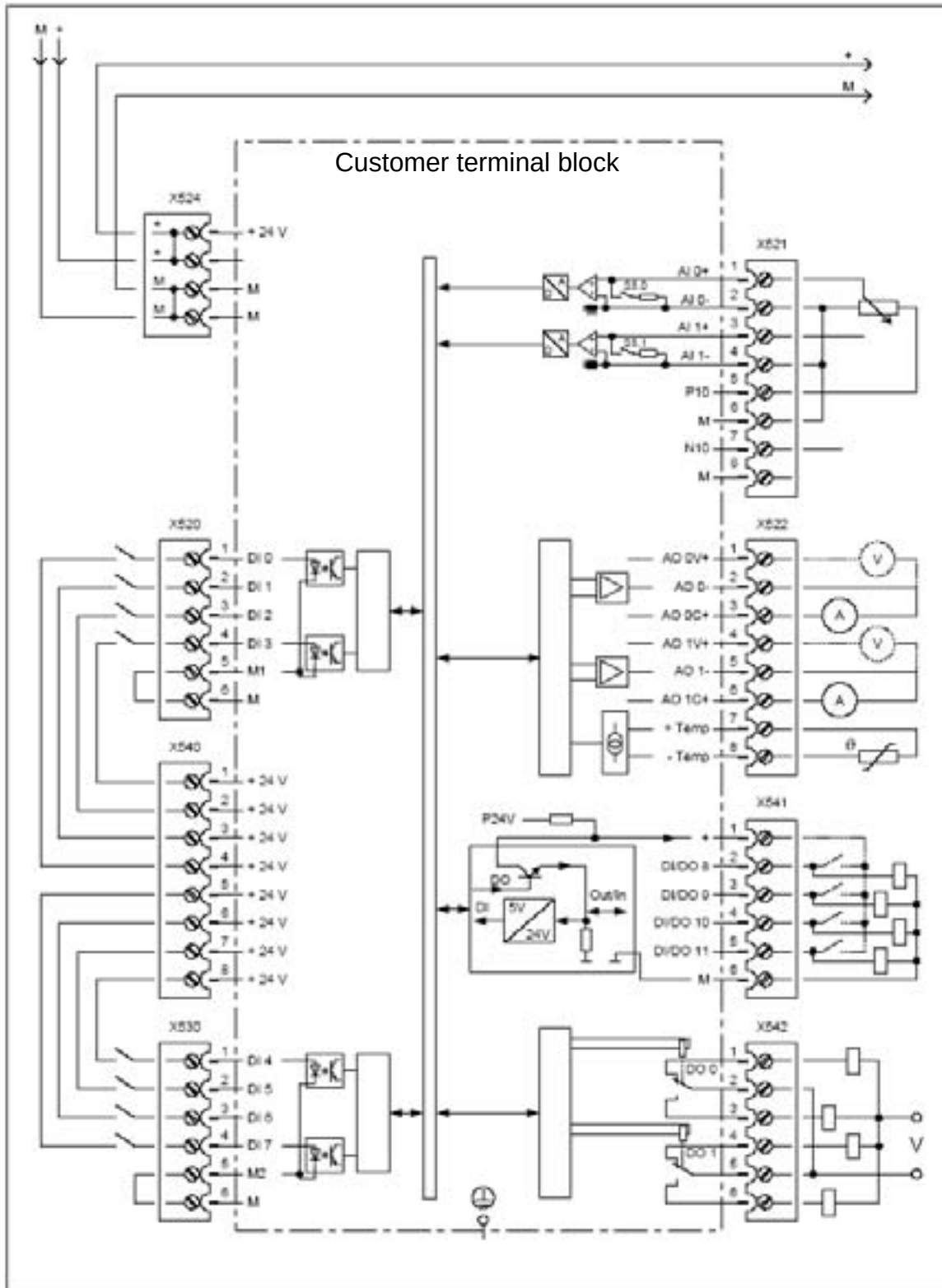
Factory settings (defaults) of customer interface on SINAMICS G150

The following factory settings are provided to simplify configuring the customer interface and commissioning. The interfaces can also be assigned freely at any time.

Terminal block on TM31		
	Factory setting	Comment
-X520	Optocoupler inputs connected to common potential	
DI0	ON/OFF 1	
DI1	Increase setpoint/fixed setpoint 0	Parameters can be set in the firmware to determine whether operation is via motorized digital potentiometer or fixed setpoint
DI2	Decrease setpoint/fixed setpoint 1	
DI3	Acknowledge fault	
-X530	Optocoupler inputs connected to common potential	
DI4	Inverter enable ¹⁾	Converter is at standby and waiting for the enable signal
DI5	OFF 3 ¹⁾	Ramp-down along quick-stop ramp, only of relevance in conjunction with the Braking Module
DI6	External fault ¹⁾	
DI7		
-X541	Bidirectional inputs/outputs	
<u>DI/DO8</u>	Message: Ready to start	
<u>DI/DO9</u>	Not assigned	Factory-set as input
<u>DI/DO10</u>	Not assigned	Factory-set as input
<u>DI/DO11</u>	Not assigned	Factory-set as input
-X542	Relay outputs (changeover contact)	
DO 0	Inverter enable (Run)	
DO 1	Checkback signal No converter fault	
-X521	Analog inputs, differential	
AI0+	Analog input for setting speed setpoint	The factory setting for the inputs is 0 to 20 mA.
AI0-		
AI1+	Analog input reserved	The factory setting for the inputs is 0 to 20 mA.
AI1-		
-X522	Analog outputs	
AO 0V+		The factory setting for the outputs is 0 to 20 mA.
AO 0V-	Analog output, actual speed value	
AO 0C+		The factory setting for the outputs is 0 to 20 mA.
AO 1V+		
AO 1V-	Analog output, actual motor current value	
AO 1C+		
-X522	Thermistor protection	
+Temp		Input for KTY84 temperature sensor or PTC thermistor
-Temp		

The factory settings of the bidirectional inputs/outputs are underscored.

¹⁾ A jumper must be inserted here if these inputs are not used



Customer terminal block on the TM31 Terminal Module

Cable cross-sections and connections on SINAMICS G150 Cabinet Units

Recommended and maximum possible cable cross-sections for line and motor connections

The following tables list the recommended and maximum possible cable connections at the line and the motor side for single converters (versions A and C) and parallel-connected converters (version A).

The recommended cross-sections are based on the listed fuses (see section "Line-side components") and single routing of the three-wire cables at an ambient temperature of 40 °C.

When the conditions differ from the above stated (cable routing, cable grouping, ambient temperature), the planning instructions for routing the cables must be taken into account.

Single converters G150 Version A

Out-put [kW]	Converter	Weight	Line supply connection				Motor connection				Cabinet grounding	
	SINAMICS G150 Version A	(Standard model)	Recommended cross-section ¹⁾	Maximum cable cross-section		M12 fixing screw (no. of holes)	Recommended cross-section ¹⁾	Maximum cable cross-section		M12 fixing screw (no. of holes)	M12 fixing screw (no. of holes)	Re-remarks
	Type 6SL3710-...	[kg]	DIN VDE [mm ²]	DIN VDE [mm ²]	NEC, CEC AWG/MCM	(no. of holes)	DIN VDE [mm ²]	DIN VDE [mm ²]	NEC, CEC AWG/MCM	(no. of holes)	(no. of holes)	

380 V – 480 V 3AC

110	1GE32-1AA0	320	2x70	4x240	4x500	(2)	2x50	2x150	2x300	(2)	(2)	
132	1GE32-6AA0	320	2x95	4x240	4x500	(2)	2x70	2x150	2x300	(2)	(2)	
160	1GE33-1AA0	390	2x120	4x240	4x500	(2)	2x95	2x150	2x300	(2)	(2)	
200	1GE33-8AA0	480	2x120	4x240	4x500	(2)	2x95	2x150	2x300	(2)	(2)	
250	1GE35-0AA0	480	2x185	4x240	4x500	(2)	2x150	2x240	2x500	(2)	(2)	
315	1GE36-1AA0	860	2x240	4x240	4x500	(2)	2x185	4x240	4x500	(2)	(2)	
400	1GE37-5AA0	865	3x185	4x240	4x500	(2)	2x240	4x240	4x500	(2)	(10)	Busbar
450	1GE38-4AA0	1075	4x150	8x240	8x500	(4)	3x185	4x240	4x500	(2)	(16)	Busbar
560	1GE41-0AA0	1360	4x185	8x240	8x500	(4)	4x185	6x240	6x500	(3)	(18)	Busbar

500 V – 600 V 3AC

110	1GF31-8AA0	390	120	4x240	4x500	(2)	95	2x150	2x300	(2)	(2)	
132	1GF32-2AA0	390	2x70	4x240	4x500	(2)	120	2x150	2x300	(2)	(2)	
160	1GF32-6AA0	390	2x95	4x240	4x500	(2)	2x70	2x185	2x350	(2)	(2)	
200	1GF33-3AA0	390	2x120	4x240	4x500	(2)	2x95	2x240	2x500	(2)	(2)	
250	1GF34-1AA0	860	2x185	4x240	4x500	(2)	2x120	4x240	4x500	(2)	(2)	
315	1GF34-7AA0	860	2x185	4x240	4x500	(2)	2x150	4x240	4x500	(2)	(2)	
400	1GF35-8AA0	865	2x240	4x240	4x500	(2)	2x185	4x240	4x500	(2)	(2)	
500	1GF37-4AA0	1320	3x185	8x240	8x500	(4)	2x240	6x240	6x500	(3)	(18)	Busbar
560	1GF38-1AA0	1360	4x150	8x240	8x500	(4)	3x185	6x240	6x500	(3)	(18)	Busbar

660 V – 690 V 3AC

75	1GH28-5AA0	320	50	4x240	4x500	(2)	35	2x70	2x2/0 AWG	(2)	(2)	
90	1GH31-0AA0	320	50	4x240	4x500	(2)	50	2x150	2x300	(2)	(2)	
110	1GH31-2AA0	320	70	4x240	4x500	(2)	70	2x150	2x300	(2)	(2)	
132	1GH31-5AA0	320	95	4x240	4x500	(2)	70	2x150	2x300	(2)	(2)	
160	1GH31-8AA0	390	120	4x240	4x500	(2)	95	2x150	2x300	(2)	(2)	
200	1GH32-2AA0	390	2x70	4x240	4x500	(2)	120	2x150	2x300	(2)	(2)	
250	1GH32-6AA0	390	2x95	4x240	4x500	(2)	2x70	2x185	2x350	(2)	(2)	
315	1GH33-3AA0	390	2x120	4x240	4x500	(2)	2x95	2x240	2x500	(2)	(2)	
400	1GH34-1AA0	860	2x185	4x240	4x500	(2)	2x120	4x240	4x500	(2)	(2)	
450	1GH34-7AA0	860	2x185	4x240	4x500	(2)	2x150	4x240	4x500	(2)	(2)	
560	1GH35-8AA0	860	2x240	4x240	4x500	(2)	2x185	4x240	4x500	(2)	(2)	
710	1GH37-4AA0	1320	3x185	8x240	8x500	(4)	3x150	6x240	6x500	(3)	(18)	Busbar
800	1GH38-1AA0	1360	4x150	8x240	8x500	(4)	3x185	6x240	6x500	(3)	(18)	Busbar

SINAMICS G150

Engineering Information

Single converters G150 Version C

Out-put [kW]	Converter SINAMICS G150 Version C Type 6SL3710-...	Weight (Stan- dard model) [kg]	Line supply connection				Motor connection				Cabinet grounding	
			Recom- mended cross- section ¹⁾ DIN VDE [mm ²]	Maximum cable cross-section DIN VDE [mm ²]	Maximum cable cross-section NEC, CEC AWG/MCM	M12 fixing screw (no. of holes)	Recom- mended cross- section ¹⁾ DIN VDE [mm ²]	Maximum cable cross-section DIN VDE [mm ²]	Maximum cable cross-section NEC, CEC AWG/MCM	M12 fixing screw (no. of holes)	M12 fixing screw (no. of holes)	Re- marks

380 V – 480 V 3AC

110	1GE32-1CA0	225	2x70	2x240	2x500	(1)	2x50	2x150	2x300	(1)	(2)	
132	1GE32-6CA0	225	2x95	2x240	2x500	(1)	2x70	2x150	2x300	(1)	(2)	
160	1GE33-1CA0	300	2x120	2x240	2x500	(1)	2x95	2x150	2x300	(1)	(2)	
200	1GE33-8CA0	300	2x120	2x240	2x500	(1)	2x95	2x150	2x300	(1)	(2)	
250	1GE35-0CA0	300	2x185	2x240	2x500	(1)	2x150	2x240	2x500	(1)	(2)	
315	1GE36-1CA0	670	2x240	8x240	8x500	(4)	2x185	8x240	8x500	(4)	(2)	
400	1GE37-5CA0	670	3x185	8x240	8x500	(4)	2x240	8x240	8x500	(4)	(8)	Busbar
450	1GE38-4CA0	670	4x150	8x240	8x500	(4)	3x185	8x240	8x500	(4)	(8)	Busbar
560	1GE41-0CA0	980	4x185	8x240	8x500	(4)	4x185	8x240	8x500	(4)	(10)	Busbar

500 V – 600 V 3AC

110	1GF31-8CA0	300	120	2x240	2x500	(1)	95	2x150	2x300	(1)	(2)	
132	1GF32-2CA0	300	2x70	2x240	2x500	(1)	120	2x150	2x300	(1)	(2)	
160	1GF32-6CA0	300	2x95	2x240	2x500	(1)	2x70	2x185	2x350	(1)	(2)	
200	1GF33-3CA0	300	2x120	4x240	4x500	(1)	2x95	2x240	2x500	(1)	(2)	
250	1GF34-1CA0	670	2x185	4x240	4x500	(2)	2x120	4x240	4x500	(2)	(2)	
315	1GF34-7CA0	670	2x185	4x240	4x500	(2)	2x150	4x240	4x500	(2)	(2)	
400	1GF35-8CA0	670	2x240	4x240	4x500	(2)	2x185	4x240	4x500	(2)	(2)	
500	1GF37-4CA0	940	3x185	8x240	8x500	(4)	2x240	6x240	6x500	(3)	(18)	Busbar
560	1GF38-1CA0	980	4x150	8x240	8x500	(4)	3x185	6x240	6x500	(3)	(18)	Busbar

660 V – 690 V 3AC

75	1GH28-5CA0	225	50	2x240	2x500	(1)	35	2x70	2x2/0 AWG	(1)	(2)	
90	1GH31-0CA0	225	50	2x240	2x500	(1)	50	2x150	2x300	(1)	(2)	
110	1GH31-2CA0	225	70	2x240	2x500	(1)	70	2x150	2x300	(1)	(2)	
132	1GH31-5CA0	225	95	2x240	2x500	(1)	70	2x150	2x300	(1)	(2)	
160	1GH31-8CA0	300	120	2x240	2x500	(1)	95	2x150	2x300	(1)	(2)	
200	1GH32-2CA0	300	2x70	2x240	2x500	(1)	120	2x150	2x300	(1)	(2)	
250	1GH32-6CA0	300	2x95	2x240	2x500	(1)	2x70	2x185	2x350	(1)	(2)	
315	1GH33-3CA0	300	2x120	4x240	4x500	(1)	2x95	2x240	2x500	(1)	(2)	
400	1GH34-1CA0	670	2x185	4x240	4x500	(2)	2x120	4x240	4x500	(2)	(2)	
450	1GH34-7CA0	670	2x185	4x240	4x500	(2)	2x150	4x240	4x500	(2)	(2)	
560	1GH35-8CA0	670	2x240	4x240	4x500	(2)	2x185	4x240	4x500	(2)	(2)	
710	1GH37-4CA0	940	3x185	8x240	8x500	(4)	3x150	6x240	6x500	(3)	(18)	Busbar
800	1GH38-1CA0	980	4x150	8x240	8x500	(4)	3x185	6x240	6x500	(3)	(18)	Busbar

- 1) The recommendations for the North American market in AWG or MCM must be taken from the appropriate NEC (National Electrical Code)/CEC (Canadian Electrical Code) standards.

Parallel-connected converters

Out-put	Converter	Weight	Line supply connection				Motor connection				Cabinet grounding	
			Recom- mended cross- section ¹⁾	Maximum cable cross-section		M12 fixing screw (no. of holes)	Recom- mended cross- section ¹⁾	Maximum cable cross-section		M12 fixing screw (no. of holes)	M12 fixing screw (no. of holes)	Re- marks
				DIN VDE	NEC, CEC			DIN VDE	NEC, CEC			
[kW]	Type	[kg]	[mm ²]	[mm ²]	AWG/MCM		[mm ²]	[mm ²]	AWG/MCM			
380 V – 480 V 3AC												
630	2GE41-1AA0	1700	2x240	4x240	4x500	(2)	2x185	4x240	4x500	(2)	(2)	
710	2GE41-4AA0	1700	3x185	4x240	4x500	(2)	2x240	4x240	4x500	(2)	(10)	Busbar
900	2GE41-6AA0	2130	3x240	8x240	8x500	(4)	2x240	4x240	4x500	(2)	(16)	Busbar
500 V – 600 V 3AC												
630	2GF38-6AA0	1700	2x185	4x240	4x500	(2)	2x150	4x240	4x500	(2)	(2)	
710	2GF41-1AA0	1700	2x240	4x240	4x500	(2)	2x185	4x240	4x500	(2)	(2)	
1000	2GF41-4AA0	2620	3x185	8x240	8x500	(4)	2x240	6x240	6x500	(3)	(18)	Busbar
660 V – 690 V 3AC												
1000	2GH41-1AA0	1700	2x240	4x240	4x500	(2)	2x185	4x240	4x500	(2)	(2)	
1350	2GH41-4AA0	2620	3x185	8x240	8x500	(4)	3x150	6x240	6x500	(3)	(18)	Busbar
1500	2GH41-5AA0	2700	4x150	8x240	8x500	(4)	3x185	6x240	6x500	(3)	(18)	Busbar

Note:

The recommended and maximum conductor cross-sections relate to the appropriate partial converter of the parallel-connected converter.

- 1) The recommendations for the North American market in AWG or MCM must be taken from the appropriate NEC (National Electrical Code)/CEC (Canadian Electrical Code) standards.

Required cable cross-sections for line and motor connections

It is always advisable to use shielded, symmetrical, 3-wire three-phase cables or to connect several cables of this type in parallel if necessary. There are basically two reasons for this choice of cable:

This is the only way in which the high IP55 degree of protection can be achieved for the motor terminal box without problems because the cables enter the terminal box via glands and the number of possible glands is limited by the geometry of the terminal box. Therefore single cables are less suitable.

With symmetrical, 3-wire, three-phase cables, the summed ampere-turns over the cable outer diameter are equal to zero and they can be routed in conductive, metal cable ducts or racks without any significant currents (ground current or leakage current) being induced in these conductive, metal connections. The danger of induced leakage currents and thus of increased cable-shield losses increases with single-wire cables.

The required cable cross-section depends on the amperage which flows through the cable. The permissible current loading of cables is defined e.g. in DIN VDE 0298 Part 2/DIN VDE 0276-1000. It depends on ambient conditions such as the temperature, but also on the routing method. It depends whether cables are routed singly and therefore relatively well ventilated, or whether groups of cables are routed together. In the latter instance, the cables heat one another and are therefore far less well ventilated. Reference should be made to the corresponding reduction factors for such conditions as specified in DIN VDE 0298 Part 2 / DIN VDE 0276-1000. With an ambient temperature of 40 °C, the cross-sections of copper cables can be based on the following table.

Cross-section of 3-wire cables [mm ²]	With single routing [A]	With several cables on a common cable rack [A]
50	138	95
70	176	121
95	212	146
120	245	169
150	282	194
185	323	222
240	380	261
300	418	289

Current-carrying capacity according to DIN VDE 0298 Part 2 at 40° C

With higher amperages, cables must be connected in parallel.

Note:

The recommendations for the North American market in AWG or MCM must be taken from the appropriate NEC (National Electrical Code)/CEC (Canadian Electrical Code) standards.

Grounding and PE conductor cross-section

The PE conductor must be dimensioned to meet the following requirements:

- In the case of a ground fault, no impermissibly high contact voltages resulting from voltage drops on the PE conductor caused by the ground fault current may occur (< 50 VAC or < 120 VDC, EN 50 178 Subsection 5.3.2.2, IEC 60 364, IEC 60 543).
- The PE conductor should not be excessively loaded by any ground fault current it carries.
- If it is possible for continuous currents to flow through the PE conductor when a fault occurs in accordance with EN 50,178 Subsection 8.3.3.4, the PE conductor cross-section must be dimensioned for this continuous current.
- The PE conductor cross-section should be selected according to EN 60 204-1, EN 60 439-1, IEC 60 364.

Cross-section of the phase conductor mm ²	Minimum cross-section of the external PE conductor mm ²
Up to 16	Minimum phase conductor cross-section
16 to 35	16
35 and above	Minimum half the phase conductor cross-section

Note:

The recommendations for the North American market in AWG or MCM must be taken from the appropriate NEC (National Electrical Code)/CEC (Canadian Electrical Code) standards.

- Switchgear systems and motors are usually grounded via a separate local ground connection. In the case of a ground fault with this configuration, the ground fault current is divided and flows through the ground connections in parallel. With this grounding system, no impermissible contact voltages can occur, despite the PE conductor cross-sections used in the above table.

Based on experience with different grounding configurations, however, we recommend that the ground wire from the motor should be routed directly back to the converter. For EMC reasons and to prevent bearing currents, symmetrical, three-wire, three-phase cables should be used in this case rather than four-wire cables. The ground connection (PE) must be routed separately or must be arranged symmetrically in the motor cable. The symmetry of the PE conductor is achieved using a conductor surrounding all phase conductors or using a cable with a symmetrical arrangement of the three phase conductors and three ground conductors. For further information, please refer to the sections "Bearing currents caused by steep voltage edges on the motor" and "Line filters" of the chapter "Fundamental Principles and System Description".

- Through their controllers, the converters limit the load current (motor and ground fault currents) to an rms value corresponding to the rated current. We therefore recommend the use of a PE conductor cross-section analogous to the phase conductor cross-section for grounding the converter cabinet.

■ Line-side components

Line fuses

The combined fuses (3NE1., class gS) for line and semiconductor protection are recommended to protect the converter. These fuses are specially adapted to provide protection for the input rectifier's semiconductors.

- Superfast
- Adapted to the overload characteristic of the semiconductor
- Low arc voltage
- Improved current limiting (lower let-through values)

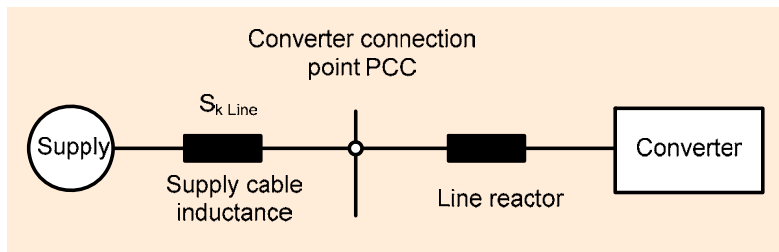
Line reactors

A line reactor must be installed whenever

- the converters are connected to a line supply system with high short-circuit power, i.e. with low line supply inductance
- more than one converter is connected to the same point of common coupling (PCC),
- the converters are equipped with line filters for RFI suppression
- the converters are equipped with Line Harmonics Filter for reducing harmonic effects on the supply
- converters are operating in parallel to achieve a higher output power.

The line reactor smoothes the current drawn by the converter and thus reduces harmonic components in the line current and thus the thermal load on the rectifier and DC link capacitors of the converter. The harmonic effects on the supply are also reduced, i.e. both the harmonic currents and harmonic voltages in the power supply are attenuated.

Line reactors can be dispensed with only if the supply cable inductance is sufficiently high or the relative short-circuit power RSC ^{*)} correspondingly low.



The following values apply to SINAMICS G150 cabinets:

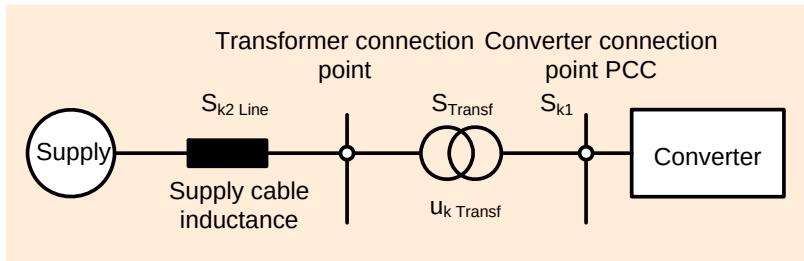
SINAMICS G150 converter output	Line reactor can be omitted with an RSC of	Line reactor is required with an RSC of
< 200 kW	$\leq 43 \rightarrow$ Option L22	$> 43 \rightarrow$ Standard
200 kW - 500 kW	$\leq 33 \rightarrow$ Option L22	$> 33 \rightarrow$ Standard
> 500 kW	$\leq 20 \rightarrow$ Standard	$> 20 \rightarrow$ Option L23

As the configuration of the supply system for operating individual converters is often not known in practice, i.e. the short-circuit power at the PCC of the converter is not certain, it is advisable to connect a line reactor on the line side of the converter in cases of doubt. For this reason, SINAMICS G150 cabinets up to an output of 500 kW are always equipped as standard with a line reactor with $u_k = 2\%$.

^{*)} RSC = **R**elative **s**hort-circuit power:

Ratio of the short-circuit power $S_{k \text{ Line}}$ at the PCC to the fundamental frequency apparent power $S_{\text{Converter}}$ of the connected converters (according to EN 50 178 / VDE 0160).

A line reactor can only be dispensed with (option L22) when the RSC value for relative short-circuit power is less than stated in the above table. This applies, for example, if the converter is connected to the supply via a transformer with specially adapted rating and none of the other reasons stated above for using a line reactor is valid.



In this case, the short-circuit power S_{k1} at the PCC of the converter is approximately

$$S_{k1} = \frac{S_{Transf}}{u_{kTransf} + \frac{S_{Transf}}{S_{k2Line}}}$$

Abbreviation	Meaning
S_{Transf}	Rated power of the transformer
$u_{kTransf}$	Relative short-circuit power of the transformer
S_{k2Line}	Short-circuit power of the higher-level voltage

As high-output converters are usually connected to medium-voltage supply systems via transformers to reduce their harmonic effects on the supply, cabinet units over 500 kW are not equipped with line reactors as standard. A line reactor (option L23) is required for cabinet units with outputs > 500 kW only if the RSC ratio is > 20.

Line reactors must always be provided if more than one converter is connected to the same point of common coupling. In this case, the reactors perform two functions, i.e. they smooth the line current and decouple the rectifiers at the line side. This decoupling is essential in ensuring fault-free operation of the rectifier circuit. For this reason, each converter must be provided with its own line reactor, i.e. it is not permissible for more than one converter to be connected to the same line reactor.

A line reactor must also be installed for any converter that is to be equipped with a line filter for RFI suppression (option L00) or with a Line Harmonics Filter (LHF) for reducing harmonic effects on the supply. This is because filters of this type cannot be 100% effective without a line reactor.

Another constellation which requires the use of line reactors is the parallel connection of converters where the paralleled rectifiers are connected to a common power supply point. This applies to parallel connections of G150 units which use a 6-pulse connection. Parallel connections of this type are therefore equipped as standard with line reactors despite their high rated outputs of > 500 kW. The line reactors provide for balanced current distribution and ensure that no individual rectifier is overloaded by excessive current imbalances.

Line filters

SINAMICS G150 cabinets are equipped as standard with an integrated line filter for limiting radio frequency interference emissions in accordance with EMC product standard EN 61800-3, category C3 (applications in industrial areas or in the "second" environment).

An optional line filter (option L00) is also available which renders the units suitable for category C2 applications in accordance with product standard EN 61800-3 (installation in residential areas or in the "first" environment).

To ensure that the converters comply with the tolerance limits defined for the above categories, it is absolutely essential that the relevant installation guidelines are followed. The efficiency of the filters as regards grounding and shielding can be guaranteed only if the drive is properly installed. For further details, please refer to the section "Line filters" of the chapter "Fundamental Principles and System Description".

Line filters can be used only on converters that are connected to grounded supply systems (TN supplies). On converters connected to non-grounded systems (IT supply systems), the standard integrated line filter must be isolated from PE potential. This can be done simply by removing a metal clip on the filter when the drive is commissioned (see operating instructions). It is not permissible to use optional line filters (option L00) in non-grounded systems to achieve compliance with the tolerance limits defined for category C2 by EMC product standard EN 61800-3.

■ Components at the DC link

Braking units

Braking units are used when regenerative energy occurs occasionally and briefly, for example when the brake is applied to the drive (emergency stop). Braking units comprise a Braking Module and a braking resistor, which must be fitted externally.

Braking units with a continuous braking power of 25 kW (P_{20} power 100 kW) or 50 kW (P_{20} power 200 kW) are available for SINAMICS G150 cabinets. Higher braking powers can be obtained for larger converters by connecting braking units in parallel (on request).

If the braking units are used at ambient temperatures $> 40^{\circ}\text{C}$ and installation altitudes > 2000 m, the derating factors for current and output power listed for the Power Units also apply here.

A thermal contact, which can be integrated into the converter's alarm and shutdown sequence, is installed in the braking resistor for monitoring.

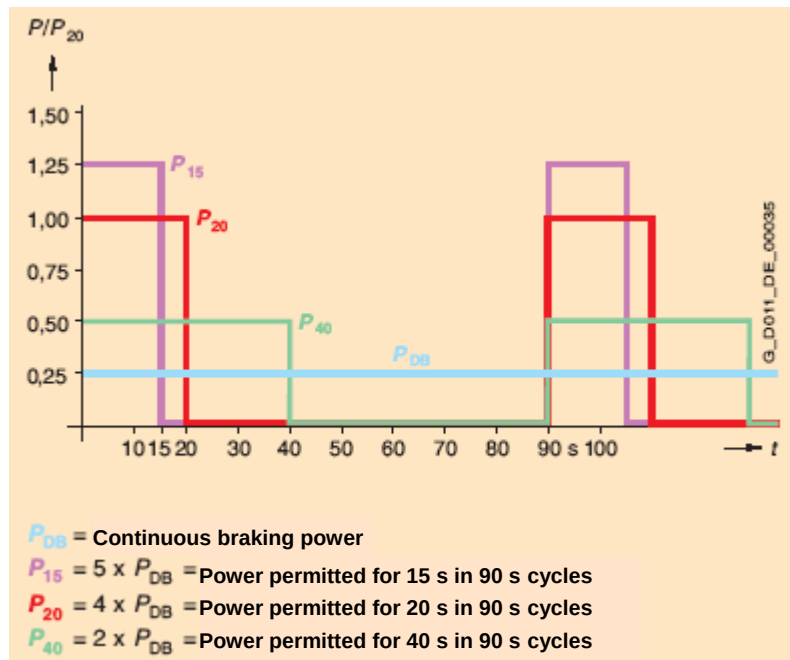
SINAMICS G150 cabinets	Rated power (continuous braking power) P_{DB}	Matching Braking Modules		Peak power P_{15}	Braking resistor R_B	Max. current
		Power P_{40}	Power P_{20}			
380 V – 480 V 3AC						
110 kW - 132 kW	25 kW	50 kW	100 kW	125 kW	4.4 Ω ±7.5 %	189 A
160 kW - 560 kW	50 kW	100 kW	200 kW	250 kW	2.2 Ω ±7.5 %	378 A
500 V – 600 V 3AC						
110 kW - 560 kW	50 kW	100 kW	200 kW	250 kW	3.4 Ω ±7.5 %	306 A
660 V – 690 V 3AC						
75 kW - 132 kW	25 kW	50 kW	100 kW	125 kW	9.8 Ω ±7.5 %	127 A
160 kW - 800 kW	50 kW	100 kW	200 kW	250 kW	4.9 Ω ±7.5 %	255 A

Braking Modules and braking resistors available for SINAMICS G150 cabinets

How to calculate the required braking units and braking resistors

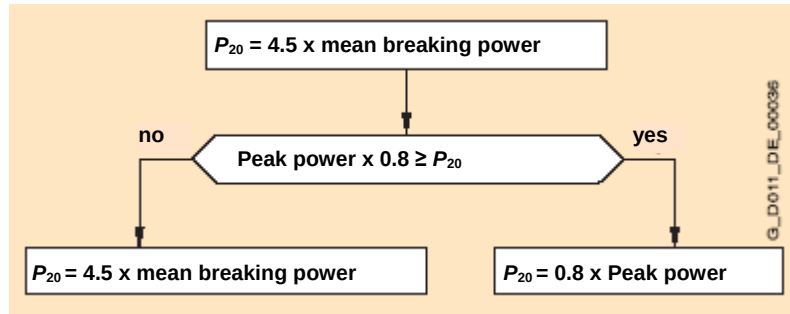
- For periodic load duty cycles with a cycle duration of ≤ 90 s, the average value of the braking power within this load duty cycle needs to be calculated. The respective period is used as the time base.
- For periodic load duty cycles with a cycle duration of ≥ 90 s or for sporadic braking operations, a time interval of 90 s in which the highest average value occurs must be selected. The 90 s period must be applied as the time base.

Apart from the average braking power, the required peak braking power must also be taken into account when braking units are selected (Braking Module and braking resistors). The tables and diagrams below illustrate the correlations.



Load duty cycle diagram and power definitions

Calculation of the P_{20} power



The ON/OFF states of the Braking Module are controlled by a 2-point controller. To reduce the voltage stress on the motor and converter, the response threshold at which the braking unit is activated and the DC link voltage generated during braking can be reduced. For example, the DC link voltage for the converters in the voltage range 380 V to 480 V can be reduced from 774 V to 673 V. This also reduces the attainable peak power. In this case, a factor of 1.06 should be applied instead of 0.8.

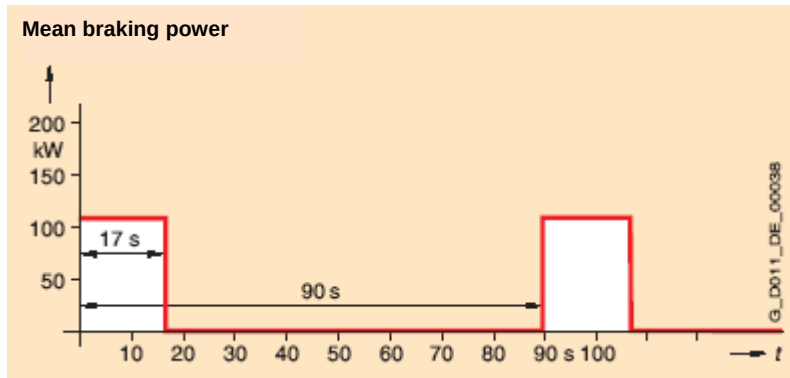
The response thresholds are shown in the following table.

Line supply voltage	Braking unit response threshold
380 V – 480 V 3AC	774 V or 673 V
500 V – 600 V 3AC	967 V or 841 V
660 V – 690 V 3AC	1158 V or 1070 V

Response thresholds of braking units

Example:

In the following example, we will calculate the rating of the Braking Module and braking resistor for a 450 kW Cabinet Unit.



The mean braking power is calculated as follows:

$$\text{Mean braking power} = 90 \text{ kW} \times 17 \text{ s} / 90 \text{ s} = 17.0 \text{ kW}$$

$$P_{20} = 4.5 \times 17.0 \text{ kW} = 76.5 \text{ kW}$$

$$\text{Peak power} = 0.8 \times 90 \text{ kW} = 72.0 \text{ kW}$$

Result:

The mean braking power is the determining factor in choosing the correct rating of Braking Module and braking resistor, i.e., a braking unit of $\geq 76.5 \text{ kW}$ must be provided.

The braking unit with 25 kW ($P_{20} = 100 \text{ kW}$) must be selected.

When the response threshold is reduced, the required braking power P_{20} is calculated as follows:

$$\text{Mean braking power} = 90 \text{ kW} \times 17 \text{ s} / 90 \text{ s} = 17.0 \text{ kW}$$

$$P_{20} = 4.5 \times 17.0 \text{ kW} = 76.5 \text{ kW}$$

$$\text{Peak power} = 1.06 \times 90 \text{ kW} = 95.4 \text{ kW}$$

Result:

The peak power requirement is the determining factor in choosing the correct rating of Braking Module and braking resistor, i.e., a braking unit of $\geq 95.4 \text{ kW}$ must be provided.

The braking unit with 25 kW ($P_{20} = 100 \text{ kW}$) must be selected.

Load-side components and cables

Motor reactor

The fast switching of the IGBTs in the inverter causes high voltage rate of rise dv/dt at the inverter output. If long motor cables are used, these voltage gradients increase the current load on the converter output due to capacitive charge/discharge currents. The length of cable which may be connected is therefore limited.

The high voltage rate of rise and the resulting voltage spikes at the motor terminals, increase the voltage stress at the motor winding in comparison to direct line operation. In conjunction with the connected cable capacitances, the motor reactors (option L08) reduce the capacitive charge/discharge currents in the motor cables and, as a function of the motor cable length, limit the voltage rate of rise dv/dt and the voltage peaks V_{PP} at the motor terminals.

For a more detailed description, please refer to the section "Motor reactors" of the chapter "Fundamental Principles and System Description".

dv/dt filter plus VPL

The dv/dt filter plus VPL (option L10) consists of two components, the dv/dt reactor and the voltage limiting network (Voltage Peak Limiter), which limits voltage peaks and returns the energy back to the DC link.

The dv/dt filter plus VPL must be used for motors for which the withstand voltage of the insulation system is unknown or insufficient. Motors in the 1LA and 1LG ranges require this type of filter only when they are connected to a supply voltage exceeding 500 V +10 % and no special insulation is used on the motor.

The dv/dt filter plus VPL limits the voltage rate of rise to values $< 500 \text{ V}/\mu\text{s}$ and the typical voltage spikes at the motor to the values below:

- V_{PP} (typically) $< 1000 \text{ V}$ for $V_{Line} < 575 \text{ V}$
- V_{PP} (typically) $< 1250 \text{ V}$ for $660 \text{ V} < V_{Line} < 690 \text{ V}$

For a more detailed description, please refer to the section "dv/dt filters plus VPL" of the chapter "Fundamental Principles and System Description".

Sine-wave filter

Sine-wave filters are LC low-pass filters and constitute the most sophisticated filter solution. They are significantly more effective than dv/dt filters plus VPL in reducing the voltage rate of rise dv/dt and peak voltages V_{PP} , but operation with sine-wave filters imposes substantial restrictions in terms of the possible pulse frequency settings and voltage and current utilization of the motor-side inverter (voltage and current derating).

For a more detailed description and for the derating data, please refer to the section "Sine-wave filters" of the chapter "Fundamental Principles and System Description".

Maximum connectable motor cable lengths

The table shows the maximum connectable motor cable lengths. The values apply to the motor cable types recommended in the tables as well as to all other types of motor cable.

Line supply voltage	Output power at 400 V / 500 V / 690 V	Maximum permissible motor cable length	
		Shielded cable e.g. Protodur NYCWY	Unshielded cable e.g. Protodur NYY
Without reactor or filter			
380 V – 480 V 3AC	110 kW - 900 kW	300 m	450 m
500 V – 600 V 3AC	110 kW - 1000 kW	300 m	450 m
660 V – 690 V 3AC	75 kW - 1500 kW	300 m	450 m
With one motor reactor (option L08)			
380 V – 480 V 3AC	110 kW - 900 kW	300 m	450 m
500 V – 600 V 3AC	110 kW - 1000 kW	300 m	450 m
660 V – 690 V 3AC	75 kW - 1500 kW	300 m	450 m

Permissible motor cable lengths for SINAMICS G150

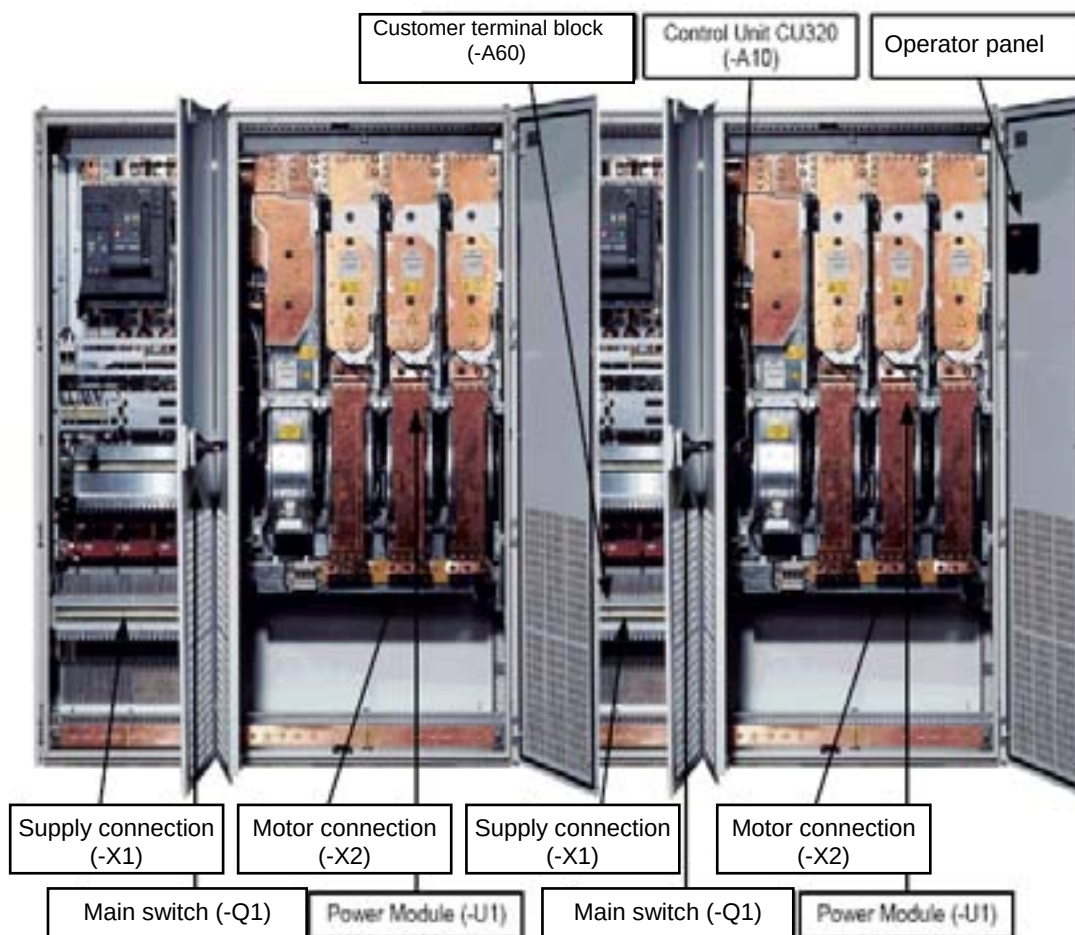
Line supply voltage	Output power at 400 V / 500 V / 690 V	Maximum permissible motor cable length	
		Shielded cable e.g. Protodur NYCWY	Unshielded cable e.g. Protodur NYY
With dv/dt filter plus VPL (option L10)			
380 V – 480 V 3AC	110 kW - 560 kW	300 m	450 m
500 V – 600 V 3AC	110 kW - 560 kW	300 m	450 m
660 V – 690 V 3AC	75 kW - 800 kW	300 m	450 m
With sine-wave filter (option L15)			
380 V – 480 V 3AC	110 kW - 250 kW	300 m	450 m
500 V – 600 V 3AC	110 kW - 132 kW	300 m	450 m

Permissible motor cable lengths for SINAMICS G150 (continued)

Under certain conditions, the permissible cable lengths can be increased even further through the series connection of two motor reactors. A second motor reactor is not a standard option and may require an additional cabinet. Information about permissible cable lengths, the limitations associated with them and clarification as to whether an additional cabinet will be required for two motor reactors is available on request.

SINAMICS G150 parallel converters (SINAMICS G150 power extension)

SINAMICS G150 converter cabinet units in the higher-output range are designed as parallel-connected converters. The devices are based on two lower-output SINAMICS G150 converter cabinets which operate in parallel to supply one motor.



SINAMICS G150 parallel converter

SINAMICS G150

Engineering Information

Due to the design principle of using two separate, low-output converter cabinet units, the configuration includes two each of the following components:

- Mains supply connections
- Main switch and main contactors
- All power unit components
- Motor connections

A parallel connection features only one of each of the following:

- CU320 Control Unit, which controls and synchronizes both individual power units
- AOP30 operator panel
- TM31 customer interface (analog and digital inputs and outputs)

Note:

In contrast to the S120 Infeed Modules and the S120 Motor Modules of the SINAMICS S120 modular system (Chassis and Cabinet Modules) in which up to four individual modules can be combined to a parallel connection, the G150 parallel converter / G150 power extension is a ready-to-connect converter cabinet unit comprising two converter cabinet units with lower outputs. It is ordered and supplied as a single unit with one order number. The technical data provided in the catalogs and in the tables of this engineering manual always refer to the complete G150 parallel converter and include already the current and power derating factors required for parallel connections.

The table below shows the power spectrum of the SINAMICS G150 parallel converters. For information purposes only, the last column contains the rated output current of the relevant individual cabinet units on which the parallel converter is based.

Rated output current	Low overload		High overload		Order number	The parallel device is constructed of two individual units with a rated output current of
	P _L	Base load current I _L	P _H	Base load current I _H		
[A]	[kW]	[A]	[kW]	[A]		[A]
Line supply voltage 380 V - 480 V 3AC						
1120	630	1092	500	850	6SL3710-2GE41-1AA0	605
1380	710	1340	560	1054	6SL3710-2GE41-4AA0	745
1560	900	1516	710	1294	6SL3710-2GE41-6AA0	840
Line supply voltage 500 V - 600 V 3AC						
860	630	836	560	770	6SL3710-2GF38-6AA0	465
1070	710	1036	630	950	6SL3710-2GF41-1AA0	575
1360	1000	1314	800	1216	6SL3710-2GF41-4AA0	735
Line supply voltage 660 V - 690 V 3AC						
1070	1000	1036	900	950	6SL3710-2GH41-1AA0	575
1360	1350	1314	1200	1216	6SL3710-2GH41-4AA0	735
1500	1500	1462	1350	1340	6SL3710-2GH41-5AA0	810

Power range of SINAMICS G150 parallel-connected converters

Since SINAMICS G150 parallel converters consist of two identical rectifiers on the line side, the rectifiers can operate either in 6-pulse or in 12-pulse configuration. The harmonic effects on the supply system are significantly lower in the 12-pulse operation than in the 6-pulse operation (see section "Harmonic effects on supply system" of the chapter "Fundamental Principles and System Description").

On the line side, certain conditions must be taken in account depending on whether the configuration is a 6-pulse or a 12-pulse configuration.

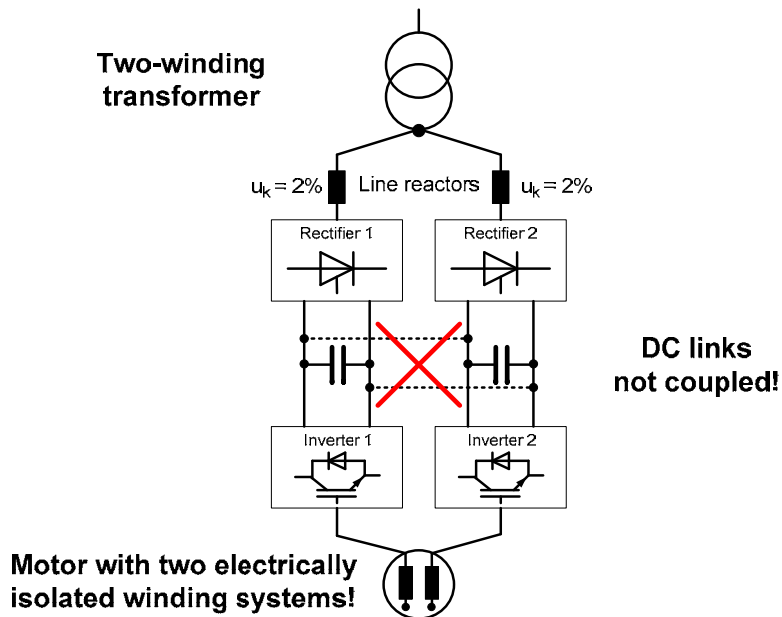
On the motor side, limitations exist related to the necessary minimum cable lengths for the motor and also to the permissible pulse modulation systems of the inverter, depending on the winding system in the motor (electrically isolated winding systems or one common winding system).

The following information describes the possible line-side and motor-side configurations of SINAMICS G150 parallel converters and the associated supplementary conditions that have to be taken in account.

6-pulse operation of SINAMICS G150 parallel converters

a) 6-pulse operation of G150 parallel converters with production date up to autumn 2007

At 6-pulse operation, both rectifiers are connected to the same secondary winding of a two-winding transformer or to a common infed point, as illustrated in the following diagram.



6-pulse operation of SINAMICS G150 parallel converters with production date up to autumn 2007

With the gating impuls generator for the thyristors implemented in the rectifiers of SINAMICS G150 parallel converters supplied up to autumn 2007, a correct 6-pulse operation can only be guaranteed when the following supplementary conditions are met:

- The DC links of both partial converters units must not be connected to each another, which is the delivery state of the factory.
- The unit must only be connected to motors with two electrically isolated winding systems.

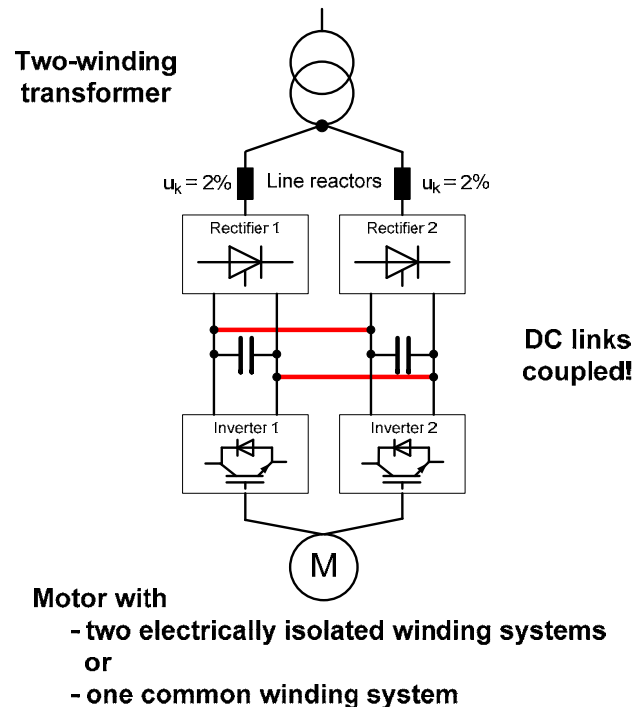
As the line-side rectifiers have no electronic current sharing control, the line-side currents must be balanced by the following measures:

- Use of line reactors with a relative short-circuit voltage of $u_k = 2\%$. The omission of the line reactors by choosing option L22 is not permissible.
- Use of symmetrical power cabling between the line connection point and the parallel-connected rectifiers (cables of identical type with the same cross-section and length)

The motor-side limitations and restrictions with respect to the operation of motors with electrically isolated winding systems are described on the following pages in the section "Operation of G150 parallel converters at motors with two electrically isolated winding systems".

b) 6-pulse operation of G150 parallel converters with production date from autumn 2007

At 6-pulse operation, both rectifiers are connected to the same secondary winding of a two-winding transformer or to a common infeed point, as illustrated in the following diagram.



6-pulse operation of SINAMICS G150 parallel converters with production date from autumn 2007

With the gating impuls generator for the thyristors implemented in the rectifiers of SINAMICS G150 parallel converters supplied from autumn 2007, it is no longer necessary to separate the DC links of both partial converters when operating in 6-pulse configuration. Thus it is no longer required to use motors with two electrically isolated winding systems at the output side. The standard configuration for 6-pulse operation with SINAMICS G150 parallel converters being produced from autumn 2007 is therefore:

- The DC links of both partial converters are connected to each other.
- It is possible to connect both, motors with two electrically isolated winding systems and motors with one common winding system.

Note: The difference between the versions described for the time frames “up to autumn 2007” and “from autumn 2007” simply lies in the improved version of the TDB board. The firmware version of the converters does not have any significance within this context.

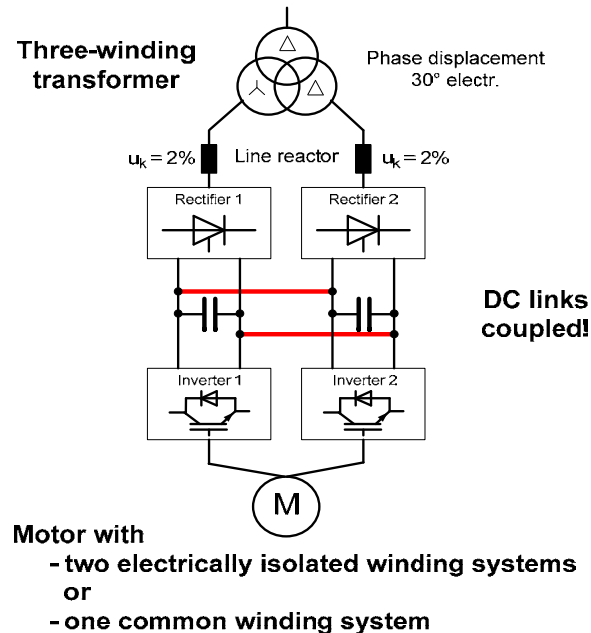
As the line-side rectifiers have no electronic current sharing control, the line-side currents must be balanced by the following measures:

- Use of line reactors with a relative short-circuit voltage of $u_k = 2\%$. The omission of the line reactors by choosing option L22 is not permissible.
- Use of symmetrical power cabling between the line connection point and the parallel-connected rectifiers (cables of identical type with the same cross-section and length)

The motor-side limitations and restrictions are described on the following pages in the section “Operation at motors with two electrically isolated winding systems and one common winding system”.

12-pulse operation of SINAMICS G150 parallel converters

At 12-pulse operation, each of the two rectifiers is connected to one secondary winding of a three-winding transformer, as illustrated in the following diagram.



12-pulse operation of SINAMICS G150 parallel converters

With SINAMICS G150 parallel converters, a correct 12-pulse operation can only be guaranteed when the following supplementary conditions are met:

- The DC links of both partial converters must be connected to each other.
- It is possible to connect both motors with two electrically isolated winding systems and motors with one common winding system.

As the line-side rectifiers have no electronic current sharing control, three-winding transformer, power cabling and line reactors must meet the following requirements in order to provide a balanced current:

- Three-winding transformer must be symmetrical, recommended vector groups Dy5d0 or Dy11d0.
- Relative short-circuit voltage of three-winding transformer $u_k \geq 4\%$.
- Difference between relative short-circuit voltages of secondary windings $\Delta u_k \leq 5\%$.
- Difference between no-load voltages of secondary windings $\Delta V \leq 0.5\%$.
- Use of symmetrical power cabling between the transformer and the two rectifiers (cables of identical type with the same cross-section and length)
- Use of line reactors with a relative short-circuit voltage of $u_k = 2\%$. (Line reactors can be omitted if a double-tier transformer is used and only one G150 parallel converter is connected to the transformer).

The relatively high demands on the three-winding transformer can generally only be met by using a double-tier transformer. In this case, the line reactors can be omitted. When using other types of three-winding transformers, line reactors are, however, required. Alternative solutions for obtaining a phase displacement of 30°, such as two separate transformers with different vector groups, cannot be used due to the inadmissibly high tolerances involved.

Since the three-winding transformer is equipped with a star and a delta winding, and the delta winding does not have a star point that is suitable for grounding, 12-pulse-operated SINAMICS G150 parallel connections are connected to two non-grounded secondary windings and, in turn, to an IT supply system. For this reason, G150 parallel connections in 12-pulse operation must be equipped with Option L87 / insulation monitor.

The motor-side limitations and restrictions are described on the following pages in the section "Operation at motors with two electrically isolated winding systems and one common winding system".

Operation at motors with electrically isolated winding systems and one common winding system

Operation of G150 parallel converters at motors with two electrically isolated winding systems

The following measures must be taken to balance the motor-side currents:

- Use of symmetrical power cabling between the two inverters and the motor (cables of identical type with the same cross-section and length)

Using a motor with two electrically isolated winding systems means that the motor-side inverters can operate with both, space vector modulation and pulse-edge modulation. Pulse-edge modulation makes it possible to achieve an output voltage which is almost equal to the value of the input voltage (97 %). (For further details, please refer to the chapter "Fundamental Principles and System Description", sections "Maximum attainable output voltage with space vector modulation SVM" and "Maximum attainable output voltage with pulse-edge modulation PEM".)

Despite the current-balancing measures described above, it is not possible to obtain an absolutely symmetrical current sharing. This means that the currents of the two converter units in a SINAMICS G150 parallel converter are 7.5 % lower than the currents of the individual converters. Allowance is already made for this reduction factor in the current values in catalog D11 and in the table on the previous pages.

Operation of G150 parallel converters at motors with one common winding system

The following measures must be taken to balance the motor-side currents:

- Electronic current sharing control in the motor-side inverters (parameter P7035 = 1).
- Use of symmetrical power cabling between the two inverters and the motor (cables of identical type with the same cross-section and length)
- Decoupling measures at the inverter outputs.

Adequate decoupling of the inverter outputs can be achieved either by installing cables of the minimum required length between the inverter outputs and the motor or, alternatively, by installing motor reactors at the inverter outputs (option L08).

The table below specifies the minimum required motor cable lengths for SINAMICS G150 parallel converters, whereby the given length is the distance between the converter output and the motor terminal box along the motor cable.

Output power [kW]	SINAMICS G150 cabinet unit Version A	Minimum motor cable length [m]
380 V to 480 V 3AC		
630	6SL3710-2GE41-1AA0	13
710	6SL3710-2GE41-4AA0	10
900	6SL3710-2GE41-6AA0	9
500 V to 600 V 3AC		
630	6SL3710-2GF38-6AA0	18
710	6SL3710-2GF41-1AA0	15
1000	6SL3710-2GF41-4AA0	13
660 V to 690 V 3AC		
630	6SL3710-2GH41-1AA0	20
1350	6SL3710-2GH41-4AA0	18
1500	6SL3710-2GH41-5AA0	15

Minimum required motor cable lengths for SINAMICS G150 parallel converters

Connecting a motor with one common winding system means that the motor-side inverters can operate only with space vector modulation, but not with pulse-edge modulation. As a result, the maximum attainable output voltage equals only approximately 92 % of the input voltage. (For further details, please refer to chapter "Fundamental Principles and System Description", sections "Maximum attainable output voltage with space vector modulation SVM" and "Maximum attainable output voltage with pulse-edge modulation PEM".)

Despite the current-balancing measures described above, it is not possible to obtain an absolutely symmetrical current sharing. This means that the currents of the two converter units in a SINAMICS G150 parallel converter are 7.5 % lower than the currents of the individual converters. Allowance is already made for this reduction factor in the current values in catalog D11 and in the table on the previous pages.

Special features to note when precharging SINAMICS G150 parallel converters

At G150 parallel converters, each of the two partial converters has a main rectifier equipped with thyristors and a small precharging rectifier equipped with diodes, which is connected in parallel to the main rectifier. If both partial converters are connected to the supply voltage at the same time, the DC links are charged via the two precharging rectifiers and the associated precharging resistors.

In the case of drive configurations where the DC links of both partial converters are connected to one another, the precharging principle described requires both of the partial converters to be connected to the supply system at the same time. Otherwise, the precharging rectifiers and precharging resistors of the partial converter connected first would have to precharge the entire DC link. These components are not thermally dimensioned for this type of operation and would, therefore, be overloaded or even destroyed.

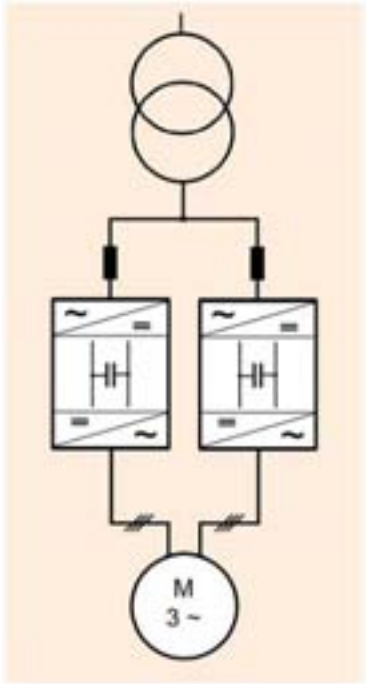
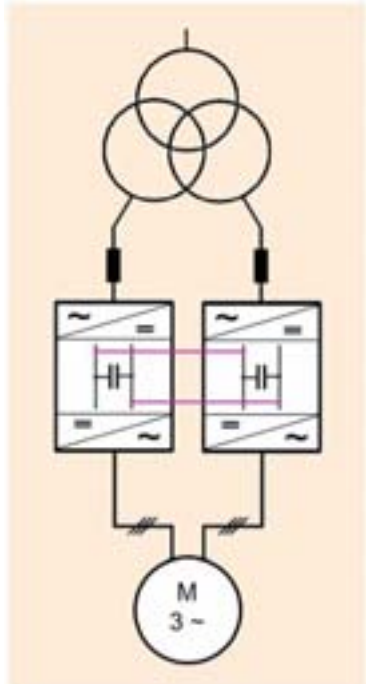
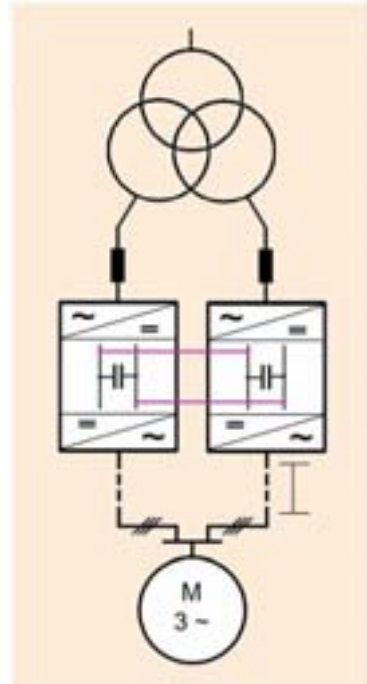
To ensure that both partial converters are connected to the supply system at the same time, the G150 parallel converters must be equipped with option L13 / main contactor (for $I_{\text{converter}} < 1500 \text{ A}$) or option L26 / circuit breaker (for $I_{\text{converter}} \geq 1500 \text{ A}$). In this way, the internal converter control can ensure that precharging takes place correctly. Options L13 and L26, which are listed in the table are, therefore, obligatory and cannot be removed from the selection.

Output power [kW]	Converter cabinet unit SINAMICS G150, Version A	Required option
380 V to 480 V 3AC		
630	6SL3710-2GE41-1AA0	L13 / main contactor
710	6SL3710-2GE41-4AA0	L13 / main contactor
900	6SL3710-2GE41-6AA0	L26 / circuit breaker
500 V to 600 V 3AC		
630	6SL3710-2GF38-6AA0	L13 / main contactor
710	6SL3710-2GF41-1AA0	L13 / main contactor
1000	6SL3710-2GF41-4AA0	L13 / main contactor
660 V to 690 V 3AC		
1000	6SL3710-2GH41-1AA0	L13 / main contactor
1350	6SL3710-2GH41-4AA0	L13 / main contactor
1500	6SL3710-2GH41-5AA0	L26 / circuit breaker

Required options for ensuring correct precharging

Brief overview of SINAMICS G150 parallel converters with production date up to autumn 2007

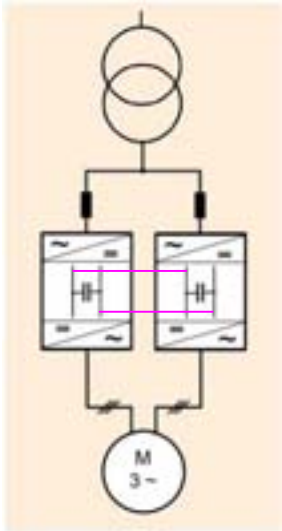
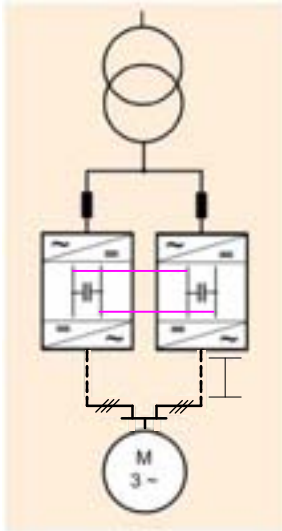
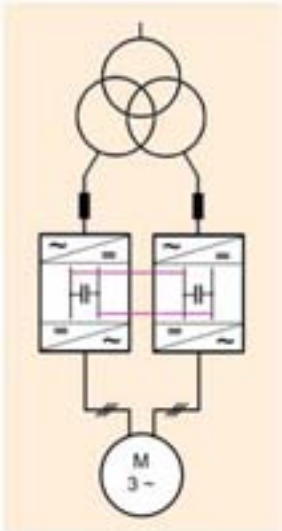
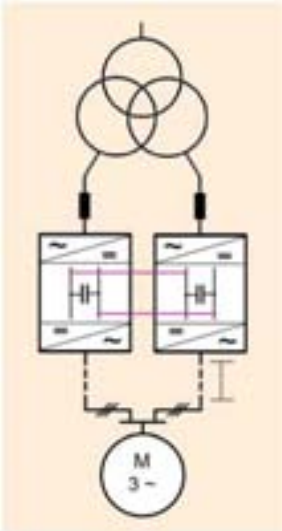
The following is a short overview of the permissible transformer-converter-motor combinations with SINAMICS G150 parallel converters.

6-pulse configuration	12-pulse configuration	12-pulse configuration
		
Line reactors required	Decoupling by means of three-winding transformer.	Decoupling by means of three-winding transformer.
Symmetrical power cabling	Symmetrical power cabling	Symmetrical power cabling
DC links of the two parallel-connected power units are not coupled.	DC links of the two parallel-connected power units are coupled.	DC links of the two parallel-connected power units are coupled.
The outputs of the two parallel-connected power units are connected to a motor with separate winding systems.	The outputs of the two parallel-connected power units are connected to a motor with separate winding systems.	The outputs of the two parallel-connected power units are connected to a motor with one common winding system.
Symmetrical power cabling	Symmetrical power cabling	Note specifications for minimum motor cable length or use motor reactors in the converter
Asynchronous motor with two separate winding systems	Asynchronous motor with two separate winding systems	Asynchronous motor with one common winding system
Control by SVM + PEM	Control by SVM + PEM	Control by SVM
Maximum motor voltage related to the line voltage: 97 %	Maximum motor voltage related to the line voltage: 97 %	Maximum motor voltage related to the line voltage: 92 %

Short overview about the configurations of SINAMICS G150 parallel converters with production date up to autumn 2007

Brief overview of SINAMICS G150 parallel converters with production date from autumn 2007

The following is a short overview of the permissible transformer-converter-motor combinations for SINAMICS G150 parallel converters.

6-pulse configuration	6-pulse configuration	12-pulse configuration	12-pulse configuration
			
Line reactors required; Symmetrical power cabling	Line reactors required; Symmetrical power cabling	Decoupling by means of a three-winding transformer. Symmetrical power cabling	Decoupling by means of a three-winding transformer. Symmetrical power cabling
DC links of the parallel-connected power units are coupled	DC links of the parallel-connected power units are coupled	DC links of the parallel-connected power units are coupled	DC links of the parallel-connected power units are coupled
The outputs of the two parallel-connected power units are connected to a motor with separate winding systems.	The outputs of the two parallel-connected power units are connected to a motor with one common winding system.	The outputs of the two parallel-connected power units are connected to a motor with separate winding systems.	The outputs of the two parallel-connected power units are connected to a motor with one common winding system.
Symmetrical power cabling	Note specifications for minimum motor cable length or use motor reactors in the converter.	Symmetrical power cabling	Note specifications for minimum motor cable length or use motor reactors in the converter.
Asynchronous motor with two separate winding systems	Asynchronous motor with one common winding system.	Asynchronous motor with two separate winding systems	Asynchronous motor with one common winding system
Control by SVM + PEM	Control by SVM	Control by SVM + PEM	Control by SVM
Maximum motor voltage related to the line voltage 97 %	Maximum motor voltage related to the line voltage 92 %	Maximum motor voltage related to the line voltage 97 %	Maximum motor voltage related to the line voltage 92 %

Short overview about the configurations of SINAMICS G150 parallel converters with production date from autumn 2007

SINAMICS S120, General Information about Built-in and Cabinet Units

General

The following sections describe those SINAMICS S120 components which are needed to create a drive system subject to certain supplementary conditions.

For information about individual components, please refer also to the online help in the SIZER configuring tool.

Assignment table

Some of the subjects discussed in this section apply generally to the SINAMICS S120 system, while others are relevant to specific unit types.

The following table is provided to help you determine which subjects are described to which unit type.

Subject	Valid for:		
	Built-in units S120 Booksize	Built-in units S120 Chassis	Cabinet unit range S120 Cabinet Modules
Control properties	X	X	X
Rating data		X	X
DRIVE CLiQ			
Basic information	X	X	X
DRIVE-CLiQ cables supplied with the unit		X	
Cable installation		X	
Specification of the required control performance and selection of the Control Unit	X	X	X
Specification of component cabling	X	X	X
Checking the maximum DC link capacitance	X	X	X
Braking Module / External braking resistor		X	X
Maximum connectable motor cable length	X	X	X
Checking the total cable length	X	X	X

Assignment table: Subject sections to different types of units

Control properties

Performance features

Features	Servo control	Vector control	V/f Control	Notes
Typical application	- Drives with highly dynamic motion control - Angular-locked synchronism with isochronous PROFIBUS - For use in machine tools and clocked production machines	- Speed-controlled drives with high speed and torque stability in general mechanical engineering systems - Particularly suitable for asynchronous motors	- Drives with low requirements on dynamic response and accuracy - Highly synchronized group drives	Mixed operation of different control modes is possible for V/f control. It is for this reason that the V/f control modes are stored only once in the Vector drive object. The V/f characteristic stored in the Servo drive object is provided only for diagnostic purposes.
Dynamic response	Very high	High	Low	
Control modes with encoder	Position control/ Speed control/ Torque control	Position control/ Speed control/ Torque control	None	

SINAMICS S120

Engineering Information

Features	Servo control	Vector control	V/f Control	Notes
Control modes without encoder	Speed control	Speed control/ Torque control	All V/f control modes	For asynchronous motors only with Servo With V/f control the speed can be kept constant by means of selectable slip compensation.
Setpoint resolution speed/frequency	31 bits + sign	31 bits + sign	0.001 Hz	
Setpoint resolution torque	31 bits + sign	31 bits + sign		
Default sampling rate Current/speed controller/pulse frequency (Booksize)	125 μ s/ 125 μ s/ 4 kHz	2 motor axes: 250 μ s/ 1000 μ s/ 4 kHz 4 motor axes: 400 μ s/ 1600 μ s/ 2.5 kHz	4 motor axes: 250 μ s/ 4 kHz 6 motor axes: 400 μ s/ 2.5 kHz 10 motor axes: 500 μ s/ 4 kHz	The sampling rate has an important influence on the dynamic control response. When "Isochronous PROFIBUS" is selected, the controller cycles are automatically adjusted to 125 μ s, 250 μ s, 375 μ s and 500 μ s.
Default sampling rate Current/speed controller/pulse frequency (Chassis frame sizes FX and GX)	250 μ s/ 250 μ s/ 2 kHz	250 μ s/ 1000 μ s/ 2 kHz	4 motor axes: 250 μ s/ 2 kHz 6 motor axes: 400 μ s/ 1.25 kHz 10 motor axes: 500 μ s/ 2 kHz	
Default sampling rate Current/speed controller/pulse frequency (Chassis frame sizes HX and JX and 690 V all frame sizes)		400 μ s/ 1600 μ s/ 1.25 kHz	6 motor axes: 400 μ s/ 1.25 kHz	
Default output frequency for current controller cycle/pulse frequency (Booksize)	650 Hz at 125 μ s/ 4 kHz	300 Hz at 250 μ s/ 4 kHz	400 Hz at 250 μ s/ 4 kHz	Note limit voltage (2 kV) and use of VPM Module with synchronous motors; see catalog PM21.
Default output frequency for current controller cycle/pulse frequency (Chassis frame sizes FX and GX)	300 Hz at 250 μ s/ 2 kHz	160 Hz at 250 μ s/ 2 kHz	200 Hz at 250 μ s/ 2 kHz	
Default output frequency for current controller cycle/pulse frequency (Chassis frame sizes HX and JX)		100 Hz at 400 μ s/ 1.25 kHz	100 Hz at 400 μ s/ 1.25 kHz	
Maximum field weakening with asynchronous motors	5 times	5 times	5 times	With Servo control combined with encoder and appropriate special motors, field weakening up to 16 times the field-weakening threshold speed is possible.
Maximum field weakening with synchronous motors	2 times 4 times with VPM, see catalog PM21	2 times	-	These values refer to synchronous motors of type 1FK7/1FT6. Please note the limit voltage (kE factor) for motors from external suppliers.

Control properties, definitions

Criteria for assessing control quality	Explanations, definitions
Rise time	The rise time is the period which elapses between a sudden change in the setpoint and the instant the actual value first reaches the specified tolerance band (2%) around the setpoint. The dead time is the period which elapses between an abrupt change in the setpoint and the moment the actual value begins to increase. The dead time is partially determined by the read-in, processing and output cycles of the digital closed-loop control. Where the dead time constitutes a significant proportion of the rise time, it must be separately identified.
Characteristic angular frequency -3 dB	The limit frequency is a measure of the dynamic response of a closed-loop control. A pure sinusoidal setpoint is input to calculate the limit frequency; no part of the control loop must reach the limit. The actual value is measured under steady-state conditions and the ratio between the amplitudes of actual value and setpoint is recorded. "-3 dB limit frequency": Frequency at which the absolute value of the actual value drops by 3 dB (to 71 %) for the first time. The closed-loop control can manage frequencies up to this value and remain stable.
Ripple	The ripple is the undesirable characteristic of the actual value which is superimposed on the mean value (useful signal). Oscillating torque is another term used in relation to torque. Typical oscillating torques are caused by motor slot grids, by limited encoder resolution or by the limited resolution of the voltage control of the IGBT power unit. The torque ripple is also reflected in the speed ripple as being indirectly in proportion to the mass inertia of the drive. The ripple is also a measure of "differential" accuracy and therefore also primarily defines the dynamic response to disturbances of the control system.
Accuracy	Accuracy is a measure of the magnitude of the average, repeatable deviation between the actual value and setpoint under nominal conditions. Deviations between the actual value and setpoint are caused by internal inaccuracies in the measuring and control systems. External disturbances, such as temperature or speed, are not included in the accuracy assessment. The closed-loop and open-loop controls should be optimized with respect to the relevant variable.

Closed-loop control characteristics

	Servo control		Vector control		Notes
Induction motor	1PH7/ 1PL6 without encoder	1PH7/ 1PL6 with incremental encoder 1024 pulses/rev.	1PH7/ 1PL6 without encoder	1PH7/ 1PL6 with incremental encoder 1024 pulses/rev.	
	Booksize format, pulse frequency 4 kHz, closed-loop torque control				
Controller cycle	125 µs	125 µs	250 µs	250 µs	
Total rise time (rise time + dead time)	-	1.8 ms (0.8 + 1)	3 ms (2 + 1)	2.2 ms (1.2 + 1)	With encoderless operation in speed operating range 1:10, with encoder 50 rpm and above up to rated speed. A dead time of 1 ms is the default setting for PROFIBUS DP.
Characteristic angular frequency -3 dB	-	600 Hz	250 Hz	400 Hz	With encoderless operation in speed operating range 1:10. The dynamic response is enhanced by an encoder feedback.
Torque ripple	-	1.5 % of M_{rated}	2 % of M_{rated}	2 % of M_{rated}	With encoderless operation in speed operating range 1:20, with encoder 20 rpm and above up to rated speed.
Torque accuracy	-	±3.5 % of M_{rated}	±2 % of M_{rated}	1.5 % of M_{rated}	Measured value averaged over 3s. With motor identification and friction compensation; temperature effects compensated by KTY84 and mass model. In torque operating range up to $\pm M_{rated}$. Approx. additional inaccuracy of ± 2.5% in field-weakening range. <u>Servo</u>: Speed operating range 1:10 referred to rated speed. <u>Vector</u>: Speed operating range 1:50 referred to rated speed.

	Servo control		Vector control		Notes
Induction motor	1PH7/ 1PL6 without encoder	1PH7/ 1PL6 with incrementtal encoder 1024 pulses/rev.	1PH7/ 1PL6 without encoder	1PH7/ 1PL6 with incremental encoder 1024 pulses/rev.	
Booksize format, pulse frequency 4 kHz, closed-loop speed control					
Controller cycle	125 µs	125 µs	250 µs	250 µs	
Total rise time (rise time + dead time)	13 ms (12 + 1)	5 ms (4 + 1)	12 ms (11 + 1)	8 ms (7 + 1)	With encoderless operation in speed operating range 1:10, with encoder 50 rpm and above up to rated speed. A dead time of 1 ms is the default setting for PROFIBUS DP.
Characteristic angular frequency -3 dB	40 Hz	120 Hz	50 Hz	80 Hz	With encoderless operation in speed operating range 1:10. The dynamic response is enhanced by an encoder feedback. Servo with encoder is slightly more favorable than Vector with encoder, as the speed controller cycle with Servo is quicker.
Speed ripple	See notes	See notes	See notes	See notes	Mainly determined by the total mass moment of inertia, the torque ripple and, most importantly, the mechanical design. It is not therefore possible to specify a generally valid value.
Speed accuracy	$0.1 \times f_{\text{slip}}$	$\leq 0.001 \%$ of n_{rated}	$0.05 \times f_{\text{slip}}$	$\leq 0.001 \%$ of n_{rated}	Without encoder: Determined primarily by the accuracy of the calculation model for the torque-producing current and rated slip of the asynchronous motor (see table "Typical slip values"). With speed operating range 1: 50 (Vector) or 1:10 (Servo) and with active temperature evaluation.
Chassis format, pulse frequency 2 kHz, closed-loop torque control					
Controller cycle	250 µs	250 µs	250 µs	250 µs	
Total rise time (rise time + dead time)	-	2.6 ms (1.6 + 1)	3.5 ms (2.5 + 1)	2.6 ms (1.6 + 1)	With encoderless operation in speed operating range 1:10, with encoder 50 rpm and above up to rated speed. A dead time of 1 ms is the default setting for PROFIBUS DP.
Characteristic angular frequency -3 dB	-	350 Hz	200 Hz	300 Hz	With encoderless operation in speed operating range 1:10. The dynamic response is enhanced by an encoder feedback.
Torque ripple	-	2 % of M_{rated}	2.5 % of M_{rated}	2 % of M_{rated}	With encoderless operation in speed operating range 1:20, with encoder 20 rpm and above up to rated speed.
Torque accuracy	-	$\pm 3.5 \%$ of M_{rated}	$\pm 2 \%$ of M_{rated}	$\pm 1.5 \%$ of M_{rated}	Measured value averaged over 3 s. With motor identification and friction compensation; temperature effects compensated by KTY84 and mass model. In torque operating range up to $\pm M_{\text{rated}}$. Approx. additional inaccuracy of $\pm 2.5 \%$ in field-weakening range. <u>Servo:</u> Speed operating range 1:10 referred to rated speed. <u>Vector:</u> Speed operating range 1:50 referred to rated speed.

	Servo control		Vector control		Notes
Induction motor	1PH7/ 1PL6 without encoder	1PH7/ 1PL6 with incremental encoder 1024 pulses/rev.	1PH7/ 1PL6 without encoder	1PH7/ 1PL6 with incremental encoder 1024 pulses/rev.	
Chassis format, pulse frequency 2 kHz, closed-loop speed control					
Controller cycle	250 µs	250 µs	250 µs	250 µs	
Total rise time (rise time + dead time)	21 ms (20 + 1)	8 ms (7 + 1)	14 ms (13 + 1)	12 ms (11 + 1)	With encoderless operation in speed operating range 1:10, with encoder 50 rpm and above up to rated speed. A dead time of 1 ms is the default setting for PROFIBUS DP.
Characteristic angular frequency -3 dB	25 Hz	80 Hz	35 Hz	60 Hz	With encoderless operation in speed operating range 1:10. The dynamic response is enhanced by an encoder feedback. Servo with encoder is slightly more favorable than Vector with encoder, as the speed controller cycle with Servo is quicker.
Speed ripple	See notes	See notes	See notes	See notes	Mainly determined by the total mass moment of inertia, the torque ripple and, most importantly, the mechanical design. It is not therefore possible to specify a generally valid value.
Speed accuracy	0.1 x f _{slip}	≤ 0.001 % of n _{rated}	0.05 x f _{slip}	≤ 0.001 % of n _{rated}	Without encoder: Determined primarily by the accuracy of the calculation model for the torque-producing current and rated slip of the asynchronous motor (see table "Typical slip values"). With speed operating range 1: 50 (Vector) or 1:10 (Servo) and with active temperature evaluation.

Typical slip values for standard asynchronous motors

Motor power	Slip values	Notes
< 1 kW	6% of n _{rated} e.g. motor with 1500 rpm: 90 rpm	Asynchronous motors 1PH7/1PH8 are very similar to standard motors where slip values are concerned.
< 10 kW	3% of n _{rated} e.g. motor with 1500 rpm: 45 rpm	
< 30 kW	2% of n _{rated} e.g. motor with 1500 rpm: 30 rpm	
< 100 kW	1% of n _{rated} e.g. motor with 1500 rpm: 15 rpm	
> 500 kW	0.5% of n _{rated} e.g. motor with 1500 rpm: 7.5 rpm	

Rating data

Maximum output frequencies

The maximum output frequency for SINAMICS S120 chassis units is limited to either 160 Hz or 100 Hz due to the factory-set pulse frequency of either $f_{\text{pulse}} = 2.00 \text{ kHz}$ or $f_{\text{pulse}} = 1.25 \text{ kHz}$. Higher output frequencies can be obtained only through an increase in the pulse frequency. As the switching losses in the motor-side IGBT inverter increase in proportion to the pulse frequency, the output current must be reduced accordingly.

Output Power at 400 V resp. 690 V	Rated Output Current at pulse frequency of		Current Derating Factor at pulse frequency of	
	2 kHz	1.25 kHz	4 kHz	2.5 kHz

380 V – 480 V 3AC

110 kW	210 A	-	82 %	-
132 kW	260 A	-	83 %	-
160 kW	310 A	-	88 %	-
200 kW	380 A	-	87 %	-
250 kW	490 A	-	78 %	-
315 kW	-	605 A	-	72 %
400 kW	-	745 A	-	72 %
450 kW	-	840 A	-	79 %
560 kW	-	985 A	-	87 %
710 kW	-	1260 A	-	87 %
800 kW	-	1405 A	-	95 %

500 V – 690 V 3AC

75 kW	-	85 A	-	89 %
90 kW	-	100 A	-	88 %
110 kW	-	120 A	-	88 %
132 kW	-	150 A	-	84 %
160 kW	-	175 A	-	87 %
200 kW	-	215 A	-	87 %
250 kW	-	260 A	-	88 %
315 kW	-	330 A	-	82 %
400 kW	-	410 A	-	82 %
450 kW	-	465 A	-	87 %
560 kW	-	575 A	-	85 %
710 kW	-	735 A	-	79 %
800 kW	-	810 A	-	95 %
900 kW	-	910 A	-	87 %
1000 kW	-	1025 A	-	86 %
1200 kW	-	1270 A	-	79 %

SINAMICS S120 Chassis: Permissible output current as a function of pulse frequency

Pulse frequency	Maximum attainable output frequency
1.25 kHz	100 Hz
2.00 kHz	160 Hz
2.50 kHz	200 Hz
≥ 4.00 kHz	300 Hz

Maximum attainable output frequency as a function of pulse frequency

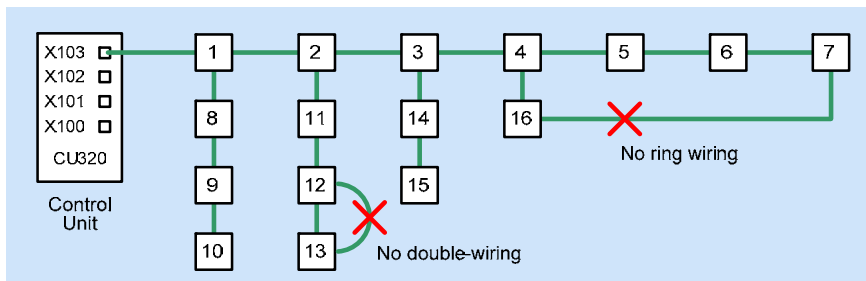
DRIVE CLiQ

Basic informations

All SINAMICS components communicate with one another via the standardized DRIVE CLiQ interface. This interface connects a Control Unit with the power components, encoders and other system components such as terminal modules.

Setpoints and actual values, control commands, status messages and rating plate data of the components are transferred via DRIVE CLiQ.

Only one current controller clock cycle can be set for modules connected via DRIVE-CLiQ. In consequence, only combinations with an identical current controller clock cycle can be operated on the same DRIVE-CLiQ connection (see tables in the sections "Specification of the required control performance and selection of the Control Unit" and "Specification of component cabling"). To simplify the configuring process, it is advisable to supply the Line Modules and Motor Modules via separate DRIVE-CLiQ connections.



Wiring of DRIVE-CLiQ components

The following rules apply to the wiring of components with DRIVE-CLiQ:

- A maximum of 16 nodes can be connected to a DRIVE-CLiQ socket on the CU320 Control Unit
- A maximum of 8 nodes can be configured in one line. A line always starts at the Control Unit.
- Maximum 6 Motor Modules in one line
- Ring wiring is not permitted
- Components must not be double-wired.

In addition, the motor encoder should be connected to the associated Motor Module.

Control Units cannot communicate with one another via DRIVE-CLiQ.

DRIVE-CLiQ cables supplied with the unit

Built-in units are supplied as standard with DRIVE-CLiQ cables. Their length is tailored to the requirements of the relevant module. This guarantees that the delivered components can be assembled into a functional unit with these standard cables.

However, the cable lengths are suitable only for standard configurations. The lengths which may be required for specific applications must be calculated at the configuring stage and ordered separately if necessary. Only cables adapted to the given ambient conditions must be used. Information can be found in the SINAMICS catalogs.

Device	Supplied DRIVE-CLiQ cables (pre-assembled)
CU320, D4xx	--
Basic Line Module	1 x 0.6 m DRIVE-CLiQ cable for connection to the Control Unit 1 x 1.45 m DRIVE-CLiQ cable for connection to the first Motor Module
Smart Line Module	
Frame size GX:	1 x 0.6 m DRIVE-CLiQ cable for connection to the Control Unit
Frame sizes HX and JX	1 x 0.3 m DRIVE-CLiQ cable for connection to the Control Unit 1 x 1.2 m DRIVE-CLiQ cable for connection to the first Motor Module
Active Interface Module	
Frame size FI	1 x 0.6 m DRIVE-CLiQ cable for connection of the Voltage Sensing Module in AIM to the Active Line Module 1 x 1.45 m DRIVE-CLiQ cable for connection to the first Motor Module
Frame size GI	1 x 0.95 m DRIVE-CLiQ cable for connection of the Voltage Sensing Module in AIM to the Active Line Module 1 x 1.45 m DRIVE-CLiQ cable for connection to the first Motor Module
Frame sizes HI and JI	1 x 2.4 m DRIVE-CLiQ cable for connection of the Voltage Sensing Module in AIM to the Active Line Module
Active Line Module	
Frame sizes FX and GX	1 x 0.6 m DRIVE-CLiQ cable for connection to the Control Unit
Frame sizes HX and JX	1 x 0.35 m DRIVE-CLiQ cable for connection to the Control Unit 1 x 2.1 m DRIVE-CLiQ cable for connection to the first Motor Module
Motor Module	
Frame size FX und GX	1 x 0.6 m DRIVE-CLiQ cable for connection to the next Motor Module
Frame size HX und JX	1 x 0.35 m DRIVE-CLiQ cable for the connection to the Control Unit 1 x 2.1 m DRIVE-CLiQ cable for connection to the next Motor Module
Liquid Cooled	
DC / AC Basic Line Module	1 x 0.6m DRIVE-CLiQ cable for connection to the Control Unit
DC / AC Active Line Module	1 x 0.6m DRIVE-CLiQ cable for connection to the Control Unit 1 x 0.6m DRIVE-CLiQ-cable for connection of the Voltage Sensing Module in AIM to the Active Line Module
DC / AC Motor Module	1 x 0.6m DRIVE-CLiQ cable for connection to the Control Unit
AC / AC Power Module	1 x 0.6m DRIVE-CLiQ cable for connection to the Control Unit

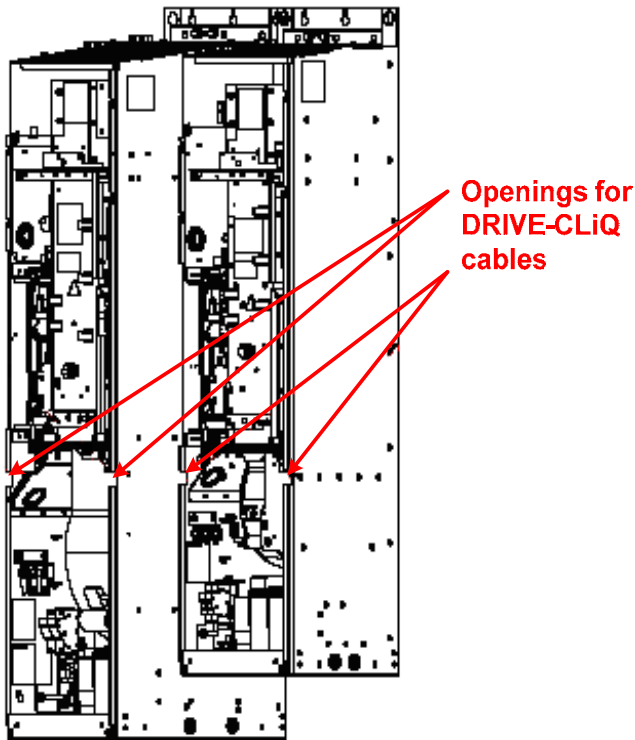
DRIVE-CLiQ cables supplied with the chassis units

For units in Booksize format the DRIVE-CLiQ cables are supplied in the relevant width to make the connection to the next following module.

Cable installation

DRIVE-CLiQ cables should be installed according to the same rules specified for signal cables.

Since the cables supplied as standard and available as options have special properties, there is no need to provide extra shield bonding in the cabinet. The cables should be routed in zones C and D of the cabinet where possible (refer to the chapter "EMC Installation Guideline").



The DRIVE-CLiQ cable connection and the Control Unit position are in the center of the power unit on Chassis models. The cables can be routed directly to the power unit by side openings on the chassis unit. The differences in depth of the various frame sizes must be taken into account. The difference in depth is about 200 mm.

The picture on the left shows these openings illustrated by the example of Motor Modules in frame sizes FX and GX. The cables supplied as standard with the equipment can be easily routed through these aperture.

Additional cables may be required, for example, if they need to be routed over cross-beams or along other routes. In this case, these cables need to be calculated and ordered individually.

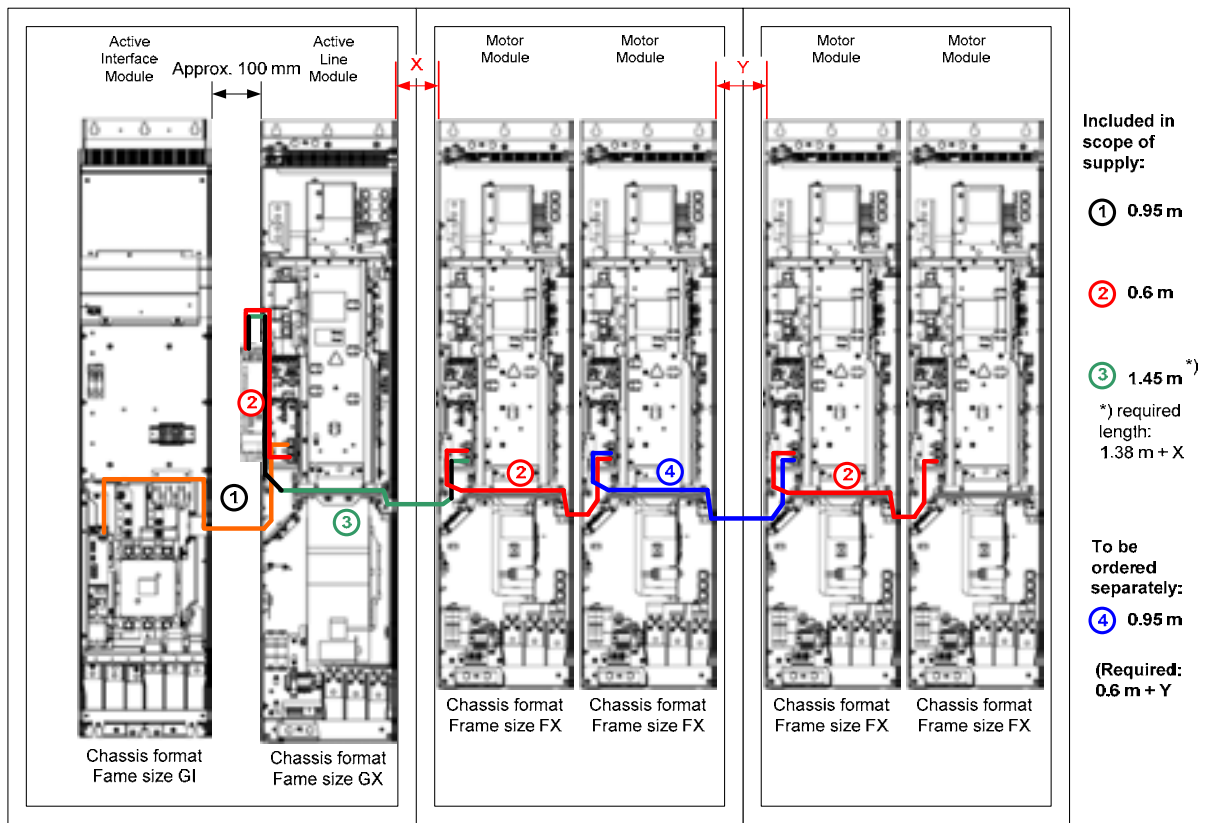
Openings in the chassis power units for cable entry and connection

Example of how to calculate and route the required DRIVE-CLiQ cables:

In this example, we will use DRIVE-CLiQ cables to connect a drive line-up comprising four Motor Modules in frame size FX, which are supplied by an Active Line Module with an Active Interface Module in frame size GX. The cabinets are assembled as shown in the picture below.

The Control Unit must be latched into the lugs provided on the left-hand side of the Active Line Module. The Active Interface Module must be mounted next to the Active Line Module, but at a distance of ≥ 100 mm so that the Control Unit connections are still accessible.

The Voltage Sensing Module (in the Active Interface Module) is connected to the Control Interface Board of the Active Line Module by means of cable [1] which is supplied with the Active Interface Module. The connection between the Control Unit and the Active Line Module is made with the 0.6 m DRIVE-CLiQ cable [2] which is supplied with the Active Line Module. The 1.45 m DRIVE-CLiQ cable [3] (supplied with the Active Interface Module) is used to link the first Motor Module to the Control Unit. The DRIVE-CLiQ cables from the Control Unit to the Active Line Module and the first Motor Module must be routed through the rubber sleeve on the left-hand side panel of the Active Line Module. The connections between adjacent Motor Modules are made with the 0.6 m DRIVE-CLiQ-cables [2] which are included in the accessories pack of each Motor Module in frame size FX.



DRIVE-CLiQ connections between Active Line Module, frame size GX, and Motor Modules, frame size FX

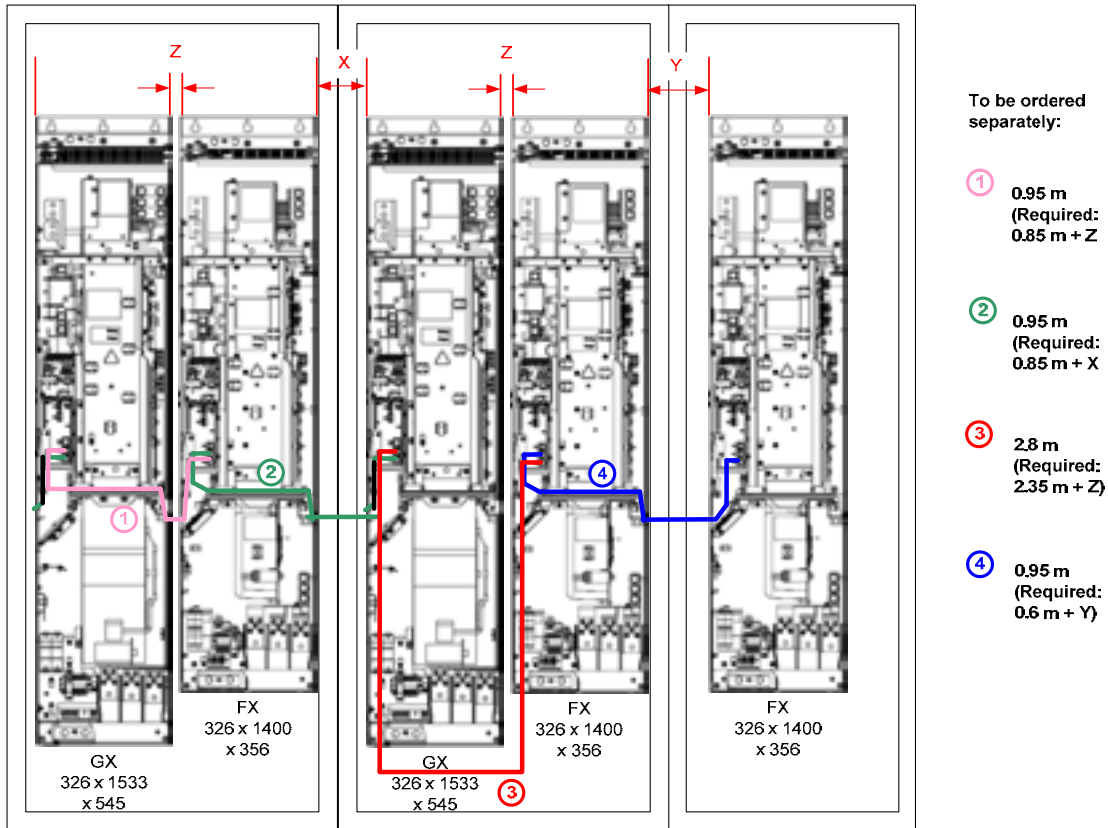
A longer DRIVE-CLiQ cable will be required to bridge cabinet cross-beams, to link Motor Modules which are not mounted adjacently, or to link combinations of Motor Modules in frame sizes FX and GX (please note depth difference between these module frame sizes). These cable lengths can be calculated using the formulas given in the picture.

A distance X of about 70 mm can be bridged with the supplied cable [3] in order to connect an Active Line Module in frame size GX with a Motor Module in frame size FX. The same cable can bridge a distance X of about 270 mm to make a connection between modules of the same frame size, as these are of the same depth.

The 0.6 m DRIVE-CLiQ cable supplied with the Motor Module is too short as cable [4] to bridge distance Y. The next-longer, pre-assembled DRIVE-CLiQ cable in the catalog, 0.95 m in length, will normally be used for this purpose. This 0.95 m DRIVE-CLiQ cable can also be used to link Motor Modules of different frame sizes, i.e. FX and GX (please note the difference in depth of 200 mm between frame sizes FX and GX).

This cable is shown as cable [2] in the picture below.

The DRIVE-CLiQ cable [2] can be brought into a Motor Module in frame size FX through the side panel only if the adjacent Motor Module in frame size GX is mounted at a distance of > about 20 mm.



DRIVE-CLiQ connections on Motor Modules of different frame sizes

If the distance Z is less than about 20 mm, i.e. the Motor Modules are mounted flush with one another, the DRIVE-CLiQ cable must be brought into the chassis unit from below, as illustrated by cable 3 in the picture.

If the unit is supplied by a Basic Line Module or a Smart Line Module, the DRIVE-CLiQ connections must be made analogous to systems supplied by the Active Line Module. The Control Unit is latched into the fixing lugs on the left-hand side of the Line Module. The DRIVE-CLiQ cables from the Control Unit to the Line Module and the first Motor Module must be routed through the rubber sleeve on the left-hand side panel of the unit.

Specification of the required control performance and selection of the Control Unit

The CU320 Control Unit has been designed to control multiple drives. It provides the control functions for the drives (Line Modules, Motor Modules) and system components.

The load on the Control Unit will vary depending on the number of individual drives and the required mode of control. The following data should be used to estimate the load:

Vector control (also includes V/f control modes)	Load with a current controller cycle of 400 µs or 250 µs
1 Line Module + 1 Motor Module	33 or 43 %
Each additional Motor Module	19 or 28 %

V/f control	Load
1 Line Module + 1 Motor Module	24 or 30 %
Each additional Motor Module	10 or 15 %

The respective load data already include central communication applications and the closed-loop control of an Active Infeed or Smart Infeed. When a Basic Line Module (uncontrolled Infeed) is used, the load is approximately 5 % lower than with other Line Modules.

The load increases by approximately 1 % per module for each installed Terminal Module.

The total performance requirement is dependent on the scope of functions and control dynamic response demanded by the application and, above all, by the number of drives to be operated on one Control Unit. Performance expansion 1 will be required for capacity utilization of 55 % or higher.

Total load	Required components (in addition to the Control Unit)
≤55 %	CompactFlash card without performance expansion (option K90 of S120 Cabinet Modules)
>55 % to ≤100 %	CompactFlash card with performance expansion 1 (option K91 of S120 Cabinet Modules)
>100 %	Additional CU320 Control Unit and CompactFlash card required

The computing capacity requirement or utilization of the CU320 Control Unit can be calculated exactly with the SIZER configuration tool. The table below also provides a rough guide.

	Dynamic response (current controller clock cycle)	Number of axes without performance expansion 1	Number of axes with performance expansion 1	Note
Servo control	125 µs	3	6	Plus one Infeed (BLM, SLM, ALM). No. of axes applies only to basic scope of functions. Without extended setpoint channel. Note power unit derating.
	250 µs	3	6	
Vector control	250 µs	1	2	Plus one Infeed (BLM, SLM, ALM). No. of axes applies only to basic scope of functions. Extended setpoint channel is a standard feature. Note power unit derating.
	400 µs	2	4	
V/f control	250 µs	2	4	Plus one Infeed (BLM, SLM, ALM). No. of axes applies only to basic scope of functions. Extended setpoint channel is a standard feature.
	400 µs	3	6	
	500 µs	4	8	

SINAMICS S120

Engineering Information

Depending on frame size and number of Motor Modules used, the following combinations can be operated on a CU320 Control Unit:

Chassis/Cabinet Modules (without Booksize Cabinet Kits)	Curr ctrl clock cycle	Settable pulse frequencies				Performance expansion 1 required
		w/o current derating (standard)	with current derating			
of frame sizes FX and GX 510 - 720 V DC; 380 - 480 V 3AC	μs	kHz	kHz	kHz	kHz	
Active Line Modules	250	4	-	-	-	
1x vector control	250	2	4	-	8	no
2x vector control	250	2	4	-	8	yes
3x vector control	400	1.25	2.5	5	-	yes
4x vector control	400	1.25	2.5	5	-	yes
2x V/f control	250	2	4	-	8	no
3x V/f control	250	2	4	-	8	yes
4x V/f control	250	2	4	-	8	yes
5x V/f control	400	1.25	2.5	5	-	yes
6x V/f control	400	1.25	2.5	5	-	yes

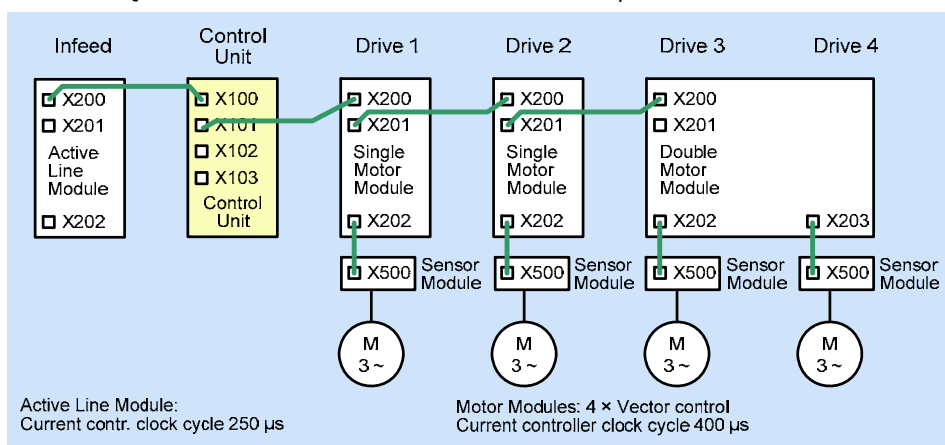
Chassis/Cabinet Modules (without Booksize Cabinet Kits)	Curr ctrl clock cycle	Settable pulse frequencies				Performance expansion 1 required
		w/o current derating (standard)	with current derating			
of frame sizes HX and JX 510 - 720 V DC; 380 - 480 V 3AC, of frame sizes FX, GX, HX and JX 750 - 1035 V DC; 500 - 690 V 3AC	μs	kHz	kHz	kHz	kHz	
Active Line Modules types FX; GX	250	4	-	-	-	
Active Line Modules types HX; JX	400	2.5	-	-	-	
1x vector control	250	1.25	2.5	5	-	no
2x vector control	250	1.25	2.5	5	-	no
3x vector control	400	1.25	2.5	5	-	yes
4x vector control	400	1.25	2.5	5	-	yes
1x V/f control	250	1.25	2.5	5	-	no
2x V/f control	250	1.25	2.5	5	-	no
3x V/f control	250	1.25	2.5	5	-	no
4x V/f control	250	1.25	2.5	5	-	yes
5x V/f control	400	1.25	2.5	5	-	yes
6x V/f control	400	1.25	2.5	5	-	yes

Specification of component cabling

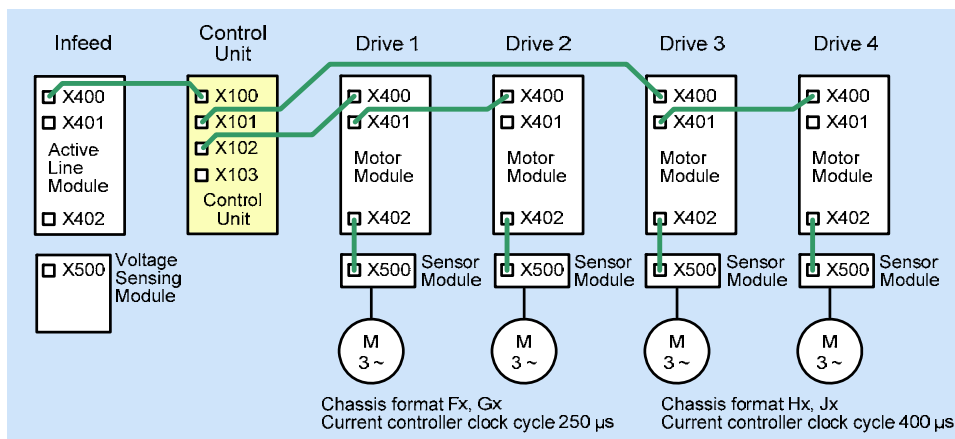
All the modules linked via one DRIVE-CLiQ connection must operate on the same current controller clock cycle. For this reason, only combinations of modules with the same current controller clock cycle can be operated in the same DRIVE-CLiQ connection. To simplify the configuring process, it is advisable to supply Line Modules and Motor Modules via separate DRIVE-CLiQ lines.

The power components are supplied with the required DRIVE-CLiQ connecting cables for connection to the adjacent DRIVE-CLiQ node in the axis grouping (line topology) (not applicable to S120 Cabinet Modules). Please follow the instructions in section "Cable installation". Pre-assembled DRIVE-CLiQ cables in various lengths up to 100 m are available for connecting motor encoders, direct measuring encoders, Terminal Modules, etc.

The DRIVE-CLiQ cable connections inside the cabinet must not exceed 70 m in length, e.g. connection between the CU320 Control Unit and the first Motor Module or between Motor Modules. The maximum permissible length of DRIVE-CLiQ MOTION-CONNECT cables to external components is 100 m.

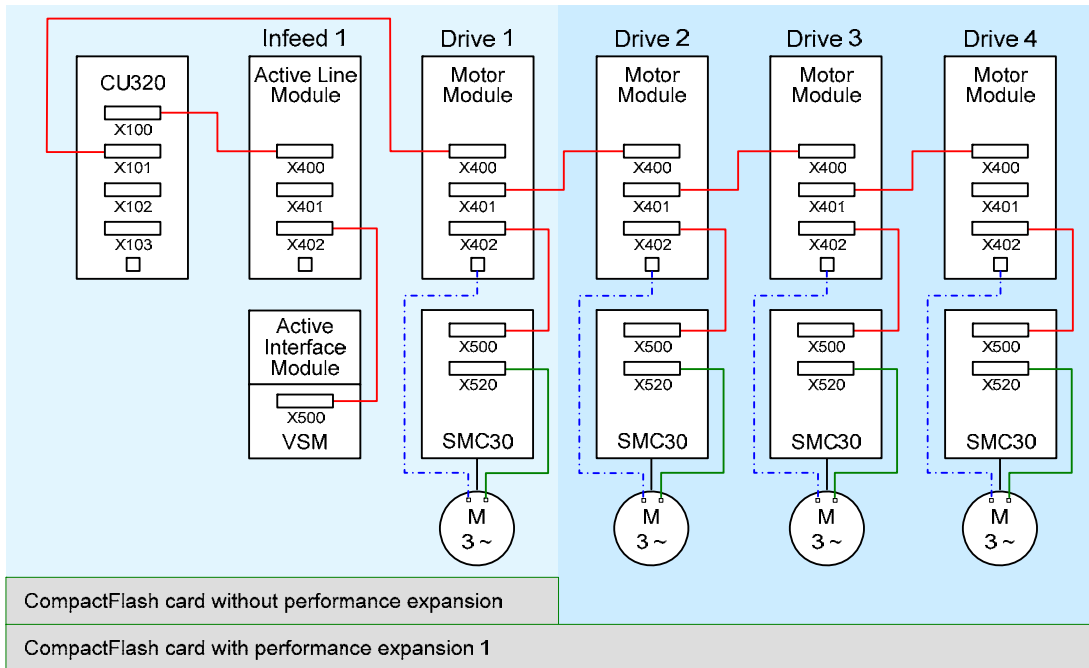


Wiring of DRIVE-CLiQ connections illustrated by example of units in Booksize format



Wiring of DRIVE-CLiQ connections illustrated by example of units in chassis format with different current controller clock cycles

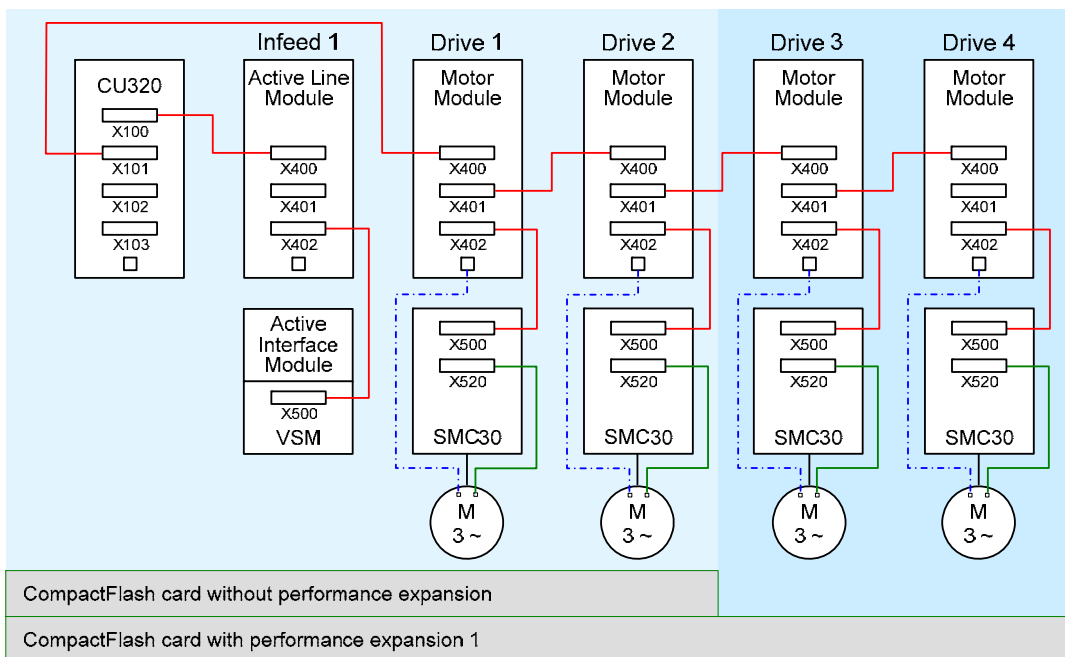
Drive group comprising up to 4 Motor Modules in chassis format with the **same** current controller clock cycle (250 μ s)



In a drive group with Motor Modules, a maximum of 4 Motor Modules with vector control can be operated on one CU 320 or a maximum of 6 Motor Modules with V/f control. In the case of Motor Modules in voltage range 380 V to 480 V, <250 kW, the pulse frequency of all the Motor Modules operating in one DRIVE-CLiQ line is automatically reduced from 2 kHz to 1.25 kHz from the third Motor Module.

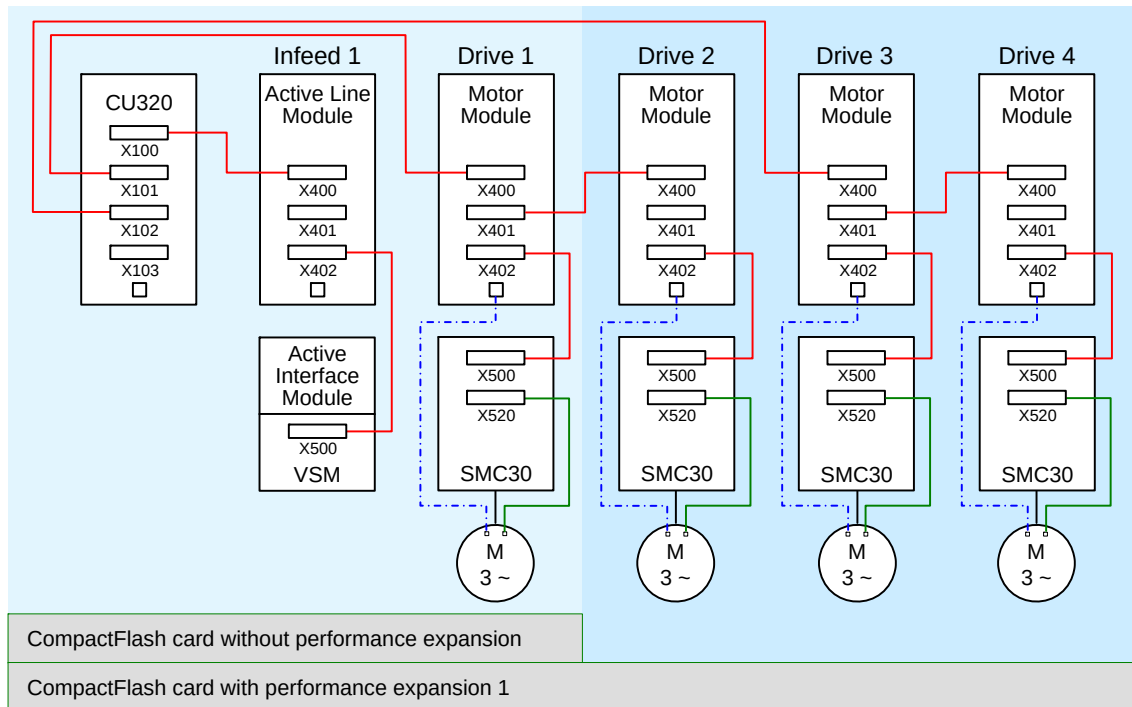
It is not permissible to connect a mixture of modules operating on different pulse frequencies (e.g. 2 kHz and 1.25 kHz) on the same port of the CU320. If the output frequency and thus also the pulse frequency need to be increased to achieve the required motor speed, the relevant DRIVE-CLiQ connection must be planned accordingly.

Drive group comprising up to 4 Motor Modules in chassis format with the **same** current controller clock cycle (400 μ s)



In a drive group with Motor Modules in chassis format, a maximum of 4 Motor Modules with vector control can be operated on one CU 320 or a maximum of 6 Motor Modules with V/f control. In the case of Motor Modules in voltage range 380 V to 480 V, >250 kW, and Motor Modules in voltage range 500 V to 690 V the modules are operated with a current controller clock cycle of 400 μ s. Please note that performance expansion will be required for the second Motor Module and above.

Drive group comprising up to 4 Motor Modules in chassis format with **different** current controller clock cycles (250 / 400 μ s) "mixed operation"



With a mixed complement, i.e. Motor Modules with different pulse frequencies, of the kind which can occur in the 380 V to 480 V voltage range, the modules must be connected to different ports on the CU320 Control Unit depending on their pulse frequency.

In the above picture, for example, two Motor Modules with an output of <250 kW and a pulse frequency of 2 kHz are connected to port X101 on the CU 320 and two Motor Modules with an output of >250 kW and a pulse frequency of 1.25 kHz are connected to port X102 on the CU 320.

If a separate control cabinet is provided for the drive system or if several S120 units (Booksize, Chassis, Cabinet Modules) are to be operated on the same CU320, the required DRIVE-CLiQ connecting cables must be ordered separately. For connections inside of S120 Cabinet Modules or Booksize Cabinet Kits, the cables are supplied as standard. For further information, please refer to the subsection "DRIVE-CLiQ wiring" of the chapter "Modular Cabinet Unit System S120 Cabinet Modules" and to the section which deals specifically with "Booksize Base Cabinet/ Booksize Cabinet Kits".

■ Check of the maximum DC link capacitance

Basic informations

The DC link of the SINAMICS devices must be precharged via a precharging circuit integrated in the SINAMICS S120 Infeed when the rectifier is connected to the supply voltage. At the moment of connection, the precharging circuit limits the charging current flowing into the capacitors of the DC link. For more information about the precharging circuits used in the various Infeed variants, see section "SINAMICS Infeeds and their properties" of the chapter "Fundamental Principles and System Description".

In the case of S120 Basic Infeeds with lower power ratings, precharging is time-controlled and takes place by changing the firing angle of the rectifier thyristors (phase angle control). In the case of S120 Basic Infeeds with higher power ratings, which are equipped with rectifier diodes, and in the case of S120 Smart Infeeds and S120 Active Infeeds, the precharging circuit comprises precharging contactors and precharging resistors, which precharge the DC link via the rectifier diodes.

If an excessive DC link capacitance is connected, this can result in an excessive precharging current, which can overheat or even destroy the precharging contactor and precharging resistors.

Under unfavorable operating conditions, however, an excessive DC link capacitance can also endanger the rectifier diodes. In this case, a critical operating condition is a short-term interruption or failure in the supply system, where the voltage is restored shortly before the undervoltage shutdown threshold in the DC link is reached. Due to the resulting voltage rise, recharge currents can occur in the DC link that can damage the rectifier diodes.

Situations such as these mean that the DC link capacitance of the drives (Motor Modules) connected to the S120 Infeeds must be limited and must not exceed the maximum permissible DC link capacitance values stipulated in the technical specifications.

The influencing factors described must be evaluated differently for different Infeeds:

For S120 Basic Infeeds, the precharging circuit is the limiting factor since, due to the fact that the precharging time is just a few seconds, excessive charging currents can occur when high DC link capacitances are connected. These can endanger the thyristors and, in particular, the precharging resistors for the diode rectifiers.

For S120 Smart Line Modules supply voltage dips are the limiting factor. The limitations of the DC link capacitance have to ensure that the recharging current into the DC link after supply voltage dips cannot damage the rectifier diodes in the Smart Line Modules as described above. This effect is almost independent of the voltage as long as the relative short-circuit voltage of the supply system is at least $u_k = 4\%$ related to the rated current of the SLM. Drive configurations supplied by Smart Line Modules, which consists of a huge number of Motor Modules, require larger values of the line supply impedance resp. larger values of the relative short-circuit voltage. The corresponding values for $u_k = 4\%$ and $u_k = 8\%$ have been incorporated into the tables below.

For Active Line Modules the precharging resistor is the critical limitation, due to the fact that the line side current is controlled by the firmware. It is, therefore, possible to define different DC link capacitances depending on the voltage range. This has also been incorporated into the table below.

With Infeed units connected in parallel, the maximum possible DC link capacitance is determined by the number of Infeed Modules connected in parallel multiplied by their maximum DC link capacitance. Prerequisite for this is that all units connected in parallel are connected to the supply voltage simultaneously (e.g. by a circuit breaker).

Capacitance values

In order to check that the overall capacitance does not exceed the limit values, all individual capacitance values at the DC link (including the internal capacitance of the Line Module) must be added. To facilitate system configuration, the possible additional capacitance of the drive configuration has been incorporated into the tables below without the internal capacitance of the Line Module. This is named "Reserve Precharging".

The following capacitance values apply:

Basic Line Modules	Power at 400 V resp. 690 V	Rated DC link current	DC link capacitance	Maximum DC link capacitance	Precharging reserve
Order No.	[kW]	[A]	[μF]	[μF]	[μF]
Supply voltage 380 V to 480 V 3AC					
6SL3x30-1TE34-2AA0 ¹	200	420	7200	57600	50400
6SL3x30-1TE35-3AA0 ¹	250	530	9600	76800	67200
6SL3x30-1TE38-2AA0 ¹	400	820	14600	116800	102200
6SL3x30-1TE41-2AA0 ¹	560	1200	23200	185600	162400
6SL3730-1TE41-2BA0 ²	560	1200	23200	185600	162400
6SL3730-1TE41-2BC0 ²	560	1200	23200	185600	162400
6SL3x30-1TE41-5AA0 ¹	710	1500	29000	232000	203000
6SL3730-1TE41-5BA0 ²	710	1500	29000	232000	203000
6SL3730-1TE41-5BC0 ²	710	1500	29000	232000	203000
6SL3730-1TE41-8AA0 ²	900	1880	34800	139200	104400
6SL3730-1TE41-8BA0 ²	900	1880	34800	139200	104400
6SL3730-1TE41-8BC0 ²	900	1880	34800	139200	104400
Supply voltage 500 V to 690 V 3AC					
6SL3x30-1TH33-0AA0 ¹	250	300	3200	25600	22400
6SL3x30-1TH34-3AA0 ¹	355	430	4800	38400	33600
6SL3x30-1TH36-8AA0 ¹	560	680	7300	58400	51100
6SL3x30-1TH41-1AA0 ¹	900	1100	11600	92800	81200
6SL3730-1TH41-1BA0 ²	900	1100	11600	92800	81200
6SL3730-1TH41-1BC0 ²	900	1100	11600	92800	81200
6SL3x30-1TH41-4AA0 ¹	1100	1400	15470	123760	108290
6SL3730-1TH41-4BA0 ²	1100	1400	15470	123760	108290
6SL3730-1TH41-4BC0 ²	1100	1400	15470	123760	108290
6SL3730-1TH41-8AA0 ²	1500	1880	19500	78000	58500
6SL3730-1TH41-8BA0 ²	1500	1880	19500	78000	58500
6SL3730-1TH41-8BC0 ²	1500	1880	19500	78000	58500

¹ The order number 6SL3x30 stands for 6SL3330 of the S120 Chassis units and also for 6SL3730 of the S120 Cabinet Modules.

² These modules are exclusively to the S120 Cabinet Modules range.

SINAMICS S120

Engineering Information

Smart Line Modules	Power at 400 V resp. 690 V	Rated DC link current	DC link capacitance	Max. DC link capacitance at $u_k \geq 4\%$	Max. DC link capacitance at $u_k \geq 8\%$	Precharging reserve at $u_k \geq 4\% / 8\%$
Order No.	[kW]	[A]	[μF]	[μF]	[μF]	[μF]
Supply voltage 380 V - 480 V 3AC						
6SL313x-6AE15-0Ax0 ^{1,2}	5	8.3	220	6000	6000	5780
6SL313x-6AE21-0Ax0 ^{1,2}	10	16.6	330	6000	6000	5670
6SL3130-6TE21-6AB0 ²	16	27	710	20000	20000	19290
6SL3130-6TE23-6AB0 ²	36	60	1410	20000	20000	18590
6SL3x30-6TE35-5AA0 ³	250	550	8400	42000	42000	33600
6SL3x30-6TE37-3AA0 ³	355	730	12000	60000	60000	48000
6SL3x30-6TE41-1AA0 ³	500	1050	16800	67200	134400	50400 / 117600
6SL3730-6TE41-1BA0	500	1050	16800	67200	134400	50400 / 117600
6SL3730-6TE41-1BC0	500	1050	16800	67200	134400	50400 / 117600
6SL3x30-6TE41-3AA0 ³	630	1300	18900	75600	151200	56700 / 132300
6SL3730-6TE41-3BA0	630	1300	18900	75600	151200	56700 / 132300
6SL3730-6TE41-3BC0	630	1300	18900	75600	151200	56700 / 132300
6SL3x30-6TE41-7AA0 ³	800	1700	28800	115200	230400	86400 / 201600
6SL3730-6TE41-7BA0	800	1700	28800	115200	230400	86400 / 201600
6SL3730-6TE41-7BC0	800	1700	28800	115200	230400	86400 / 201600
Supply voltage 500 V – 690 V 3AC						
6SL3x30-6TG35-5AA0 ³	450	550	5600	28000	28000	22400
6SL3x30-6TG38-8AA0 ³	710	900	7400	29600	59200	22200 / 51800
6SL3730-6TG38-8BA0	710	900	7400	29600	59200	22200 / 51800
6SL3730-6TG38-8BC0	710	900	7400	29600	59200	22200 / 51800
6SL3x30-6TG41-2AA0 ³	1000	1200	11100	44400	88800	33300 / 77700
6SL3730-6TG41-2BA0	1000	1200	11100	44400	88800	33300 / 77700
6SL3730-6TG41-2BC0	1000	1200	11100	44400	88800	33300 / 77700
6SL3x30-6TG41-7AA0 ³	1400	1700	14400	57600	115200	43200 / 100800
6SL3730-6TG41-7BA0	1400	1700	14400	57600	115200	43200 / 100800
6SL3730-6TG41-7BC0	1400	1700	14400	57600	115200	43200 / 100800

¹ The order number stands for Booksize units with internal and external air cooling.

² This units are not available to the S120 Cabinet Modules range.

³ The order number 6SL3x30 stands for 6SL3330 of the S120 Chassis units and also for 6SL3730 of the S120 Cabinet Modules.

Active Line Modules	Power at 400 V resp. 690 V	Rated DC link current	DC link capacitance	Max. DC link capacitance at $V_{Rated} = 400\text{ V}$ resp. 500 V	Max. DC link capacitance at $V_{Rated} = 480\text{ V}$ resp. 690 V	Precharging reserve at 400 V resp. 500 V/ 480 V bzw. 690 V
Order No.	[kW]	[A]	[μF]	[μF]	[μF]	[μF]
Supply voltage 380 V - 480 V 3AC						
6SL313x-7TE21-6Axx ^{1,2}	16	27	710	20000	20000	19290
6SL313x-7TE23-6Axx ^{1,2}	36	60	1410	20000	20000	18590
6SL313x-7TE25-5Axx ^{1,2}	55	92	1880	20000	20000	18120
6SL313x-7TE28-0Axx ^{1,2}	80	134	2820	20000	20000	17180
6SL313x-7TE31-2Axx ^{1,2}	120	200	3995	20000	20000	16005
6SL3x30-7TE32-1xA0 ³	132	235	4200	62400	41600	58200 / 37400
6SL3x30-7TE32-6xA0 ³	160	291	5200	62400	41600	57200 / 36400
6SL3x30-7TE33-8xA0 ³	235	425	7800	115200	76800	107400 / 69000
6SL3x30-7TE35-0xA0 ³	300	549	9600	115200	76800	105600 / 67200
6SL3x30-7TE36-1xA0 ³	380	678	12600	201600	134400	189000 / 121800
6SL3x30-7TE38-4xA0 ³	500	940	16800	201600	134400	184800 / 117600
6SL3x30-7TE41-0xx0 ³	630	1103	18900	345600	230400	326700 / 211500
6SL3x30-7TE41-4xx0 ³	900	1574	28800	345600	230400	316800 / 201600
Supply voltage 500 V – 690 V 3AC						
6SL3x30-7TG35-8xA0 ³	560	644	7400	112500	59200	105100 / 51800
6SL3x30-7TG37-4xx0 ³	800	823	11100	291800	153600	280700 / 142500
6SL3x30-7TG41-0xx0 ³	1100	1148	14400	291800	153600	277400 / 139200
6SL3x30-7TG41-3xx0 ³	1400	1422	19200	291800	153600	272600 / 134400

¹ The order number stands for Booksize units with internal and external air cooling.

² This units are not available to the S120 Cabinet Modules range.

³ The order number 6SL3x30 stands for 6SL3330 of the S120 Chassis units and also for 6SL3730 of the S120 Cabinet Modules. The precharging is limited by the precharging circuit in the corresponding Active Interface Module.

SINAMICS S120

Engineering Information

Motor Modules	Rated power at 400 V resp. 690 V	Rated output current	DC link capacitance
Order No.	[kW]	[A]	[μF]
Supply voltage 380 V - 480 V 3AC			
6SL3x2x-2TE13-0Ax0 ¹	2 x 1.6	2 x 3	110
6SL3x2x-2TE15-0Ax0 ¹	2 x 2.7	2 x 5	220
6SL3x2x-2TE21-0Ax0 ¹	2 x 4.8	2 x 9	220
6SL3x2x-2TE21-8Ax0 ¹	2 x 9.7	2 x 18	710
6SL3x2x-1TE13-0Ax0 ¹	1.6	3	110
6SL3x2x-1TE15-0Ax0 ¹	2.7	5	110
6SL3x2x-1TE21-0Ax0 ¹	4.8	9	110
6SL3x2x-1TE21-8Ax0 ¹	9.7	18	220
6SL3x2x-1TE23-0Ax0 ¹	16	30	710
6SL3x2x-1TE24-5Ax0 ¹	24	45	1175
6SL3x2x-1TE26-0Ax0 ¹	32	60	1410
6SL3x2x-1TE28-5Ax0 ¹	46	85	1880
6SL3x2x-1TE31-3Ax0 ¹	71	132	2820
6SL3x2x-1TE32-0Ax0 ¹	107	200	3995
6SL3x20-1TE32-1AA0 ²	110	210	4200
6SL3x20-1TE32-6AA0 ²	132	260	5200
6SL3x20-1TE33-1AA0 ²	160	310	6300
6SL3x20-1TE33-8AA0 ²	200	380	7800
6SL3x20-1TE35-0AA0 ²	250	490	9600
6SL3x20-1TE36-1AA0 ²	315	605	12600
6SL3x20-1TE37-5AA0 ²	400	745	15600
6SL3x20-1TE38-4AA0 ²	450	840	16800
6SL3x20-1TE41-0AA0 ²	560	985	18900
6SL3x20-1TE41-2AA0 ²	710	1260	26100
6SL3x20-1TE41-4AA0 ²	800	1405	28800
Supply voltage 500 V - 690 V 3AC			
6SL3x20-1TG28-5AA0 ²	75	85	1200
6SL3x20-1TG31-0AA0 ²	90	100	1200
6SL3x20-1TG31-2AA0 ²	110	120	1600
6SL3x20-1TG31-5AA0 ²	132	150	2800
6SL3x20-1TG31-8AA0 ²	160	175	2800
6SL3x20-1TG32-2AA0 ²	200	215	2800
6SL3x20-1TG32-6AA0 ²	250	260	3900
6SL3x20-1TG33-3AA0 ²	315	330	4200
6SL3x20-1TG34-1AA0 ²	400	410	7400
6SL3x20-1TG34-7AA0 ²	450	465	7400
6SL3x20-1TG35-8AA0 ²	560	575	7400
6SL3x20-1TG37-4AA0 ²	710	735	11100
6SL3x20-1TG38-1AA0 ²	800	810	11100
6SL3x20-1TG38-8AA0 ²	900	910	14400
6SL3x20-1TG41-0AA0 ²	1000	1025	14400
6SL3x20-1TG41-3AA0 ²	1200	1270	19200

¹ The order number 6SL3x20 stands for 6SL3720 of the S120 Cabinet Modules/ Booksize Cabinet Kits and also for 6SL3120 of the S120 Booksize units with internal and external air cooling

² The order number 6SL3x20 stands for 6SL3320 of the S120 Chassis units and also for 6SL3720 of the S120 Cabinet Modules.

■ Braking Module / External braking resistor

Braking Module for power units in chassis format

A Braking Module and an external braking resistor are required in order to be able to decelerate a drive to a stand still in the event of a power failure (e.g. emergency withdrawal or emergency stop category 1) or for limiting the DC link voltage during short-term regenerative operation of the motor, if, for example, a regenerative operation of the Line Module is not possible (BLM) or the regenerative operation has been deactivated (SLM or ALM).

The Braking Module for the chassis units contains the power electronics and the corresponding control facility. When in operation the energy of the DC link is converted into heat in an external braking resistor outside of the cabinet unit. The Braking Module operates autonomously, meaning that there is no communication between the Braking Module and the controller of the chassis unit.



Braking Module for installation in a power unit in chassis format

Parallel operation of several Braking Modules is possible, but each Braking Module must be connected to its own braking resistor. A parallel configuration of up to four Braking Modules per DC busbar is possible. For higher braking power, cabinet units in the S120 Cabinet Module range are available, see chapter "Modular Cabinet Unit System SINAMICS S120 Cabinet Modules", section "Central Braking Modules".

Braking Modules can be installed in every power unit in chassis format. Depending on the frame size of the Line Module resp. Motor Module it is possible to install up to three Braking Modules. The Braking Modules are installed in the air outlet at the top of the Power unit.

There are up to three places for installation available depending on the frame size of the Power Unit:

- Frame size FX, GX: 1 place for installation
- Frame size HX: 2 places for installation
- Frame size JX: 3 places for installation

The Braking Unit is made up of two components:

- A Braking Module, which is installed in the Power Unit
- A braking resistor, which is installed externally (degree of protection IP20).

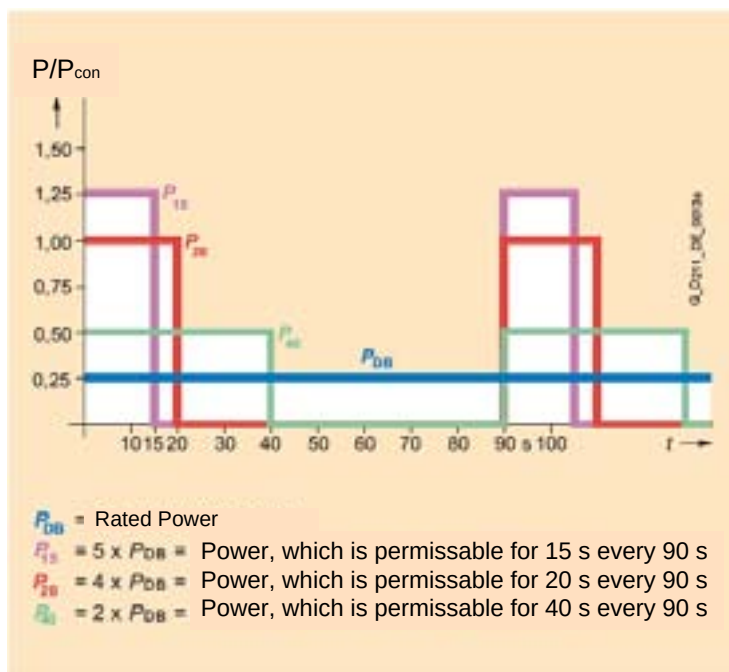
The Braking Units operate as autonomous units and require no external voltage supply. The Braking Modules are installed in the air outlet at the top of the Power Units. During braking operation, the kinetic energy of the motor is converted into heat in the externally installed braking resistor. Between the Braking Module and braking resistor, a maximum cable length of 100 m is permissible. The braking resistor can, therefore, be installed externally to release the heat losses outside of the room where the converter is installed. The braking resistor is connected directly to the terminals of the Braking Module.

The response threshold of the Braking Modules, where they start to operate, can be adapted to the requirements on site using a switch in the Braking Module. The values for the response thresholds of the Braking Modules and the corresponding DC link voltages during braking operation are given in the following table.

Voltage	Response Threshold	Switch position	Comments
380 V – 480 V 3AC	673 V	1	The factory setting is 774 V. With supply voltages of 380 V to 400 V 3AC, the response threshold can be set to 673 V, in order to reduce the voltage stress of motor and converter. In such cases, the maximum attainable output power P_{15} also decreases in proportion to the square of the voltage $(673/774)^2 = 0.75$. Thus the maximum available output power is approx. 75 % of P_{15} .
	774 V	2	
500 V – 600 V 3AC	841 V	1	The factory setting is 967 V. With a supply voltage of 500 V 3AC, the response threshold can be set to 841 V, in order to reduce the voltage stress of motor and converter. In such cases, the maximum attainable output power P_{15} also decreases in proportion to the square of the voltage $(841/967)^2 = 0.75$. Thus the maximum available output power is approx. 75 % of P_{15} .
	967 V	2	
660 V – 690 V 3AC	1070 V	1	The factory setting is 1158 V. With a supply voltage of 660 V 3AC the response threshold can be set to 1070 V, in order to reduce the voltage stress of motor and converter. In such cases, the maximum attainable output power P_{15} also decreases in proportion to the square of the voltage $(1070/1158)^2 = 0.85$. Thus the maximum available output power is approx. 85 % of P_{15} .
	1158 V	2	

Values of the response threshold for the Braking Modules

When Braking Modules are used, it must be taken in account that they are supplied with cooling air from the fans installed in the Power Unit. Thus it has to be ensured that these Power Units and the associated fans are supplied with auxiliary voltage and are in operation, if the Braking Modules are working.



Two Braking Modules are available.

The rated power is 25 kW resp. 50 kW (continuous power P_{DB}) with a maximum available output power of P_{15} of 125 kW resp. 250 kW and a braking time of 15 seconds based on a cycle of 90 seconds.

Different load duty cycles can be obtained from the diagram on the left.

Braking Modules with two different voltage levels are available for units with the large voltage ranges (input voltage 500 V – 690 V 3AC). Please take note of the possible input voltages when making the selection of the Braking Modules.

Load diagram for Braking Module and braking resistor

The Braking Modules are delivered without a braking resistor. The resistor must be ordered separately.

The Braking Modules are included in the option range for S120 Cabinet Modules (Options L61, L62 resp. L64, L65). These options include the corresponding braking resistor as well as installation and cabinet-internal connections of the Braking Modules.

Braking resistors for power units in chassis format

The surplus energy of the DC link is converted to heat via the braking resistor. The braking resistor is connected to a Braking Module. By locating the braking resistor outside of the cabinet resp. outside of the converter room, the heat losses occur away from the Power Units. This reduces air conditioning costs.



Braking resistor for connection to Braking Modules

Resistors suitable for connection to Braking Modules with a rated power of 25 kW resp. 50 kW are available. Larger outputs can be achieved through the parallel configuration of Braking Modules.

A thermostat monitors the braking resistor for overheating and, if the limit value is exceeded, it issues a warning via an isolated contact.

Installation

The braking resistors are only suitable for vertical installation and not for installation on a wall. During operation surface temperatures can exceed 80°C. In view of this, sufficient distance from flammable objects must be maintained. A free-standing braking resistor installation with at least 200 mm of free space on each side for ventilation is required. Objects must not be deposited on or above the braking resistor. The installation should not be carried out near fire detectors as they could respond by the produced heat. It has also to be ensured that the place of installation is able to dissipate the energy produced by the braking resistor.

The connection cables to the Braking Module must not exceed 100 m. A short circuit-proof and ground fault-proof cable routing must also be provided.

Technical Data

Order No.	Module	500 V – 720 V DC		650 V – 900 V DC		850 V – 1035 V DC	
		6SL3000-1BE31-3AA0	6SL3000-1BE32-5AA0	6SL3000-1BF31-3AA0	6SL3000-1BF32-5AA0	6SL3000-1BH31-3AA0	6SL3000-1BH32-5AA0
P _{DB} (Rated power)	kW	25	50	25	50	25	50
P15 (Maximum power)	kW	125	250	125	250	125	250
Resistor	Ω	4.4 ± 7.5%	2.2 ± 7.5%	6.8 ± 7.5%	3.4 ± 7.5 %	9.8 ± 7.5%	4.9 ± 7.5%
Max. current	A	189	378	153	306	125	255
Cable entry		Cable gland M50	Cable gland M50	Cable gland M50	Cable gland M50	Cable gland M50	Cable gland M50
Power connection		Bolt M8	Bolt M8	Bolt M8	Bolt M8	Bolt M8	Bolt M8
Max. connectable cable cross-section	mm ²	50	70	50	70	50	70
Degree of protection		IP20	IP20	IP20	IP20	IP20	IP20
Width x Height x Depth	mm	740 x 605 x 485	810 x 1325 x 485	740 x 605 x 485	810 x 1325 x 485	740 x 605 x 485	810 x 1325 x 485
Approx. Weight	kg	50	120	50	120	50	120
Fits to the Braking Module with order number		6SL3300-1AE31-3AA0	6SL3300-1AE32-5 . A0	6SL3300-1AF31-3AA0	6SL3300-1AF32-5 . A0	6SL3300-1AH31-3AA0	6SL3300-1AH32-5 . A0

■ Maximum connectable motor cable lengths

Booksized units

The Motor Modules generate an AC voltage to supply the connected motor from the DC link voltage. Capacitive leakage currents are generated in clocked operation and these limit the permissible length of the motor cable.

The following maximum motor cable lengths have to be taken into account:

Line supply voltage	Output power	Rated output current	Con-struction type	Maximum permissible motor cable length	
				Shielded cable	Unshielded cable
Without reactor or filter					
380 V – 480 V 3AC	1.6 kW - 4.8 kW	3 A – 9 A	Single	50 m	75 m
	2*1.6 kW – 2*9.7 kW	2*3 A – 2*18 A	Double	50 m	75 m
	9.7 kW	18 A	Single	70 m	100 m
	16 kW - 107 kW	30 A – 200 A	Single	100 m	150 m

Permissible motor cable lengths for SINAMICS S120 Booksized units

Where a longer motor cable is required, a higher rating of Motor Module must be selected or the permissible continuous output current $I_{\text{continuous}}$ must be reduced in relation to the rated output current I_{rated} .

The configuring data for Booksized format Motor Modules are given in the following table:

Rated output current	Length of motor cable (shielded)			
	> 50 m to 100 m	> 100 m to 150 m	> 150 m to 200 m	> 200 m
3 A / 5 A	Use 9 A Motor Module	Use 9 A Motor Module	Not permissible	Not permissible
9 A	Use 18 A Motor Module	Use 18 A Motor Module	Not permissible	Not permissible
18 A	Use 30 A Motor Module or $I_{\text{max}} \leq 1.5 * I_{\text{rated}}$ $I_{\text{contin.}} \leq 0.95 * I_{\text{rated}}$	Use 30 A Motor Module	Not permissible	Not permissible
30 A	Permissible	$I_{\text{max}} \leq 1.35 * I_{\text{rated}}$ $I_{\text{contin.}} \leq 0.9 * I_{\text{rated}}$	$I_{\text{max}} \leq 1.1 * I_{\text{rated}}$ $I_{\text{contin.}} \leq 0.85 * I_{\text{rated}}$	Not permissible
45 A / 60 A	Permissible	$I_{\text{max}} \leq 1.75 * I_{\text{rated}}$ $I_{\text{contin.}} \leq 0.9 * I_{\text{rated}}$	$I_{\text{max}} \leq 1.5 * I_{\text{rated}}$ $I_{\text{contin.}} \leq 0.85 * I_{\text{rated}}$	Not permissible
85 A / 132 A	Permissible	$I_{\text{max}} \leq 1.35 * I_{\text{rated}}$ $I_{\text{contin.}} \leq 0.95 * I_{\text{rated}}$	$I_{\text{max}} \leq 1.1 * I_{\text{rated}}$ $I_{\text{contin.}} \leq 0.9 * I_{\text{rated}}$	Not permissible
200 A	Permissible	$I_{\text{max}} \leq 1.25 * I_{\text{rated}}$ $I_{\text{contin.}} \leq 0.95 * I_{\text{rated}}$	$I_{\text{max}} \leq 1.1 * I_{\text{rated}}$ $I_{\text{contin.}} \leq 0.9 * I_{\text{rated}}$	Not permissible

Permissible motor cable lengths for over-dimensioned modules

The permissible cable length for an unshielded motor cable is 150 % of the length for a shielded motor cable.

Motor reactors can also be used on motors operating in vector and V/f control modes to allow the use of longer motor cables. Motor reactors limit the rate of rise and magnitude of the capacitive leakage currents, thereby allowing longer motor cables to be used. The motor reactor and motor cable capacitance form an oscillating circuit which must not be excited by the pulse pattern of the output voltage. The resonant frequency of this oscillating circuit must therefore be significantly higher than the pulse frequency. The longer the motor cable, the higher the cable capacitance and the lower the resonant frequency. To provide a sufficient safety margin between this resonant frequency and the pulse frequency, the maximum possible motor cable length is limited, even when several motor reactors are connected in series.

SINAMICS S120

Engineering Information

Line supply voltage	Output power	Rated output current	Maximum permissible motor cable length	
			Shielded cable	Unshielded cable
With one motor reactor				
380 V – 480 V 3AC	1.6 kW - 2.7 kW	3 A – 5 A	100 m	150 m
	4.8 kW	9 A	135 m	200 m
	9.7 kW	18 A	160 m	240 m
	16 kW	30 A	190 m	280 m
	24 kW - 107 kW	45 A – 200 A	200 m	300 m

Permissible motor cable lengths for SINAMICS S120 Booksize units with motor reactors

The motor reactors are designed for a pulse frequency of 4 kHz. Higher pulse frequencies are not permissible. The maximum permissible output frequency when a motor reactor is used is 120 Hz. Motor reactors are approved for use only in combination with "Vector" and "V/f control" modes.

When SINAMICS S120 units in Booksize format are used within the S120 Cabinet Modules range, please read the supplementary information in the section "Options" of the chapter "Modular Cabinet Unit System SINAMICS S120 Cabinet Modules".

Chassis units

As standard (i.e. without motor reactors or motor filters (dv/dt filters, sine-wave filters) connected to the Motor Module output), the following permissible cable lengths apply to SINAMICS S120 Motor Modules (Chassis and Cabinet Modules).

Line supply voltage	Maximum permissible motor cable length as standard	
	Shielded cable e. g. Protodur NYCWY	Unshielded cable e. g. Protodur NYY
380 V – 480 V 3AC	300 m	450 m
500 V – 690 V 3AC	300 m	450 m

Permissible motor cable lengths as standard for SINAMICS S120 Motor Modules in Chassis and Cabinet Modules format

When a motor reactor is used or two motor reactors are connected in series, the permissible cable lengths can be increased. A second motor reactor is not a standard option for the S120 Cabinet Modules and may require an additional cabinet (available on request).

The table below specifies the maximum motor cable lengths with motor reactor(s) that can be connected to S120 Motor Modules in Chassis and Cabinet Modules format. The values apply to the motor cable types recommended in the tables and to other standard types of cable.

Line supply voltage	Maximum permissible motor cable length			
	with 1 reactor (Option L08 with S120 Cabinet Modules)		with 2 series-connected reactors (No standard option with S120 Cabinet Modules)	
	Shielded cable e.g. Protodur NYCWY	Unshielded cable e.g. Protodur NYY	Shielded cable e.g. Protodur NYCWY	Unshielded cable e.g. Protodur NYY
380 V – 480 V 3AC	300 m	450 m	525 m	787 m
500 V – 690 V 3AC	300 m	450 m	525 m	787 m

Maximum permissible motor cable lengths with 1 or 2 motor reactors for Motor Modules in SINAMICS S120 Chassis and Cabinet Modules format

The motor reactors are only approved for use in combination with control types "Vector" and "V/f control".

The specified motor cable lengths always refer to the distance between the S120 Motor Module and motor along the cable route. They allow for the fact that several cables must be routed in parallel for high-output drives. The recommended and maximum connectable cross-sections as well as the permissible number of parallel motor cables are unit-specific values. You must, therefore, refer to the technical specifications for the relevant Motor Modules.

For more information, see section "Motor reactors" of the chapter "Fundamental Principles and System Description".

■ Checking the total cable length for multi-motor drives

In the case of SINAMICS S120 multi-motor drives, the total cable length (i.e. the sum of the motor cable lengths for all the Motor Modules that are fed by a common Infeed Module and via a common DC busbar) must be restricted. This is necessary in order to ensure that the resulting total capacitive leakage current ΣI_{Leak} (sum of the capacitive leakage currents I_{Leak} generated from the individual Motor Modules 1...n), which depends on the overall motor cable length, does not overload the Infeed Module if this current flows back to the DC busbar via the line filter of the Infeed Module or via the supply system, and the Infeed Module itself.

The following table specifies the values for the permissible total cable lengths I_{perm} for the various types of SINAMICS S120 Infeed Modules when feeding multi-motor drives. The following must be noted here:

- The total cable length I_{perm} is the cable length that is really routed. This means in the case of drives which have higher output currents and more than one motor cable routed in parallel, that each of the parallel cables must be taken into account when the total cable length is calculated.
- The total cable length I_{perm} applies to shielded motor cables. In the case of unshielded motor cables, values 1.5 times higher are permissible.
- When S120 Infeed Modules are connected in parallel, the specified permissible total cable length I_{perm} must be multiplied by the number of Infeed Modules connected in parallel. A derating of 7.5% must be observed for Basic Line Modules and Smart Line Modules, and a derating of 5% for Active Line Modules.
- The values apply regardless of the type of supply system, i.e. for both grounded TN supply systems and non-grounded IT supply systems.

SINAMICS S120 Infeed Module	Frame size	Rated power at 400 V / 690 V [kW]	Input current at 400 V / 690 V [A]	Permissible total cable length for shielded cables I_{perm} [m]
Supply voltage 380 V to 480 V 3AC				
Basic Line Module	FB	200 to 400	365 to 710	2600
Basic Line Module	GB	560 to 710	1010 to 1265	4000
Basic Line Module	GD	900	1630	4800
Smart Line Module	GX	250 to 355	463 to 614	4000
Smart Line Module	HX+JX	500 to 800	883 to 1430	4800
Active Line Module	FX+GX	132 to 300	210 to 490	2700
Active Line Module	HX+JX	380 to 900	605 to 1405	3900
Supply voltage 500 V to 690 V 3AC				
Basic Line Module	FB	250 to 560	260 to 575	1500
Basic Line Module	GB	900 to 1100	925 to 1180	2250
Basic Line Module	GD	1500	1580	2750
Smart Line Module	GX	450	463	2250
Smart Line Module	HX+JX	710 to 1400	757 to 1430	2750
Active Line Module	HX+JX	560 to 1400	575 to 1270	2250

Permissible total cable length for SINAMICS S120 Infeed Modules feeding multi-motor drives

Modular Cabinet Unit System SINAMICS S120 Cabinet Modules

■ General

Design

SINAMICS S120 Cabinet Modules are compact cabinet elements specially developed to allow simple construction of multi-motor systems. They have been designed according to the "zone" concept and therefore offer the highest possible standard of operational reliability. EMC measures have been implemented throughout and the cabinets are partitioned for the purpose of air-flow guidance and temperature control. Attention has been paid to providing possible cable routing options and special design concepts are applied consistently to broaden the scope of application and simplify servicing.

The units feature all the necessary connections and connecting elements. The cabinets are shipped in a ready-to-connect state or, in the case of multiple transport units, ready for quick assembly.

The properties of S120 Cabinet Modules described in this section are not transferable to adapted cabinets constructed to meet the requirements of specific applications. The components installed in the Cabinet Modules cannot be ordered separately.

General configuring process

The starting point for a drive configuring process is provided by the performance requirements of individual machines in the drive line-up. The definition of the components is based on physical interdependencies and is usually carried-out as follows:

Step	Description of the configuring process
1.	Clarify the type of drive and Infeed • Basic Line Module • Smart Line Module • Active Line Module
2.	Define the supplementary conditions and integration into an automation system
3.	Define the load, calculate the maximum load torque, select the motor
4.	Select the SINAMICS S120 Motor Module
5.	Repeat steps 3 and 4 for any further drives
6.	Calculate the required DC link power, taking the demand factor into account, and select the SINAMICS S120 Line Module
7.	If the DC link power required is calculated to be such that a parallel connection of Infeed Modules is needed to provide the necessary Infeed power, then the correct Infeed Modules for the parallel connection must also be selected. Only Infeed Modules with the same output power rating may be connected in parallel. Note derating data!
8.	Select the Line Connection Modules based on the assignment table (see section "Line Connection Modules")
9.	Determine the line-side power options (main circuit breaker, fuses, line reactors, etc.)
10.	Check the precharging of the DC link by calculating the DC link capacitance
11.	Select further system components
12.	Calculate the required current for the electronics with 24V DC (please see technical data for the Cabinet Modules) as well as for optional components.
13.	Calculate the required current for the components with 230 V AC (please see technical data for the Cabinet Modules).
14.	Calculate the required current for the fans with 380 V to 480V AC resp. 500 V to 690 V AC (please see technical data for the Cabinet Modules)
15.	Select the power supply according to the above calculated auxiliary currents at the different voltage levels (external line supply, option K76, auxiliary power supply modules)
16.	Determine the required control performance, select the SINAMICS S120 Control Unit and the Compact Flash Card, define the component cabling (DRIVE-CLiQ topology)
17.	Select the components for connections. Select the DRIVE-CLiQ cables, including the DRIVE-CLiQ cables which have to be laid and connected on site. Select the PROFIBUS cables, if communication is established by means of PROFIBUS and several Control Units (CU320) have to be connected to one another. Alternatively selection of order-specific integration engineering (please see catalog)
18.	Sequencing of the components of the drive configuration
19.	Separation of the drive configuration into individual transportation units

■ Dimensioning and selection information

Derating data

Current derating as a function of installation altitude (Cabinet Modules based on chassis units)

If the Cabinet Modules based on chassis units are operated at **installation altitude of >2000 m above sea level**, the corresponding reduction factors for the maximum permissible output current must be considered (derating). These factors are given in the following table. It has to be ensured that the air flow rate for the corresponding Cabinet Modules given in the tables of technical data is guaranteed. The values already include a permitted correction between installation altitude and ambient temperature (air temperature at air inlet of the Cabinet Module).

Installation altitude above sea level m	Current derating at an ambient temperature (inlet air temperature) of						
	20 °C	25 °C	30 °C	35 °C	40 °C	45 °C	50 °C
0 ... 2000	100 %					95.0 %	87.0 %
... 2500						96.3 %	91.4 %
... 3000						92.5 %	87.9 %
... 3500			96.7 %	92.3 %	88.8 %	84.3 %	77.3 %
... 4000		97.8 %	92.7 %	88.4 %	85.0 %	80.8 %	74.0 %

Current derating as a function of ambient temperature (temperature of inlet air) and installation altitude for Cabinet Modules based on chassis units with degree of protection IP20, IP21, IP23 and IP43

Installation altitude above sea level m	Current derating at an ambient temperature (inlet air temperature) of						
	20 °C	25 °C	30 °C	35 °C	40 °C	45 °C	50 °C
0 ... 2000	100 %				95.0 %	87.5 %	80.0 %
... 2500					96.3 %	91.4 %	84.2 %
... 3000					92.5 %	87.9 %	81.0 %
... 3500		96.7 %	92.3 %	88.8 %	84.3 %	77.7 %	71.1 %
... 4000	97.8 %	92.7 %	88.4 %	85.0 %	80.8 %	74.7 %	68.0 %

Current derating as a function of ambient temperature (temperature of inlet air) and installation altitude, for Cabinet Modules based on chassis units with degree of protection IP54

Voltage derating as a function of installation altitude

In addition to current derating, voltage derating as stipulated in the table below is applicable at installation altitudes of > 2000 m above sea level.

Installation altitude Above sea level m	Voltage derating ¹ at a rated line supply voltage of										
	380 V	400 V	420 V	440 V	460 V	480 V	500 V	525 V	575 V	600 V	660 V
0 ... 2000	100 %										
... 2250											
... 2500											
... 2750				98 %	94 %	90 %				98 %	94 %
... 3000				95 %	91 %	88 %				94 %	90 %
... 3250			97 %	93 %	89 %	85 %				91 %	88 %
... 3500		98 %	93 %	89 %	85 %	82 %			98 %	94 %	89 %
... 3750		95 %	91 %	87 %	83 %	79 %			95 %	91 %	87 %
... 4000	96 %	92 %	87 %	83 %	80 %	76 %			91 %	87 %	83 %

Voltage derating as a function of installation altitude

¹ The units with supply voltages of 660 V to 690 V 3AC (Order number 6SL3720-1THxx-xAA0) cannot be used at installation altitudes > 3500m.

SINAMICS S120 Cabinet Modules

Engineering Information

Current derating as a function of installation altitude (Cabinet Modules based on booksize units)

Compared with Cabinet Modules based on chassis units, Cabinet Modules based on booksize units have different derating factors. From an **installation altitude of > 1000m above sea level**, the corresponding reduction factors for the maximum permissible output current must be considered (derating). These factors are given in the following table. As with Cabinet Modules based on chassis units it has to be ensured that the air flow rate for the corresponding Cabinet Modules given in the tables of technical data is guaranteed. The values already include a permitted correction between installation altitude and ambient temperature (air temperature at air inlet of the Cabinet Module).

Installation altitude above sea level m	Current derating at an ambient temperature (inlet air temperature) of						
	20 °C	25 °C	30 °C	35 °C	40 °C	45 °C	50 °C
0 ... 1000	100 %					86 %	73 %
... 1500	92 %	92 %	92 %	92 %	92 %	79 %	67 %
... 2000	84 %	84 %	84 %	84 %	84 %	72 %	61 %
... 2500	79 %	79 %	79 %	79 %	79 %	68 %	57 %
... 3000	75 %	75 %	75 %	75 %	75 %	65 %	54 %
... 3500	66 %	66 %	66 %	66 %	66 %	56 %	48 %
... 4000	63 %	63 %	63 %	63 %	63 %	54 %	46 %

Current derating as a function of ambient temperature (temperature of inlet air) and installation altitude for Cabinet Modules based on Booksize units with degree of protection IP20, IP21, IP23, IP43 and IP54

Voltage derating as a function of the installation altitude (Cabinet Modules based on booksize units)

In addition to current derating, voltage derating as stipulated in the table below is applicable at installation altitudes of > 1000 m above sea level.

Installation altitude above sea level	Voltage Derating at a rated line supply of						
	380 V	400 V	420 V	440 V	460 V	480 V	
m							
0 ... 2000	100 %						
... 2250							96 %
... 2500							94 %
... 2750							90 %
... 3000							88 %
... 3250		97 %	93 %	89 %	85 %		
... 3500		98 %	93 %	89 %	85 %	82 %	
... 3750		95 %	91 %	87 %	83 %	79 %	
... 4000	96 %	92 %	87 %	83 %	80 %	76 %	

Voltage derating as a function of installation altitude

Additional derating values (e.g. with increased pulse frequency) can be found in the chapter "SINAMICS S120, General Information about Built-in and Cabinet Units".

Degrees of protection of S120 Cabinet Modules

The **EN 60529** standard covers the protection of electrical equipment by means of housings, covers or equivalent, and includes:

1. Protection of persons against accidental contact with live or moving parts within the housing and protection of the equipment against the penetration of solid foreign matter (shock protection)
2. Protection of the equipment against the penetration of water (water protection)
3. Abbreviations for the internationally agreed degrees of protection.

The degrees of protection are specified by abbreviations comprising the code letters IP and two digits.

Degree of protection	First digit (protection against accidental contact and solid matter)	Second digit (protection of the equipment against the penetration of water)
IP20	Protected against solid matter, diameter 12.5 mm and larger	No water protection
IP21	Protected against solid matter, diameter 12.5 mm and larger	Protected against drip water Vertically falling drip water must not have a harmful effect.
IP23	Protected against solid matter, diameter 12.5 mm and larger	Protected against spray water Water sprayed on both sides of the vertical at an angle of up to 60° must not have a harmful effect
IP43	Protected against solid matter, diameter 1 mm and larger	Protected against spray water Water sprayed on both sides of the vertical at an angle of up to 60° must not have a harmful effect
IP54	Protected against dust Entry of dust is not totally prevented, but the entry of dust is not allowed in such quantities that the operation of equipment or the safety will be impaired.	Protected against splash water. Water splashing against the enclosure from any direction must not have a harmful effect.

Standardized degrees of protection of S120 Cabinet Modules

For the safe operation of the cabinet units at the different degrees of protection no additional measures (e.g. cooling units, air conditioning, etc.) are necessary, as long as the ambient conditions are within the specified values. Only the derating factors as well as the modified cabinet dimensions have to be taken into account.

Required cross-sections of DC busbars

DC busbars are not integrated in S120 Cabinet Modules as standard, but must be selected for specific modules as a "required option". The busbars must be dimensioned according to the applicable load requirements and operating modes of the drive line-up as well as the individual arrangement of the Cabinet Modules. The purpose of the "required option" approach is to reduce errors and facilitate accurate configuring.

The required busbar option does not apply to the following Cabinet Modules:

- Line Connection Module
- Auxiliary Power Supply Module

These modules can be installed in the cabinet group in such a way (e.g. at the end of the cabinet line) that no DC busbars are required.

The rated currents for the DC link must be calculated according to the rating of individual Motor Modules and the operating mode (demand factor, motor/generator mode) and the DC busbars selected accordingly.

For optimum cost-effectiveness, different combinations of busbar sizes can be selected. When selecting busbars, it is important to remember that systems of adjacent Cabinet Modules must be mutually compatible (see table below and options selection matrix of the relevant Cabinet Modules in the catalog).

SINAMICS S120 Cabinet Modules

Engineering Information

Order code	DC busbar Rated current I_{DC} [A]	Number	Dimensions [mm]	Compatible with
M80	1170	1	60 x 10	M83
M81	1500	1	80 x 10	M84 and M86
M82	1840	1	100 x 10	M85 and M87
M83	2150	2	60 x 10	M80
M84	2730	2	80 x 10	M81 and M86
M85	3320	2	100 x 10	M82 and M87
M86	3720	3	80 x 10	M81 and M84
M87	4480	3	100 x 10	M82 and M85

DC busbar options

In a typical application such as a gearing test station, for example, one Motor Module might supply an asynchronous motor that simulates a combustion engine, while other Motor Modules are driving asynchronous motors that simulate the load. While the asynchronous motor simulating the combustion engine operates as a motor, the two load-simulating motors are feeding all their energy back into the DC link. As regards the total energy balance, this means that only a small proportion of energy is drawn from the feeding (power loss of the complete drive line plus energy required for acceleration). In this application, energy is exchanged primarily between the Motor Modules. The significance of this in relation to DC busbar dimensioning is that a smaller size of busbar can be installed between the Line Module / Infeed and the first Motor Module.

The Modules must be arranged according to the relevant load conditions and demand factor so that the DC busbars can be dimensioned as efficiently as possible.

The DC busbars between the Cabinet Modules are interconnected by means of special busbar links. These form part of the busbar system and are attached to the right-hand face of the bar for a module / transport unit when it is delivered. When the Cabinet Modules have been lined up, the links can be unfastened, taken into the adjacent cabinet and fastened tight again.

If Cabinet Modules are ordered with option Y11, i.e. as factory-assembled transport units, the busbars must be uniform throughout the transport unit.

Required cable cross-sections for line and motor connections

It is always advisable to use symmetrical, 3-wire, three-phase cables or to connect several cables of this type in parallel. This is especially important for two reasons:

- This is the only way in which the high IP55 degree of protection or better can be achieved for the motor terminal box without any problems because the cables are introduced into the terminal box via screwed glands and the number of possible glands is limited by the geometry of the terminal box. Therefore single cables are less suitable.
- With three-phase cables, the summed ampere-turns over the cable outer diameter are equal to zero. They can easily be routed in (conductive, metal) cable ducts or racks without any significant currents (ground current or leakage current) being induced in these conductive, metal connections.

The danger of induced leakage currents and thus of increased cable sheath losses is greater for single cables.

The required cable cross-section depends on the amperage which flows through the cable. The permissible current loading of cables is defined e.g. in DIN VDE 0298 Part 2/DIN VDE 0276-1000. It depends on ambient conditions such as the temperature, but also on the type of routing.

Cross-section of 3-wire cables [mm ²]	Single routing [A]	Several cables on a common cable rack [A]
50	138	95
70	176	121
95	212	146
120	245	169
150	282	194
185	323	222
240	380	261
300	418	289

Routing cables singly ensures relatively good cooling. It must be noted that cables can heat one another and are therefore far less well ventilated if several cables are routed together. Reference should be made to the corresponding reduction factors for such conditions as specified in DIN VDE 0298 Part 2 / DIN VDE 0276-1000. With an ambient temperature of 40 °C, the cross-sections of copper cables can be based on the following table.

Current carrying capacity of cables acc. to DIN VDE 0298 part 2 at 40°C

SINAMICS S120 Cabinet Modules

Engineering Information

Cooling air requirements

A specific quantity of cooling air must be supplied to S120 Cabinet Modules. This cooling air requirement is always important, even under challenging boundary conditions. The cooling air is drawn in from the front through the ventilation grilles in the lower part of the cabinet doors. The warmed air is expelled through the perforated top cover or the ventilation grilles in the top cover (with option M23/ M43/ M54). The minimum ceiling height (for unhindered air outlet) specified in the dimension drawings must be observed. Cooling air can also be supplied from below through raised floors or air ducts, for example. Openings in the 3-section baseplate must be made for this purpose. Please also refer to the supplementary information for option M59 (cabinet door closed).

The cooling air requirement of individual Cabinet Modules is specified in the tables below:

Line Connection Modules		Cooling air requirement
Frame size	I _{rated} [A]	[m³/s]
Supply voltage 380 V to 480 V 3AC		
FL	250	- ¹
FL	400	- ¹
GL	630	- ¹
HL	800	- ¹
JL	1000	0.36 ^{1,2}
JL	1250	0.36 ^{1,2}
JL	1600	0.36 ^{1,2}
KL	2000	0.72 ^{1,2}
KL	2500	0.72 ^{1,2}
LL	3200	0.72 ^{1,2}

Line Connection Modules		Cooling air requirement
Frame size	I _{rated} [A]	[m³/s]
Supply voltage 500 V to 690 V 3AC		
FL	280	- ¹
FL	400	- ¹
GL	630	- ¹
HL	800	- ¹
JL	1000	0.36 ^{1,2}
JL	1250	0.36 ^{1,2}
JL	1600	0.36 ^{1,2}
KL	2000	0.72 ^{1,2}
KL	2500	0.72 ^{1,2}
LL	3200	0.72 ^{1,2}

Basic Line Modules		Cooling air requirement
Frame size	P _{rated} at 400 V [kW]	[m³/s]
Supply voltage 380 V to 480 V 3AC		
FB	200	0.17
FB	250	0.17
FB	400	0.17
GB	560	0.36
GB	710	0.36
GD	900	0.36

Basic Line Modules		Cooling air requirement
Frame size	P _{rated} at 690 V [kW]	[m³/s]
Supply voltage 500 V to 690 V 3AC		
FB	250	0.17
FB	355	0.17
FB	500	0.17
GB	900	0.36
GB	1100	0.36
GD	1500	0.36

Smart Line Modules		Cooling air requirement
Frame size	P _{rated} at 400 V [kW]	[m³/s]
Supply voltage 380 V to 480 V 3AC		
GX	250	0.36
GX	355	0.36
HX	500	0.78
JX	630	1.08
JX	800	1.08

Smart Line Modules		Cooling air requirement
Frame size	P _{rated} at 690 V [kW]	[m³/s]
Supply voltage 500 V to 690 V 3AC		
GX	450	0.36
HX	710	0.78
JX	1000	1.08
JX	1400	1.08

¹ Components use natural convection

² Fan for degree of protection IP23, IP43, IP54 (in combination with Basic Line Modules)

SINAMICS S120 Cabinet Modules

Engineering Information

Active Line Module + Active Interface Module		Cooling air requirement
Frame size	P _{rated} at 400 V [kW]	[m³/s]

Supply voltage 380 V to 480 V 3AC

FI+FX	132	0.41
FI+FX	160	0.47
GI+GX	235	0.83
GI+GX	300	0.83
HI+HX	380	1.18
HI+HX	500	1.18
JI+JX	630	1.5
JI+JX	900	1.5

Active Line Module + Active Interface Module		Cooling air requirement
Frame size	P _{rated} at 690 V [kW]	[m³/s]

Supply voltage 500 V to 690 V 3AC

HI+HX	560	1.18
JI+JX	800	1.5
JI+JX	1100	1.5
JI+JX	1400	1.5

Motor Modules Chassis		Cooling air requirement
Frame size	P _{rated} at 400 V [kW]	[m³/s]

Supply voltage 380 V to 480 V 3AC

FX	110	0.17
FX	132	0.23
GX	160	0.36
GX	200	0.36
GX	250	0.36
HX	315	0.78
HX	400	0.78
HX	450	0.78
JX	560	1.1
JX	710	1.1
JX	800	1.1

Motor Module Chassis		Cooling air requirement
Frame size	P _{rated} at 690 V [kW]	[m³/s]

Supply voltage 500 V to 690 V 3AC

FX	75	0.17
FX	90	0.17
FX	110	0.17
FX	132	0.17
GX	160	0.36
GX	200	0.36
GX	250	0.36
GX	315	0.36
HX	400	0.78
HX	450	0.78
HX	560	0.78
JX	710	1.474
JX	800	1.474
JX	900	1.474
JX	1000	1.474
JX	1200	1.474

Booksize Cabinet Kits		Cooling air requirement
Frame size	I _{rated} [A]	[m³/s]

Supply voltage 380 V to 480 V 3AC

100mm	3	0.008
200mm	2*3	0.008
100mm	5	0.008
200mm	2*5	0.008
100mm	9	0.008
200mm	2*9	0.008
100mm	18	0.008
200mm	2*18	0.016
100mm	30	0.016
200mm	45	0.031
200mm	60	0.031
200mm	85	0.044
300mm	132	0.144
300mm	200	0.144

Central Braking Modules		Cooling air requirement
Frame size	P _{rated} [kW]	[m³/s]

Supply voltage 380 V to 480 V

Supply voltage 500 V to 600 V

Supply voltage 660 V to 690 V

400mm	500-1200	0.14

SINAMICS S120 Cabinet Modules

Engineering Information

Auxiliary power requirements

Cabinet Modules require an auxiliary energy supply to function properly. This power requirement must be included in the configuration and supplied from an external source.

Please ask your Siemens contact for a solution.

Line Connection Modules

The auxiliary voltage for the Line Connection Modules is connected directly to input terminals. The following components require auxiliary power:

230 V AC Cabinet ventilation / circuit breaker

Fuse protection of 16 A must be provided on the plant distribution board.

Order No.	Frame size	Rated current I_{rated} [A]	Current requirement 230 V AC 50/60 Hz ¹⁾		
			Making current [A]	Holding current [A]	Fan [A]

Supply voltage 380 V - 480 V 3AC

6SL3700-0LE32-5AA0	FL	250	3.6	0.04	--
6SL3700-0LE34-0AA0	FL	400	3.6	0.04	--
6SL3700-0LE36-3AA0	GL	630	3.6	0.04	--
6SL3700-0LE38-0AA0	HL	800	10.8	0.12	--
6SL3700-0LE41-0AA0	JL	1000	0.5	0.06	1.07
6SL3700-0LE41-3AA0	JL	1250	0.5	0.06	1.07
6SL3700-0LE41-6AA0	JL	1600	0.5	0.06	1.07
6SL3700-0LE42-0AA0	KL	2000	0.5	0.06	2.14
6SL3700-0LE42-0BA0	KL	2000	0.5	0.06	2.14
6SL3700-0LE42-5BA0	KL	2500	0.5	0.06	2.14
6SL3700-0LE43-2BA0	LL	3200	0.5	0.04	2.14

Supply voltage 500 V - 690 V 3AC

6SL3700-0LG32-8AA0	FL	280	3.6	0.04	--
6SL3700-0LG34-0AA0	FL	400	3.6	0.04	--
6SL3700-0LG36-3AA0	GL	630	3.6	0.04	--
6SL3700-0LG38-0AA0	HL	800	10.8	0.12	--
6SL3700-0LG41-0AA0	JL	1000	0.5	0.06	1.07
6SL3700-0LG41-3AA0	JL	1250	0.5	0.06	1.07
6SL3700-0LG41-6AA0	JL	1600	0.5	0.06	1.07
6SL3700-0LG42-0BA0	KL	2000	0.5	0.06	2.14
6SL3700-0LG42-5BA0	KL	2500	0.5	0.06	2.14
6SL3700-0LG43-2BA0	LL	3200	0.5	0.06	2.14

¹⁾ Power requirement of contactors / circuit breaker and fans for degree of protection IP23, IP43, IP54 (in combination with Basic Line Modules)

SINAMICS S120 Cabinet Modules

Engineering Information

Basic Line Modules

The auxiliary voltage for Basic Line Modules is connected by means of cables supplied with the module. The connection should be made to the auxiliary voltage busbar of the adjacent Motor Module where possible. The following components require auxiliary power:

24 V DC: Control electronics

Fuse protection down-circuit of the auxiliary voltage busbar is provided in the Cabinet Module.

The power unit fans are supplied directly via the line-side input terminals for Basic Line Modules. A separate connection is not needed.

Order No.	Frame size	Rated power at 400 V resp. 690 V	Rated Input current I_{rated}	Current requirement ¹⁾		
				24 V DC	400 V resp. 690V AC	
		[kW]	[A]	[A]	50 Hz [A]	60 Hz [A]

Supply voltage 380 V – 480 V 3AC (DC link voltage 510 V – 650 V)

6SL3730-1TE34-2AA0	FB	200	365	1.1	0.5	0.6
6SL3730-1TE35-3AA0	FB	250	460	1.1	0.5	0.6
6SL3730-1TE38-2AA0	FB	400	710	1.1	0.5	0.6
6SL3730-1TE41-2AA0	GB	560	1010	1.1	1.8	2.6
6SL3730-1TE41-2BA0	GB	560	1010	1.1	1.8	2.6
6SL3730-1TE41-2BC0	GB	560	1010	1.1	1.8	2.6
6SL3730-1TE41-5AA0	GB	710	1265	1.1	1.8	2.6
6SL3730-1TE41-5BA0	GB	710	1265	1.1	1.8	2.6
6SL3730-1TE41-5BC0	GB	710	1265	1.1	1.8	2.6
6SL3730-1TE41-8AA0	GD	900	1630	1.1	1.8	2.6
6SL3730-1TE41-8BA0	GD	900	1630	1.1	1.8	2.6
6SL3730-1TE41-8BC0	GD	900	1630	1.1	1.8	2.6

Supply voltage 500 V – 690 V 3AC (DC link voltage 675 V – 930 V)

6SL3730-1TH33-0AA0	FB	250	260	1.1	0.3	0.4
6SL3730-1TH34-3AA0	FB	355	375	1.1	0.3	0.4
6SL3730-1TH36-8AA0	FB	560	575	1.1	0.3	0.4
6SL3730-1TH41-1AA0	GB	900	925	1.1	1.1	1.6
6SL3730-1TH41-1BA0	GB	900	925	1.1	1.1	1.6
6SL3730-1TH41-1BC0	GB	900	925	1.1	1.1	1.6
6SL3730-1TH41-4AA0	GB	1100	1180	1.1	1.1	1.6
6SL3730-1TH41-4BA0	GB	1100	1180	1.1	1.1	1.6
6SL3730-1TH41-4BC0	GB	1100	1180	1.1	1.1	1.6
6SL3730-1TH41-8AA0	GD	1500	1580	1.1	1.1	1.6
6SL3730-1TH41-8BA0	GD	1500	1580	1.1	1.1	1.6
6SL3730-1TH41-8BC0	GD	1500	1580	1.1	1.1	1.6

¹⁾ Power requirement of control electronics

SINAMICS S120 Cabinet Modules

Engineering Information

Smart Line Modules

The auxiliary voltage for Smart Line Modules is connected via the auxiliary voltage busbar. The following components require auxiliary power:

24 V DC: Control electronics
 400 V resp. 690 V AC: Power unit fans

Fuse protection down-circuit of the auxiliary voltage busbar is provided in the Cabinet Module.

Order No.	Frame size	Rated rectifier/regenerative power at 400 V resp. 690 V [kW]	Rated Input current I_{rated} [A]	Current requirement ¹⁾		
				24 V DC [A]	400 V resp. 690V AC 50 Hz [A]	60 Hz [A]

Supply voltage 380 V – 480 V 3AC (DC link voltage 500 V – 630 V)

6SL3730-6TE41-1AA0	HX	500	883	1.4	3.2	In preparation
6SL3730-6TE41-1BA0	HX	500	883	1.4	3.2	
6SL3730-6TE41-1BC0	HX	500	883	1.4	3.2	
6SL3730-6TE41-3AA0	JX	630	1093	1.5	4.7	
6SL3730-6TE41-3BA0	JX	630	1093	1.5	4.7	
6SL3730-6TE41-3BC0	JX	630	1093	1.5	4.7	
6SL3730-6TE41-7AA0	JX	800	1430	1.7	4.7	
6SL3730-6TE41-7BA0	JX	800	1430	1.7	4.7	
6SL3730-6TE41-7BC0	JX	800	1430	1.7	4.7	

Supply voltage 500 V – 690 V 3AC (DC link voltage 650 V – 900 V)

6SL3730-6TG38-8AA0	HX	710	757	1.4	3.2	In preparation
6SL3730-6TG38-8BA0	HX	710	757	1.4	3.2	
6SL3730-6TG38-8BC0	HX	710	757	1.4	3.2	
6SL3730-6TG41-2AA0	JX	1000	1009	1.5	4.7	
6SL3730-6TG41-2BA0	JX	1000	1009	1.5	4.7	
6SL3730-6TG41-2BC0	JX	1000	1009	1.5	4.7	
6SL3730-6TG41-7AA0	JX	1400	1430	1.7	4.7	
6SL3730-6TG41-7BA0	JX	1400	1430	1.7	4.7	
6SL3730-6TG41-7BC0	JX	1400	1430	1.7	4.7	

¹⁾ Power requirement of Control electronics, auxiliary power supply for fans.

SINAMICS S120 Cabinet Modules

Engineering Information

Active Line Modules + Active Interface Modules

Active Infeeds must be regarded as requiring two separate auxiliary voltage supplies, i.e. one for the Active Interface Module (AIM) and one for the Active Line Module (ALM).

The AIM requires the following voltages:

24 V DC: Control electronics

230 V AC: Cabinet ventilation, control voltage of precharging contactors depending on type

The ALM requires the following voltages:

24 V DC: Control electronics

400 V resp. 690 V AC: Power unit fans

Active Interface Modules and Active Line Modules together are delivered due to the required performance connections as one unit. For this reason, the AIM's auxiliary voltage connections are already made to the ALM's auxiliary voltage busbar when the unit is delivered. Fuse protection down-circuit of the auxiliary voltage busbar is provided in the Cabinet Modules.

The power requirement in the table below is based on a combination of Active Interface Module and Active Line Module.

Order No.	Frame size	Rated rectifier/ regenerative power at 400 V resp 690 V [kW]	Rated rectifier/ regenerative current I_{rated} [A]	Current requirement ¹⁾				
				24 V DC	230 V AC		400 V resp. 690V AC	
				[A]	50 Hz	60 Hz	50 Hz	60 Hz
					[A]	[A]	[A]	[A]

Supply voltage 380 V – 480 V 3AC (DC link voltage 570 V – 720 V)

6SL3730-7TE32-1BA0	FX+FI	132	210	1.27	0.3	0.4	0.5	0.6
6SL3730-7TE32-6BA0	FX+FI	160	260	1.27	0.3	0.4	1.4	2.0
6SL3730-7TE33-8BA0	GX+GI	235	380	1.52	0.65	0.93	1.8	2.6
6SL3730-7TE35-0BA0	GX+GI	300	490	1.52	0.65	0.93	1.8	2.6
6SL3730-7TE36-1BA0	HX+HI	380	605	1.57	3.4	4.8	3.6	5.3
6SL3730-7TE38-4BA0	HX+HI	500	840	1.57	3.4	4.8	3.6	5.3
6SL3730-7TE41-0BA0	JX+JI	630	985	1.67	3.5	4.9	5.4	7.9
6SL3730-7TE41-0BC0	JX+JI	630	985	1.67	3.5	4.9	5.4	7.9
6SL3730-7TE41-4BA0	JX+JI	900	1405	1.87	3.5	4.9	5.4	7.9
6SL3730-7TE41-4BC0	JX+JI	900	1405	1.87	3.5	4.9	5.4	7.9

Supply voltage 500 V – 690 V 3AC (DC link voltage 750 V – 1035 V)

6SL3730-7TG35-8BA0	HX+HI	560	575	1.57	3.4	4.8	2.1	3.1
6SL3730-7TG37-4BA0	JX+JI	800	735	1.67	3.5	4.9	3.2	4.7
6SL3730-7TG37-4BC0	JX+JI	800	735	1.67	3.5	4.9	3.2	4.7
6SL3730-7TG41-0BA0	JX+JI	1100	1025	1.87	3.5	4.9	3.2	4.7
6SL3730-7TG41-0BC0	JX+JI	1100	1025	1.87	3.5	4.9	3.2	4.7
6SL3730-7TG41-3BA0	JX+JI	1400	1270	1.87	3.5	4.9	3.2	4.7
6SL3730-7TG41-3BC0	JX+JI	1400	1270	1.87	3.5	4.9	3.2	4.7

¹⁾ Power requirement of Control electronics, auxiliary power supply for fans.

SINAMICS S120 Cabinet Modules

Engineering Information

Motor Modules Chassis

The auxiliary voltage for Motor Modules is connected via the auxiliary voltage busbar. The following components require auxiliary power:

24 V DC: Control electronics
400 V or 690 V AC: Power unit fans

Fuse protection down-circuit of the auxiliary voltage busbar is provided in the Cabinet Module.

Order No.	Frame size	Output power at 400 V resp. 690 V [kW]	Current requirement		
			24 V DC	400 V resp. 690V AC	
			[A]	50Hz [A]	60 Hz [A]
Supply voltage 380 V – 480 V 3AC (DC link voltage 500 V – 720 V)					
6SL3720-1TE32-1AA0	FX	110	0.8	0.5	0.6
6SL3720-1TE32-6AA0	FX	132	0.8	1.4	2.0
6SL3720-1TE33-1AA0	GX	160	0.9	1.8	2.6
6SL3720-1TE33-8AA0	GX	200	0.9	1.8	2.6
6SL3720-1TE35-0AA0	GX	250	0.9	1.8	2.6
6SL3720-1TE36-1AA0	HX	315	1.0	3.6	5.3
6SL3720-1TE37-5AA0	HX	400	1.0	3.6	5.3
6SL3720-1TE38-4AA0	HX	450	1.0	3.6	5.3
6SL3720-1TE41-0AA0	JX	560	1.25	5.4	7.9
6SL3720-1TE41-2AA0	JX	720	1.4	5.4	7.9
6SL3720-1TE41-4AA0	JX	800	1.4	5.4	7.9
Supply voltage 500 V – 690 V 3AC (DC link voltage 650 V – 1035 V)					
6SL3720-1TG28-5AA0	FX	75	0.8	0.3	0.4
6SL3720-1TG31-0AA0	FX	90	0.8	0.3	0.4
6SL3720-1TG31-2AA0	FX	110	0.8	0.3	0.4
6SL3720-1TG31-5AA0	FX	132	0.8	0.3	0.4
6SL3720-1TG31-8AA0	GX	160	0.9	1.1	1.6
6SL3720-1TG32-2AA0	GX	200	0.9	1.1	1.6
6SL3720-1TG32-6AA0	GX	250	0.9	1.1	1.6
6SL3720-1TG33-3AA0	GX	315	0.9	1.1	1.6
6SL3720-1TG34-1AA0	HX	400	1.0	2.1	3.1
6SL3720-1TG34-7AA0	HX	450	1.0	2.1	3.1
6SL3720-1TG35-8AA0	HX	560	1.0	2.1	3.1
6SL3720-1TG37-4AA0	JX	710	1.25	3.2	4.7
6SL3720-1TG38-1AA0	JX	800	1.25	3.2	4.7
6SL3720-1TG38-8AA0	JX	900	1.4	3.2	4.7
6SL3720-1TG41-0AA0	JX	1000	1.4	3.2	4.7
6SL3720-1TG41-3AA0	JX	1200	1.4	3.2	4.7

SINAMICS S120 Cabinet Modules

Engineering Information

Central Braking Modules

The auxiliary voltage for Central Braking Modules is connected via the auxiliary voltage busbar. The following components require auxiliary power:

230 V: Power unit fans

Fuse protection down-circuit of the auxiliary voltage busbar is provided in the Cabinet Module.

Order No.	P ₁₅₀ power at 400 V resp. 500 V resp. 690 V [kW]	Current requirement 230 V	
		50Hz [A]	60 Hz [A]
Supply voltage 380 V – 480 V 3AC (DC link voltage 500 V – 720 V)			
6SL3700-1AE35-0AA1	500	0.4	In preparation
6SL3700-1AE41-0AA1	1000	0.4	
Supply voltage 500 V – 600 V 3AC (DC link voltage 650 V – 900 V)			
6SL3700-1AF35-5AA1	550	0.4	In preparation
6SL3700-1AF41-1AA1	1050	0.4	
Supply Voltage 660 V – 690 V 3 AC (DC link voltage 850 V - 1035 V)			
6SL3700-1AH36-3AA1	630	0.4	In preparation
6SL3700-1AH41-2AA1	1200	0.4	

Auxiliary Power Supply Modules

Auxiliary Power Supply Modules do not require an auxiliary voltage supply. No auxiliary power needs to be configured for this type of cabinet.

Power requirement of supplementary components

The following components are each connected in the installed modules down-circuit of the fuse protection. The power requirement must be added to the basic requirement of the module.

CU320 Control Unit	
Max. power requirements (at 24 V DC) without taking account of digital outputs, option slot expansion	0.8 A
Max. fuse protection	20 A
▪ Voltage	-3 V to 30 V
▪ Low level (an open digital input is interpreted as "low")	-3 V to 5 V
▪ High level	15 V to 30 V
▪ Power consumption (typ. at 24 V DC)	10 mA
Digital outputs (continued-short-circuit-proof)	8 bidirectional, non-floating digital outputs/inputs
▪ Voltage	24 V DC
▪ Max. load current per digital output	500 mA
Terminal Module 31	
Voltage	24 V DC (20.4 V – 28.8 V)
Max. power requirement (at 24 V DC) without taking account of digital outputs and DRIVE-CLiQ	0.5 A
Digital outputs (continued-short-circuit-proof)	4 bidirectional, non-floating digital outputs/inputs
▪ Voltage	24 V DC
▪ Max. load current per digital output	100 mA
Sensor Module Cabinet 10 (SMC10)	
Voltage	24 V DC (20.4 V – 28.8 V)
Max. power requirement (at 24 V DC)	0.3 A
Sensor Module Cabinet 20 (SMC20)	
Voltage	24 V DC (20.4 V – 28.8 V)
Max. power requirement (at 24 V DC)	0.4 A
Sensor Module Cabinet 30 (SMC30)	
Voltage	24 V DC (20.4 V – 28.8 V)
Max. current requirement (at 24 V DC)	0.6 A
AOP30 Advanced Operator Panel	
Voltage	24 V DC (20.4 V – 28.8 V)
Max. power requirement (at 24 V DC)	
Without backlit display	100 mA
With maximum backlit display	200 mA

SINAMICS S120 Cabinet Modules

Engineering Information

Line reactors

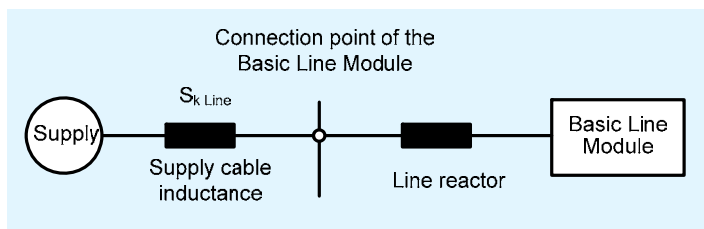
Line reactors are used in conjunction with Basic Line Modules or Smart Line Modules.

A line reactor must be installed whenever

- the rectifiers are connected to a line supply system with high short-circuit power, i.e. with low line supply inductance
- more than one rectifier is connected to the same point of common coupling (PCC),
- the rectifiers are equipped with line filters for RFI suppression filters
- rectifiers are operating in parallel to achieve a higher output power.

The line reactor smoothes the current drawn by the rectifier, thereby reducing harmonic components in the line current and thus the thermal load on the DC link capacitors of the rectifier. The harmonic effects on the supply are also reduced, i.e. both the harmonic currents and harmonic voltages in the power supply are attenuated.

Line reactors can be dispensed with only if the supply cable inductance is sufficiently high or the relative short-circuit power RSC ^{*)} correspondingly low.



The following values apply to Basic Line Modules:

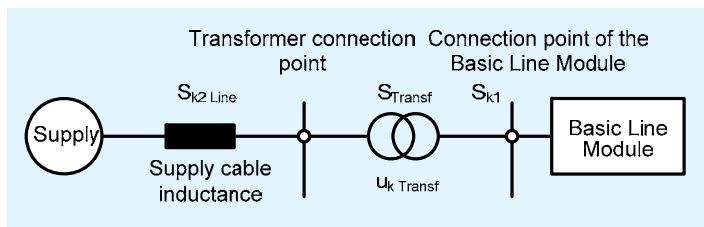
Output power kW	Line reactor can be omitted for an RSC of	Option Code	Line reactor required for an RSC of
<200	≤ 43	L22	> 43
200 to 500	≤ 33	L22	> 33
>500	≤ 20	L22	> 20

With Smart Line Modules the use of line reactors is generally necessary. Therefore line reactors are included as a standard and cannot be omitted.

With Basic Line Modules operating in parallel connection on a common Line Connection Module, line reactors must always be used.

As the configuration of the supply system for operating individual Basic Line Modules is often not known in practice, i.e. the short-circuit power at the PCC of the modules is not certain, it is advisable to connect a line reactor on the line side in cases of doubt.

A line reactor can only be dispensed with when the RSC value for relative short-circuit power is less than stated in the above table. For example, this applies if, as illustrated in the diagram below, the Basic Line Module is connected to the supply via a transformer with specially adapted rating and none of the other reasons stated above for using a line reactor is valid.



^{*)} RSC = Relative short-circuit power:

Ratio of the short-circuit power $S_{k \text{ line}}$ at the PCC to the fundamental frequency apparent power $S_{\text{Converter}}$ of the connected converters (according to EN 50 178 / VDE 0160).

In this case, the short-circuit power S_{k1} at the PCC of the Basic Line Module is approximately

$$S_{k1} = \frac{S_{Transf}}{u_{kTransf} + \frac{S_{Transf}}{S_{k2Line}}}$$

Abbreviation	Meaning
S_{Transf}	Rated power of the transformer
$u_{kTransf}$	Relative short-circuit power of the transformer
S_{k2Line}	Short-circuit power of the higher-level voltage level

Line reactors must always be provided if more than one rectifier is connected to the same point of common coupling. In this instance, the reactors perform two functions, i.e. they smooth the line current and decouple the rectifiers at the line side. This decoupling is essential in ensuring fault-free operation of the rectifier circuit. For this reason, each rectifier must be provided with its own line reactor, i.e. it is not permissible for more than one rectifier to be connected to the same line reactor.

A line reactor must also be installed for any rectifier that is to be equipped with a line filter for RI suppression. This is because filters of this type cannot be 100% effective without a line reactor.

Another constellation which requires the use of line reactors is the parallel connection of rectifiers where these are connected to a common power supply point. This generally applies to 6-pulse connections. The line reactors provide for balanced current distribution and ensure that no individual rectifier is overloaded by excessive current imbalances.

Parallel configuration

SINAMICS S120 Cabinet Modules are designed in such a way that standard devices can be operated in a parallel connection at any time. A maximum possible configuration of up to four identical modules can be operated in a parallel connection for the purpose of increasing their output power.

As a result of potential imbalances in the current distribution, the derating factors given below may apply.

Since the possibility of imbalances in current distribution cannot be completely precluded in parallel connections of Cabinet Modules, the derating factors for current or output need to be taken into account when parallel connections are configured:

Designation	Derating factor for parallel connection of 2 to 4 modules	Max. permissible number of parallel-connected modules
Active Line Modules	0.95	4
Basic Line Modules	0.925	4
Smart Line Modules	0.925	4
Motor Modules Chassis	0.95	4

It is not permissible to operate a mixture of Line Modules.

Modules in a parallel connection must all have the same voltage and output power rating. Further supplementary conditions to parallel-connected Motor Modules must be taken into account when the system is configured (see section "Motor Modules"). The parallel configuration of booksize units is not possible.

Power units connected in parallel are controlled by a common Control Unit via DRIVE-CLiQ. The separate ordering of DRIVE-CLiQ cables which establish the connections between the paralleled cabinet units must be considered (please see section "DRIVE-CLiQ wiring").

SINAMICS S120 Cabinet Modules

Engineering Information

Weights of S120 Cabinet Modules

The weights of the SINAMICS S120 Cabinet Modules are one of the essential configuring parameters. The weights of the cabinets to be included in the final assembly must be recorded and checked against the load-bearing capacity of the floor at the installation site.

The weights of the SINAMICS S120 Cabinet Modules are listed below. The weight data specified in the tables refer to standard models without options. The relevant weight of a cabinet is specified on the test certificate supplied and on the rating plate. The specified weight corresponds to the actual configuration level of the supplied cabinet.

The weight values specified below must be regarded as the minimum weights of Cabinet Modules:

Line Connection Modules		Weight
Frame size	I _{rated} [A]	[kg]
Supply voltage 380 V to 480 V 3AC		
FL	250	210
FL	400	230
GL	630	310
HL	800	340
JL	1000	450
JL	1250	470
JL	1600	490
KL	2000	600
KL	2000_P	620
KL	2500	620
LL	3200	720

Line Connection Modules		Weight
Frame size	I _{rated} [A]	[kg]
Supply voltage 500 V to 690 V 3AC		
FL	280	220
FL	400	230
GL	630	310
HL	800	340
JL	1000	450
JL	1250	470
JL	1600	490
KL	2000	600
KL	2500	620
LL	3200	720

Basic Line Modules		Weight
Frame size	P _{rated} at 400 V [kW]	[kg]
Supply voltage 380 V to 480 V 3AC		
FB	200	166
FB	250	166
FB	400	166
GB	560	320
GB	560_PR ¹	440
GB	560_PL ²	480
GB	710	320
GB	710_PR ¹	440
GB	710_PL ²	480
GD	900	320
GD	900_PR ¹	440
GD	900_PL ²	480

Basic Line Modules		Weight
Frame size	P _{rated} at 690 V [kW]	[kg]
Supply voltage 500 V to 690 V 3AC		
FB	250	166
FB	355	166
FB	500	166
GB	900	320
GB	900_PR ¹	440
GB	900_PL ²	480
GB	1100	320
GB	1100_PR ¹	440
GB	1100_PL ²	480
GD	1500	320
GD	1500_PR ¹	440
GD	1500_PL ²	480

Smart Line Modules		Weight
Frame size	P _{rated} at 400 V [kW]	[kg]
Supply voltage 380 V to 480 V 3AC		
GX	250	270
GX	355	270
HX	500	490
JX	630	775
JX	800	775

Smart Line Modules		Weight
Frame size	P _{rated} at 690 V [kW]	[kg]
Supply voltage 500 V to 690 V 3AC		
GX	450	270
HX	710	550
JX	1000	795
JX	1400	795

¹ Unit prepared for parallel connection on a Line Connection Module on right

² Unit prepared for parallel connection on a Line Connection Module on left

SINAMICS S120 Cabinet Modules

Engineering Information

Active Line Module + Active Interface Module		Weight
Frame size	P _{rated} at 400 V [kW]	[kg]

Supply voltage 380 V to 480 V 3AC

FI+FX	132	500
FI+FX	160	500
GI+GX	235	640
GI+GX	300	640
HI+HX	380	930
HI+HX	500	930
JI+JX	630	1360
JI+JX	900	1360

Active Line Module + Active Interface Module		Weight
Frame size	P _{rated} at 690 V [kW]	[kg]

Supply voltage 500 V to 690 V 3AC

HI+HX	560	930
JI+JX	800	1360
JI+JX	1100	1360
JI+JX	1400	1360

Motor Modules	Chassis	Weight
Frame size	P _M at 400 V [kW]	[kg]

Supply voltage 380 V to 480 V 3AC

FX	110	145
FX	132	145
GX	160	286
GX	200	286
GX	250	286
HX	315	490
HX	400	490
HX	450	490
JX	560	700
JX	710	700
JX	800	700

Motor Modules	Chassis	Weight
Frame size	P _M at 690 V [kW]	[kg]

Supply voltage 500 V to 690 V 3AC

FX	75	145
FX	90	145
FX	110	145
FX	132	145
GX	160	286
GX	200	286
GX	250	286
GX	315	286
HX	400	490
HX	450	490
HX	560	490
JX	710	700
JX	800	700
JX	900	700
JX	1000	700
JX	1200	700

Booksize Cabinet Kits		Weight
Frame size	I _{rated} [A]	[kg]

Supply voltage 380 V to 480 V 3AC

100mm	3	20.1
200mm	2*3	23.3
100mm	5	20.1
200mm	2*5	23.3
100mm	9	20
200mm	2*9	23.3
100mm	18	20
200mm	2*18	24.8
100mm	30	21.9
200mm	45	27
200mm	60	27
200mm	85	33
300mm	132	41
300mm	200	41

SINAMICS S120 Cabinet Modules

Engineering Information

Booksize Base Cabinets		Weight
Frame size	I _{rated} [A]	[kg]
Supply voltage 380 V to 480 V 3AC		
800mm		170
1200mm		240

Central Braking Modules		Weight
Frame size	P _{rated} [kW]	[kg]
Supply voltage 380 V to 480 V 3AC		
Supply voltage 500 V to 600 V 3AC		
Supply voltage 660 V to 690 V 3AC		
400mm	500-1200	180

Auxiliary Power Supply Modules		Weight
Frame size	I _{rated} [A]	[kg]
Supply voltage 380 V to 480 V 3AC		
Supply voltage 500 V to 690 V 3AC		
600mm	125	170
600mm	160	180
600mm	200	210
600mm	250	240

These values do not include the weight of optional components. For more detailed information, please ask your Siemens contact.

Please note the centers of gravity when lifting or installing the cabinets. A sticker showing the precise specifications regarding the center of gravity is attached to all cabinets/ transport units. Each cabinet or transport unit is weighed prior to delivery. The weight specified on the check sheet enclosed with the delivery might deviate slightly from the standard weights specified above.

Suitable hoisting gear operated by trained personnel is also required due to the weight of the cabinets.

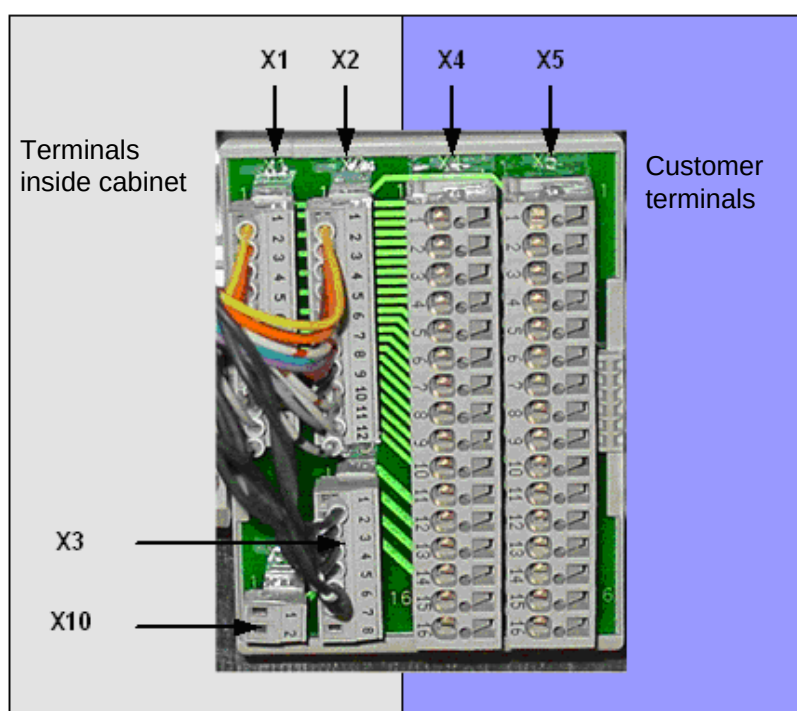
Information about equipment handling

Customer terminal block -A55

Overview

The customer terminal block -A55 acts as the interface to the automation system and collects a range of cabinet-internal signals to a central terminal block module mounted near the bottom of the cabinet.

It is integrated as standard in the chassis format Motor Modules and in combination with a CU320 Control Unit in the Cabinet Modules Basic Line, Smart Line, Active Line and Booksize Cabinet Kits.



Design

Terminals -X4 and -X5 are provided for the connection of customer signal cables. The connectable cable cross-section is 0.14 to 2.5 mm² which means that both solid and stranded cables can be used.

Terminals -X1 to -X3 are assigned internally in the cabinet depending on the cabinet variant (with / without option K90 or K91).

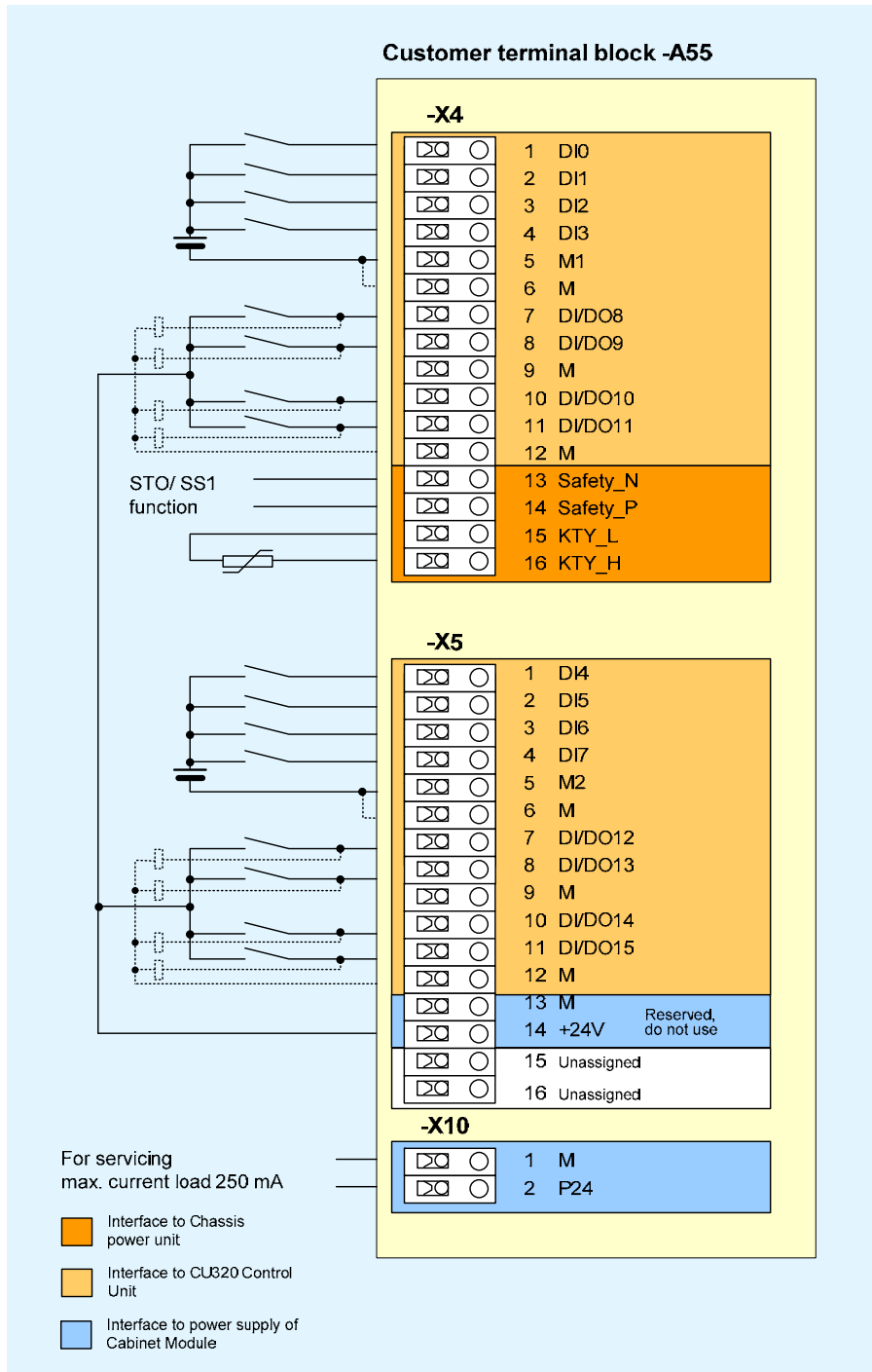
The customer terminal block –A55 includes:	Motor Modules		Line Modules/ Booksize Cabinet Kits	
	With CU320 (K90/K91)	Without CU320	With CU320 (K90/K91)	Without CU320
8 digital inputs	X	-	X	-
8 bidirectional inputs/outputs (DI/DO)	X	-	X	-
Temperature sensor connection (KTY84)	X	X	¹⁾	¹⁾
Auxiliary voltage output (+24 V)	X	X	X	X ²⁾
Safety function ("Safe Torque Off/ Safe Stop1")	X	X	¹⁾	¹⁾

¹⁾ Connection is provided on the separate customer terminal block –X55 with Booksize Cabinet Kits

²⁾ Not on Line Modules

SINAMICS S120 Cabinet Modules

Engineering Information



Customer terminal block -A55

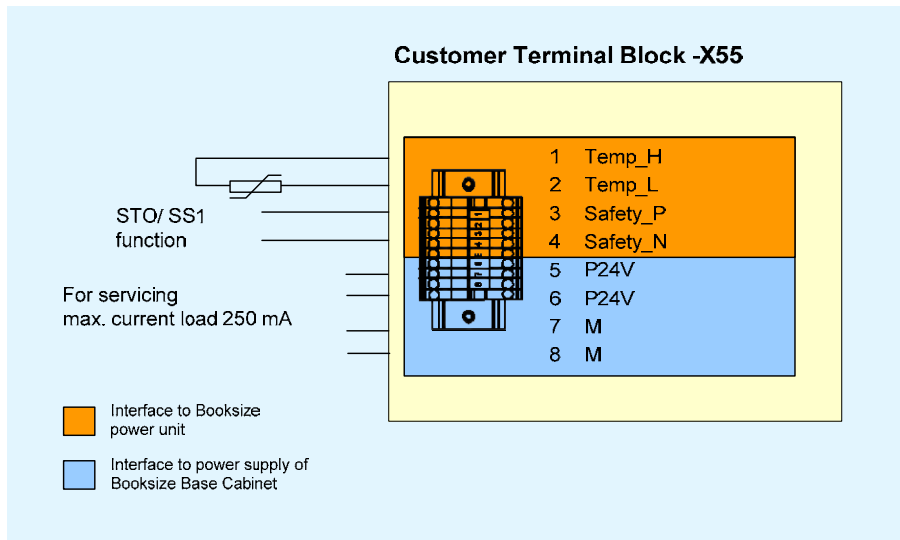
Terminal -X10 has a connector and is provided for servicing purposes. It is important to note its max. current load rating of 250 mA. This connection is not short-circuit-proof and the wiring and cable routing must be planned accordingly. The connectable cable cross-section is 0.14 to 1.5 mm².

The connections of the safety function Safe Torque Off (X4) are per default pre-occupied. When option K82 is installed, the connections to its relay combination are connected at X4. When option K82 is not installed, voltage supply links are connected so that a pulse disable is not triggered because option K82 is missing. It is of course still possible to connect an external interface.

Customer terminal block -X55

Overview

Instead of the terminal module –A55, Booksize Cabinet Kits are equipped as standard with a terminal block designated –X55. The signals from the power units are passed to this terminal block near the bottom of the cabinet, which is the terminal area of the Booksize Base Cabinet.



Customer terminal block -X55

Besides the possibility of getting connected to the 24 V DC supply the terminal also features a temperature evaluation and terminals for the safety functions of the power units. A cable cross-section of between 0.2 - 2.5 mm² can be connected to this block. Depending on the ordered variant, the safety functions (-X55:3/4) are either connected to the voltage supply of the terminal or wired to option K82.

The voltage at terminals -X55:5-8 is generated by the SITOP power supply which will be installed in the Booksize Base Cabinets. The units in Booksize format cannot supply a 24 V DC voltage backed up by the DC link. The permissible current load at -X55:5/6 is 250 mA for each Booksize Cabinet Kit. All the Cabinet Kits incorporated in a Base Cabinet are protected by a common 4 A fuse. The terminals might be partially assigned if the equipment is ordered with option L37 / DC link interface and/or option K82 / Connection of function "Safe Torque Off" and "Safe Stop1". In this case, one terminal will still be available for customer assignment. In this case, the maximum current rating must be noted and short-circuit protection provided.

Booksize Cabinet Kits with Double Motor Modules (order number 6SL3720-2TExx-xAB0) have a separate –X55.1 for the second inverter output in addition to –X55. These interfaces are identical.

The terminal module –A55 is installed in addition to terminal block -X55 on units with option K90/K91, i.e. a CU320, and provides access to the digital inputs and outputs of the connected Control Unit at the bottom of the cabinet. The terminals have the same properties as those on the standard terminal module (see section "Customer terminal block –A55"). Terminal –X10 on the module is also assigned which means that a 24 V supply can be picked off via a connector for servicing purposes. The maximum current rating is 250 mA.

SINAMICS S120 Cabinet Modules

Engineering Information

Auxiliary voltage distribution

To simplify the auxiliary voltage supply to S120 Cabinet Modules, the individual modules are fitted with a special busbar system. This auxiliary voltage busbar is ready fitted and wired in the delivered units and the necessary connections from this busbar into the relevant cabinet are pre-assembled.

The standard busbar assignments are as follows:



Busbar	Voltage
1 and 2	Line voltage (2 phases for fan supply via transformer) - for 380 V – 480 V 2AC: 380 V to 480 V - for 500 V – 690 V 2AC: 500 V to 690 V
3-4	230 V AC e.g. for distribution to circuit breaker, Booksize Base Cabinet
5-6	24 V DC for electronics power supply

The existing busbars in the individual modules can be interconnected by means of special busbar links supplied with the modules.

The busbar is fitted with Faston terminals throughout. The busbar Infeed can be connected by means of special Infeed plugs or with standard Faston connectors. Infeed plugs rated to match the current of the auxiliary voltage busbar are supplied with the Line Connection Module, but can also be ordered separately.

Voltages to supply additional components mounted in the cabinet can be picked off at any point along the busbar. Connectors, usually of the standard Faston type, can also be used for this purpose. In this case, separate fuse protection for the pick-off must be provided.

The voltages on the auxiliary voltage busbar must be provided by an external auxiliary power supply. The Auxiliary Power Supply Module is one possible source. The maximum load rating of the busbar is 100 A (80 A UL). If the total power requirement exceeds the maximum load rating, it is advisable to split the busbar line into segments and select additional Infeed points.

The auxiliary voltage busbars are available in the following cabinet types:

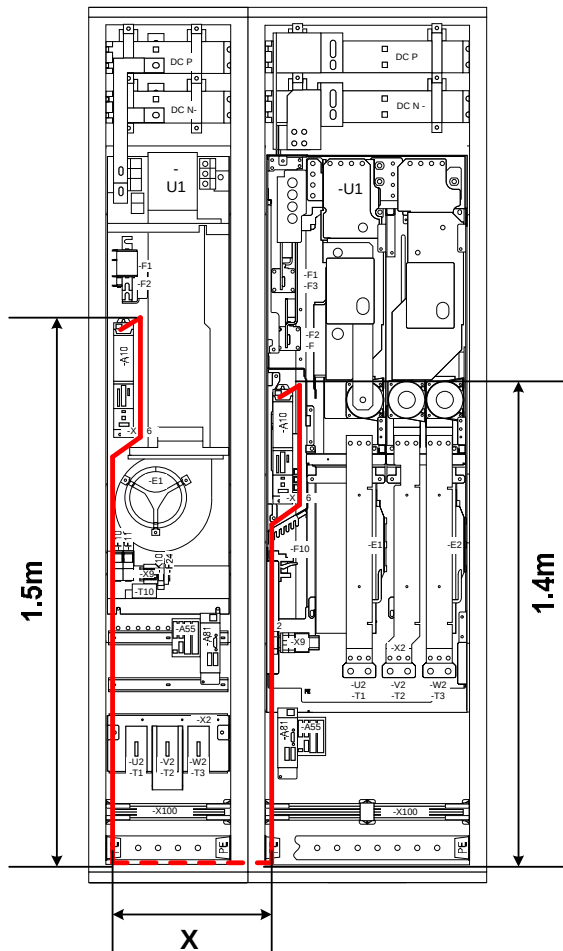
- Smart Line Modules
- Active Line Modules
- Booksize Base Cabinet
- Motor Modules Chassis format
- Central Braking Modules
- Auxiliary Power Supply Modules

Cabinet Modules without an auxiliary voltage busbar are either supplied with cables for connecting to busbars in adjacent cabinets or feature the appropriate interfaces. The selection is function-dependent, i.e. a busbar where general disconnection of the auxiliary voltage is required, or a terminal if the preferred option, for example, is to supply the auxiliary voltage separately via an emergency power supply. It is, of course, always possible to connect a terminal to the auxiliary voltage busbar.

DRIVE-CLiQ wiring

Cabinet Modules are shipped with all DRIVE-CLiQ connections ready wired within the cabinet. This applies regardless of any options ordered. DRIVE-CLiQ connections between cabinets cannot be ready wired on shipped units, as the customer's final implementation requirements cannot be determined from the order and the very wide range of connection / topology options would make ready wiring impossible. This also applies to connections which extend beyond a Booksize Cabinet Kit. These cable connections must be ordered separately.

The following cable routes are recommended:



Cables within the power unit should be routed according to the specifications for signal cabling in the equipment manual. A route designed for minimum cross-interference and thus fault-free operation is defined within the units. Furthermore, when units are wired to conform with specifications, component replacement will not be hindered by cable routing. Proper cable routing also ensures that cables are securely mounted.

Cables are routed within the power unit down to the bottom cabinet cross-beam. From there they can be taken to the next cabinet. It is always advisable to install cables along cross-beams to provide EMC protection.

For planning purposes, the distance between the terminals on the Control Unit or power unit down to the bottom cross-beam is 1.5 m for sizes FX and GX and 1.4 m for sizes HX and JX.

The relevant cabinet width (indicated with x in the diagram) can be used to plan the connection distance between cabinets.

One exception is the Basic Line Module in the version for parallel connection on a Line Connection Module. The cable length calculation must be based on $200 \text{ mm} + x$ when cables are routed from the left-hand side. The following can be assumed for routing to the right: $x = \text{cabinet width} - 200 \text{ mm}$.

For information about Booksize Base Cabinets, please refer to section "Booksize Base Cabinet/ Booksize Cabinet Kits".

Cabling route for DRIVE-CLiQ connections with FS FX/GX and HX/JX

The appropriate DRIVE-CLiQ cables can be supplied pre-assembled in defined standard lengths up to 5 m, in meter lengths up to 70 m or reeled cable with separately available connectors. For ordering information, please refer to the catalog.

Example of a cable length calculation:

In this example, the Cabinet Modules illustrated in the diagram above must be operated on one Control Unit. The Control Unit is mounted in the left-hand Motor Module. (The right-hand module also contains a CU320 in the diagram above. This is merely illustrated for the sake of completeness. DRIVE-CLiQ cannot be used to connect two Control Units.).

All the connections in the left-hand cabinet are ready made at the factory. In the right-hand cabinet as well, all DRIVE-CLiQ links, including the connection to the encoder module, have been made in the factory. The only connection still required is the link between the right-hand power unit and the left-hand Cabinet Module. This can involve a connection to the Control Unit or require a connection to the power unit as defined by the rules for DRIVE-

SINAMICS S120 Cabinet Modules

Engineering Information

CLiQ wiring (see subsection "DRIVE-CLiQ" of the chapter "SINAMICS S120, General Information about Built-in and Cabinet Units").

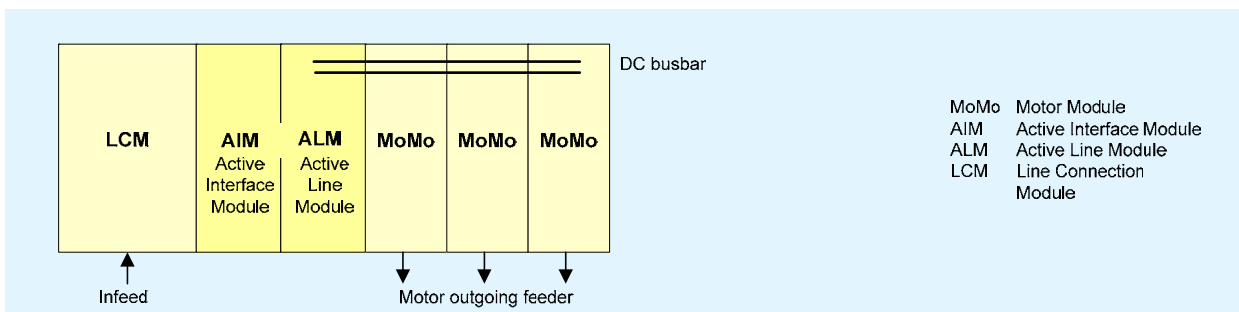
The additional cabling required is calculated as follows: 1.5 m + 0.4 m cabinet width + 1.4 m = 3.3 m. A pre-assembled, 4 m long cable is recommended for this purpose: 6FX2002-1DC00-1AE0

Inter-cabinet DRIVE-CLiQ connecting cables can also be fitted in the factory on request. The order-specific Integration Engineering (order number 6SL3780-0Ax00-0AA0) can, for example, be used for this purpose. For further details, please ask your Siemens contact.

Erection of cabinets

The standard erection sequence for Cabinet Modules is from the left, starting with the Line Connection Modules, followed by the Line Modules and ending with the Motor Modules on the far right.

To make allowance for the DC link busbar design, the Motor Modules should be arranged in decreasing order of output rating, i.e. with the highest output at the Infeed and the lowest on the right or outside.

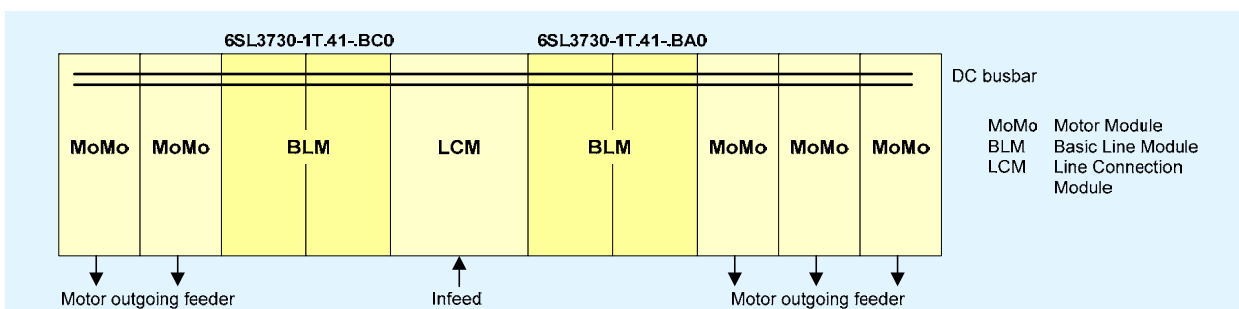


Configurations with parallel-connected Infeeds for increasing the output power should be arranged as a symmetrical, mirror image. In this instance, the Line Connection Module is positioned in the center of the cabinet group with the two Line Modules. The Motor Modules are then arranged on the left and right of the Infeed units (see configuration examples below).

Side panels (option L26 or L27) must be provided at both ends of the group to provide the requisite degree of protection.

Examples of Cabinet Module arrangements

Supply of two Basic Line Modules via a common Line Connection Module (6-pulse infeed)

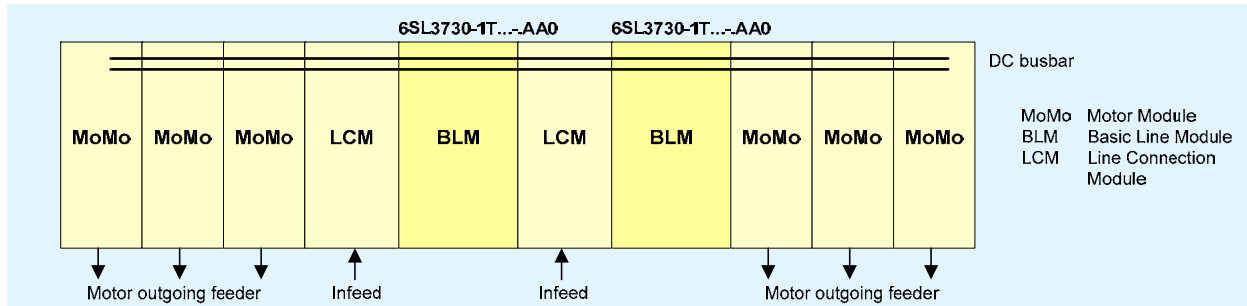


In the case of parallel connections of Basic Line Modules supplied by a common Line Connection Module, a derating factor of 7.5 % must be applied due to the possibility of current imbalances.

In this case Basic Line Modules with mirror-image configuration must be selected, version 6SL3730-1T□41-□BA0 for erection to the right of the LCM and 6SL3730-1T□41-□BC0 for erection to the left of the LCM must be selected for such applications.

These module versions include integrated line-side fuses that are needed because the circuit breaker in the LCM is not capable of providing selective protection for the Basic Line Modules. They are therefore 200 mm wider in each case than version 6SL3730-1T□□□-□AA0.

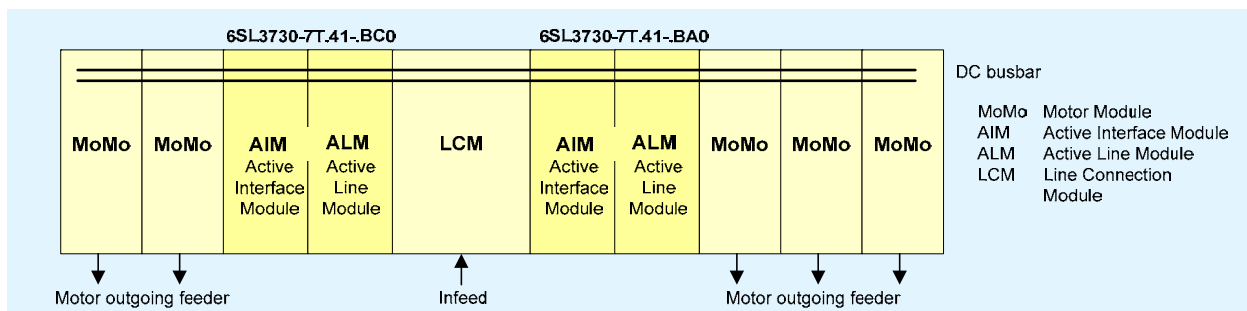
Supply of two Basic Line Modules via two separate Line Connection Modules (12-pulse Infeed)



A double-tier converter transformer must be selected in order to obtain a 12-pulse Infeed which has lower harmonic effects on the supply. The two secondary windings are mutually phase-shifted by 30 el (vector group e.g. Dy5Dd0 or Dy11Dd0).

This arrangement then supplies one Basic Line Module via one LCM in each case. The Basic Line Modules are protected by the fuses or circuit breakers (at $I > 800$ A) in the LCMs, i.e. BLMs with supplementary line fuses are not required (each module is version 6SL3730-1T...-AA0).

Supply of two Active Infeeds via a common Line Connection Module



To obtain a higher Infeed capacity with Active Infeeds, these modules can be connected in parallel.

A compact arrangement can be achieved by supplying the Active Infeeds from a common line supply. The combinations of Active Line Modules and Active Interface Modules are erected to the left and right of the Line Connection Module. Derating of 5 % must be applied to parallel connections to compensate for current imbalances.

As regards the cabinet sequence, the Motor Modules with high output ratings should be placed closest to the Infeed and the others arranged in descending order of output rating. This configuration is not absolutely essential, but allows the DC link busbars to be arranged more efficiently and is therefore cheaper.

Door opening angle

The doors on Cabinet Modules are the same width as the cabinets themselves. Cabinets up to a width of 600 mm have a single door which is hinged on the right-hand side. Wider cabinets have double doors.

The following information is important, for example, in the planning of emergency exit routes:

- Maximum door width: 600 mm
- Maximum door opening angle:
 - o with degree of protection IP20/IP21 without options in the cabinet door 135 °
 - o with degree of protection IP23/IP43/IP54 110 °
 - o with option L37 (DC-Switch) 110 °

SINAMICS S120 Cabinet Modules

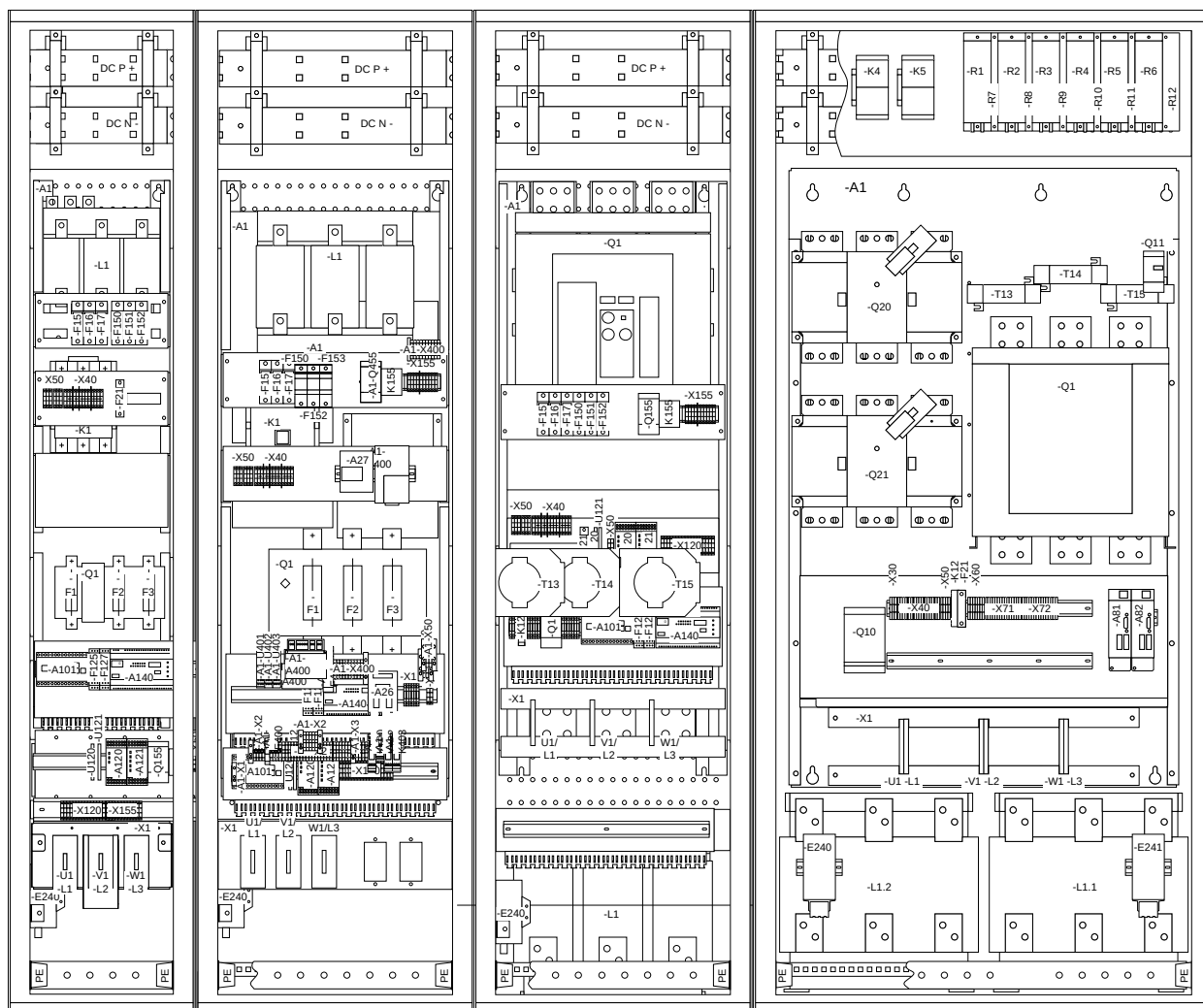
Engineering Information

Line Connection Modules

Design

Line Connection Modules contain the line-side components as main circuit breaker and fuse switch-disconnector or circuit breaker and provide the connection between the plant power system and the Line Modules.

Various frame sizes are available depending on the input power rating.



Example configuration of Line Connection Modules in frame sizes FL, GL/HL, JL, KL/LL

Different frame sizes have been developed to meet the requirements of different applications which vary in terms of their power demand and optional component complement.

Main breakers with fuse switch-disconnectors are used in frame sizes FL, GL and HL. Type 3WL circuit breakers are installed in Line Connection Modules with higher output power ratings. The incoming supply is fed in from below on all units. The supply can be brought in from the top, but requires an additional cabinet.

Line Connection Modules are designed such that they do not need a cabinet fan for operation at standard ambient conditions. Partitions and air-flow guides inside the cabinets obviate the need for fan cooling.

When combined with a Basic Line Module in combination with degree of protection IP23, IP43 or IP54, frame sizes JL, KL and LL are equipped with a fan to provide extra internal cooling. On these models, the fan is mounted in the hood, protected by fuses and connected separately to a clamp in the terminal area.

SINAMICS S120 Cabinet Modules

Engineering Information

Planning recommendations, special features

Line Modules should be connected as standard on the right of a Line Connection Module. Line Modules can also be erected to the left of the LCM with frame size KL and LL. However, this rule applies only to Line Modules. Other types of Cabinet Modules can be connected at any side of a Line Connection Module. It must be noted that option M26 (side panel mounted on right) cannot be used on an LCM.

Options L42 (LCM for Active Infeed), L43 (LCM for Basic Line Module) and L44 (LCM for Smart Line Module) must also be taken into account. These serve to assign the LCM to the adjacent Line Modules. They include precharging circuits and cable connections to the relevant Infeed. For this reason, it is advisable to place the LCM and Line Modules within the same transport unit. In this case, the necessary cable connections will be made in the factory.

If a grounding switch is also needed, the space it requires means that an LCM in frame size KL or LL must be used.

Assignment to rectifiers

To facilitate the configuring process, the correct Line Connection Modules are already assigned to the rectifiers. The table below shows the possible combinations.

Line Connection Modules		Basic Line Modules		Smart Line Modules		Active Line Modules	
Current [AC] ¹⁾ A	Order No.	Current [AC] A	Order No.	Current [AC] A	Order No.	Current [AC] A	Order No.
Supply voltage 380 V - 480 V							
250	6SL3700-0LE32-5AA0					210	6SL3730-7TE32-1BA0
400	6SL3700-0LE34-0AA0					260	6SL3730-7TE32-6BA0
630	6SL3700-0LE36-3AA0	365 460	6SL3730-1TE34-2AA0 6SL3730-1TE35-3AA0	463	6SL3730-6TE35-5AA0	380 490	6SL3730-7TE33-8BA0 6SL3730-7TE35-0BA0
800	6SL3700-0LE38-0AA0	710	6SL3730-1TE38-2AA0	614	6SL3730-6TE37-3AA0	605	6SL3730-7TE36-1BA0
1000	6SL3700-0LE41-0AA0			883	6SL3730-6TE41-1AA0	840	6SL3730-7TE38-4BA0
1250	6SL3700-0LE41-3AA0	1010	6SL3730-1TE41-2AA0	1093	6SL3730-6TE41-3AA0	985	6SL3730-7TE41-0BA0
1600	6SL3700-0LE41-6AA0	1265	6SL3730-1TE41-5AA0	1430	6SL3730-6TE41-7AA0	1405	6SL3730-7TE41-4BA0
2000	6SL3700-0LE42-0AA0	1630	6SL3730-1TE41-8AA0				
2000	6SL3700-0LE42-0BA0	2 x 935	6SL3730-1TE41-2BA0 6SL3730-1TE41-2BC0	2 x 817	6SL3730-6TE41-1BA0 6SL3730-6TE41-1BC0	2 x 936	6SL3730-7TE41-0BA0 6SL3730-7TE41-0BC0
2500	6SL3700-0LE42-5BA0	2 x 1170	6SL3730-1TE41-5BA0 6SL3730-1TE41-5BC0	2 x 1011	6SL3730-6TE41-3BA0 6SL3730-6TE41-3BC0		
3200	6SL3700-0LE43-2BA0	2 x 1508	6SL3730-1TE41-8BA0 6SL3730-1TE41-8BC0	2 x 1323	6SL3730-6TE41-7BA0 6SL3730-6TE41-7BC0	2 x 1335	6SL3730-7TE41-4BA0 6SL3730-7TE41-4BC0
Supply voltage 500 V - 690 V							
280	6SL3700-0LG32-8AA0	260	6SL3730-1TH33-0AA0				
400	6SL3700-0LG34-0AA0	375	6SL3730-1TH34-3AA0				
630	6SL3700-0LG36-3AA0	575	6SL3730-1TH36-8AA0	463	6SL3730-6TG35-5AA0	575	6SL3730-7TG35-8BA0
800	6SL3700-0LG38-0AA0			757	6SL3730-6TG38-8AA0	735	6SL3730-7TG37-4BA0
1000	6SL3700-0LG41-0AA0	925	6SL3730-1TH41-1AA0				
1250	6SL3700-0LG41-3AA0	1180	6SL3730-1TH41-4AA0	1009	6SL3730-6TG41-2AA0	1025	6SL3730-7TG41-0BA0
1600	6SL3700-0LG41-6AA0	1580	6SL3730-1TH41-8AA0	1430	6SL3730-6TG41-7AA0	1270	6SL3730-7TG41-3BA0
2000	6SL3700-0LG42-0BA0	2 x 855	6SL3730-1TH41-1BA0 6SL3730-1TH41-1BC0	2 x 700	6SL3730-6TG38-8BA0 6SL3730-6TG38-8BC0	2 x 698	6SL3730-7TG37-4BA0 6SL3730-7TG37-4BC0
				2 x 934	6SL3730-6TG41-2BA0 6SL3730-6TG41-2BC0	2 x 974	6SL3730-7TG41-0BA0 6SL3730-7TG41-0BC0
2500	6SL3700-0LG42-5BA0	2 x 1092	6SL3730-1TH41-4BA0 6SL3730-1TH41-4BC0			2 x 1206	6SL3730-7TG41-3BA0 6SL3730-7TG41-3BC0
3200	6SL3700-0LG43-2BA0	2 x 1462	6SL3730-1TH41-8BA0 6SL3730-1TH41-8BC0	2 x 1323	6SL3730-6TG41-7BA0 6SL3730-6TG41-7BC0		

Parallel connection of two Line Modules with identical output rating.

The required derating factors listed below are already included in the current values given above:

- 7,5 % for Basic Line Modules
- 7,5 % for Smart Line Modules
- 5 % for Active Line Modules

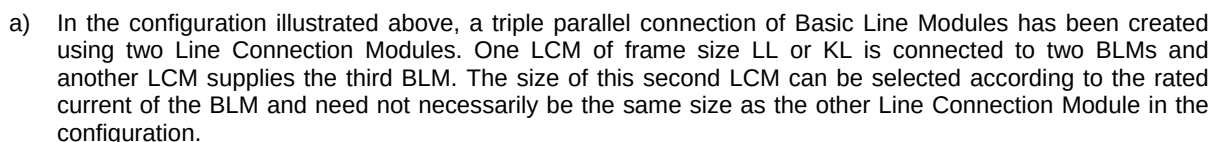
¹⁾ The listed current values are based on an ambient temperature (inlet air temperature) of 40 °C

Engineering Information

For other combinations of Cabinet Modules which deviate from the standard, please ask your Siemens contact for further information.

Parallel connections can be created with Line Connection Modules. Line Modules can be operated in a double parallel connection on one LCM in frame sizes KL and LL. In addition it is easy feasible to implement parallel connections of larger numbers of rectifiers by paralleling Line Connection Modules.

Implementation of a triple parallel connection of BLMs



The parallel connection is made up of standard components. Orders for modules for parallel connection are not subject to any special conditions. Line Connection Modules prepared for parallel connection (displayed on yellow background in the table above) already include two reactors when used with Basic Line Modules. Smart Line Modules are generally equipped with reactors which are integrated in the SLM. Please note the supplementary physical conditions described in the chapter "Fundamental Principles and System Description".

DC busbar

The DC busbar for Cabinet Modules is available as an option (M80 - M87) and must be ordered separately. In contrast to other modules, however, this is not a "required" essential option for the Line Connection Modules. For example, if the Line Connection Module is positioned at the end of a cabinet line and not required to transfer any DC link energy, then the DC busbar system can be dispensed with.

Circuit breakers

Line Connection Modules for current ratings up to 800 A are equipped as standard with a manually operated fuse switch-disconnector. SIEMENS circuit breakers from the SENTRON WL product range are installed for higher input currents.

The circuit breaker is controlled and supplied internally. It is not necessary to install additional cabinet wiring or provide separate control cables.

The Line Connection Module is designed in such a way that the front panel of the circuit breaker projects through a cutout section in the door, i.e. all control elements and displays for the breaker remain accessible when the cabinet door is closed.

Equipment of the circuit breaker

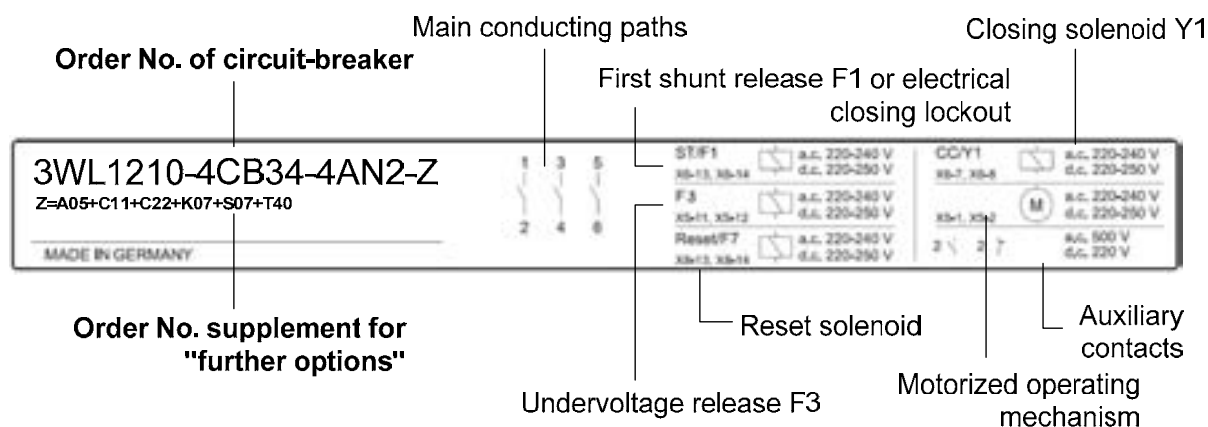
The type of circuit breaker used has been selected to meet the exacting standards of a multi-motor plant configuration. The modular structure of the Sentron WL also allows the breaker to be tailored to meet specific plant requirements.

Components such as the auxiliary contacts, communication modules, overcurrent release characteristics, current sensors, auxiliary power signaling switch, automatic reset mechanism, interlocks and moving mechanism can be replaced or retrofitted at a later date so that the breaker can be adapted to meet new or different requirements. The main contacts can be replaced to increase the endurance of the breaker.

The standard features of SENTRON WL circuit breakers are as follows:

- Mechanical CLOSE and mechanical OPEN buttons
- Manual operating mechanism with mechanical demand
- Position indicator 0/1
- Ready to close indicator []/OK
- Storage status indicator
- Auxiliary power switch 2NO + 2NC
- Contact erosion indicator for main contacts.
- Mechanical "tripped" indicator for overcurrent trip system
- Mechanical closing lockout after tripping
- Breaker front panel cannot be removed when the breaker is closed

The equipment features and other special characteristics are shown on the equipment plate.



Equipment plate of a circuit breaker

SINAMICS S120 Cabinet Modules

Engineering Information

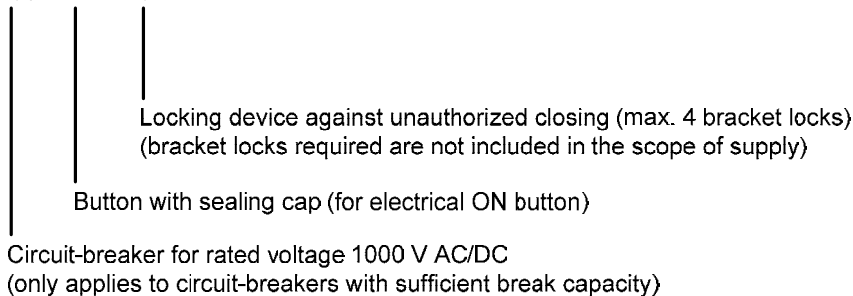
The breaking capacity / short-circuit breaking capacity of the circuit breakers is 100 kA up to 500 V or 85k A up to 690 V in accordance with switching class H.

The circuit breakers for S120 Cabinet Modules are also equipped with a motorized operating mechanism which allows automatic reclosing or breaker closing from a control station. It can be controlled by means of a 208-240 V AC 50/60 Hz or 220-250 V DC signal.

To facilitate operation of the Line Connection Modules, the circuit breaker is equipped with additional standard features. This can be identified by the supplementary codes appended to the breaker's order number.

The following additional equipment features are supplied:

Z= A05+ C11+ S07



Standard options of supplied circuit breakers

Apart from these optional supplementary features, the circuit breakers offer additional functions than standard breakers which make them ideal for application in multi-axis systems. They are equipped with RI suppression for operation on converters. Various signaling switches also support communication with selected Line Modules and therefore optimize the breakers for integration in the plant periphery. The breakers are also fitted with a special door sealing frame to render the units suitable for application in Line Connection Modules in compliance with the selected protection class.

Definition of terms

Motorized operating mechanism: For automatic loading of the integrated storage spring. It is activated if the storage spring has been unloaded and control voltage is present. Switches off automatically when the spring is loaded. Manual actuation of the storage spring is independent of the motor operating mechanism. This allows remote closing operations in combination with the closing solenoid.

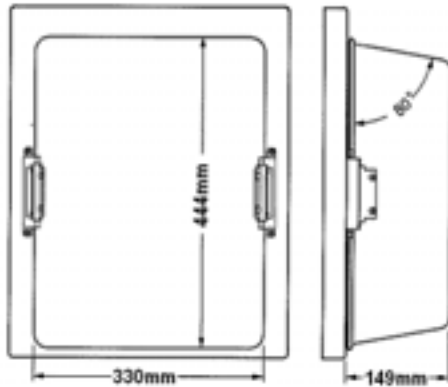
"Tripped" indicator: If the circuit breaker has tripped as a result of overload, short circuit or ground fault, this condition can be signaled by the "Tripped" indicator.

"Ready to close" indicator: SENTRON WL circuit breakers are equipped as standard with an optical "Ready to close" indicator. The circuit breakers used also allow the "ready to close" condition to be annunciated by a signaling switch.

Sealing cap over button "Electrical ON": The "Electrical ON button" is fitted as standard with a sealing cap.

Locking bracket for "OFF": The locking bracket for "OFF" can be covered with up to 4 bracket locks Ø 6 mm. The circuit breaker cannot then be closed mechanically and the disconnecter condition in the OFF position is fulfilled.

For Cabinet Modules with degree of protection IP54, shrouding covers are installed as standard in front of the circuit breaker to meet the stringent requirements of this degree of protection.



Shrouding cover for a circuit breaker

Protective functions

The standard circuit breakers feature protective functions in compliance with equipment class ETU 25B.

The integrated electronic overcurrent release provides the following functionality:

- Overload protection (L release)
- Short-time delayed short-circuit protection (S release)
- Instantaneous short-circuit protection (I release)

The basic protective functions of the overcurrent release operate reliably without an additional auxiliary voltage. The required energy is provided by energy converters in the breaker. The overcurrent release electronics bases its current evaluation on an RMS calculation.

The individual functions are parameterized by a rotary coding switch.

Overload protection – L release

The setting value I_R defines the maximum continuous current at which the breaker can operate without tripping. The time-lag class t_R defines the maximum period of overload before the breaker trips.

Setting values for I_R = (0.4 / 0.45 / 0.5 / 0.55 / 0.6 / 0.65 / 0.7 / 0.8 / 0.9 / 1.0) $\times I_{rated}$

Setting values for t_R = 10 s (with 6 $\times I_R$)

Short-time delayed short-circuit protection– S release

The overcurrent release provided allows tripping as a result of short-circuit current I_{sd} to be delayed by the period t_{sd} . This means that short-circuit protection can be applied selectively in switchgear with several time-grading levels.

Setting values for I_{sd} = (1.25 / 1.5 / 2 / 2.5 / 3 / 4 / 6 / 8 / 10 / 12) $\times I_{rated}$

Setting values for t_{sd} = 0 / 0.02(M) / 0.1 / 0.2 / 0.3 / 0.4 s

Instantaneous short-circuit protection with an adjustable response value lower than the preset response value I_i can be implemented with the setting value $t_{sd} = 0$ s.

Instantaneous short-circuit protection– I release

The circuit breaker trips instantaneously when the current exceeds the setting value for I_i .

Setting values for I_i $\geq 20 \times I_{rated}$ (preset), max. = 50 kA

Short-circuit strength

The Line Connection Modules are mechanically designed to withstand the tolerance limits of the circuit breaker. Higher short-circuit strengths are available on request.

SINAMICS S120 Cabinet Modules

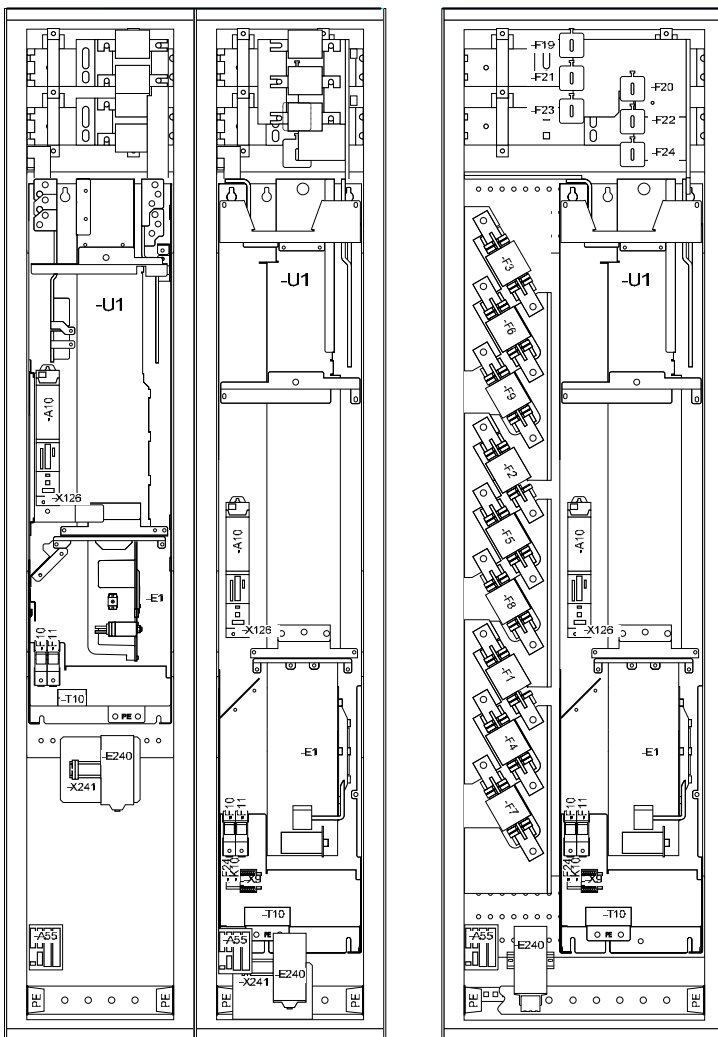
Engineering Information

Basic Line Modules

Design

Basic Line Modules are available for S120 Cabinet Modules in the output power range 200 to 900 kW at 400 V and 250 to 1500 kW at 690 V. The largest variant in each case therefore differs from the chassis unit spectrum. These units can be supplied only as S120 Cabinet Modules.

Basic Line Modules can be used in combination with Line Connection Modules. In this case, the two module types must be directly connected. The BLM cannot be installed at a remote location from the LCM. Possible combinations can be found in the section "Line Connection Modules".



Example configuration of Basic Line Modules in frame sizes FB and GB/GD and also for a parallel connection

Every Basic Line Module requires a connection to a Control Unit. Differences between frame sizes FB and GB/GD in terms of mechanical design and optional equipment only consist in use of different chassis frame sizes.

A fully controlled thyristor bridge is used on frame sizes FB and GB to precharge the connected DC link by the Basic Line Module. The thyristors operate normally with a firing angle of 0°.

Basic Line Modules of frame size GD with a power rating of 900 kW (400 V) resp. 1500 kW (690 V) feature a diode bridge. On these units, the DC link is precharged via a separate, line-side precharging circuit. This is fitted in the Line Connection Module and selected via option L43 of the LCM.

DC link fuses

The Basic Line Modules do not have DC link fuses as standard.

If fuses are required, they can be ordered with option N52. The fuses are mounted on the connecting rail to the DC busbar in the cabinet and not in the power unit itself.

Parallel connections of Basic Line Modules

Frame sizes GB/ GD are designed as a special variant which is also suitable for operation in parallel connections on one Line Connection Module. Line-side fuses need to be provided to selectively protect the individual Basic Line Modules in a parallel connection. The standard cabinet needs to be widened by 200 mm for this purpose. These units can be identified by the "B" in the third to last position of the order number (example: 6SL3730-1T.41-.AA0 is the variant without line-side fuses, 6SL3730-1T.41-.BA0 resp. 6SL3730-1T.41-.BC0 is the variant prepared for parallel connection).

These units are installed to the right and left of the Line Connection Module. The design of the two variants is identical. The Basic Line Module for mounting on the left of the LCM differs only in that it is provided with additional connecting rails. The distinction between the left and right variants can be identified by the last but one position in the order number, i.e. an "A" stands for the right-hand variant and a "C" for the left-hand variant.

Rated power at 400 V [kW]	Basic Line Modules Order No.	
Supply voltage 380 V – 480 V 3AC (DC link voltage 510 – 650 V)		
200	6SL3730-1TE34-2AA0	
250	6SL3730-1TE35-3AA0	
400	6SL3730-1TE38-2AA0	
560	6SL3730-1TE41-2AA0	
560	6SL3730-1TE41-2BA0	For parallel connection, mounted on right of LCM
560	6SL3730-1TE41-2BC0	For parallel connection, mounted on left of LCM
710	6SL3730-1TE41-5AA0	
710	6SL3730-1TE41-5BA0	For parallel connection, mounted on right of LCM
710	6SL3730-1TE41-5BC0	For parallel connection, mounted on left of LCM
900	6SL3730-1TE41-8AA0	
900	6SL3730-1TE41-8BA0	For parallel connection, mounted on right of LCM
900	6SL3730-1TE41-8BC0	For parallel connection, mounted on left of LCM
Rated power at 500 V resp. 690 V [kW]		
Supply voltage 500 V – 690 V 3AC (DC link voltage 675 – 930 V)		
180 / 250	6SL3730-1TH33-0AA0	
255 / 355	6SL3730-1TH34-3AA0	
400 / 560	6SL3730-1TH36-8AA0	
650 / 900	6SL3730-1TH41-1AA0	
650 / 900	6SL3730-1TH41-1BA0	For parallel connection, mounted on right of LCM
650 / 900	6SL3730-1TH41-1BC0	For parallel connection, mounted on left of LCM
800 / 1100	6SL3730-1TH41-4AA0	
800 / 1100	6SL3730-1TH41-4BA0	For parallel connection, mounted on right of LCM
800 / 1100	6SL3730-1TH41-4BC0	For parallel connection, mounted on left of LCM
1085 / 1500	6SL3730-1TH41-8AA0	
1085 / 1500	6SL3730-1TH41-8BA0	For parallel connection, mounted on right of LCM
1085 / 1500	6SL3730-1TH41-8BC0	For parallel connection, mounted on left of LCM

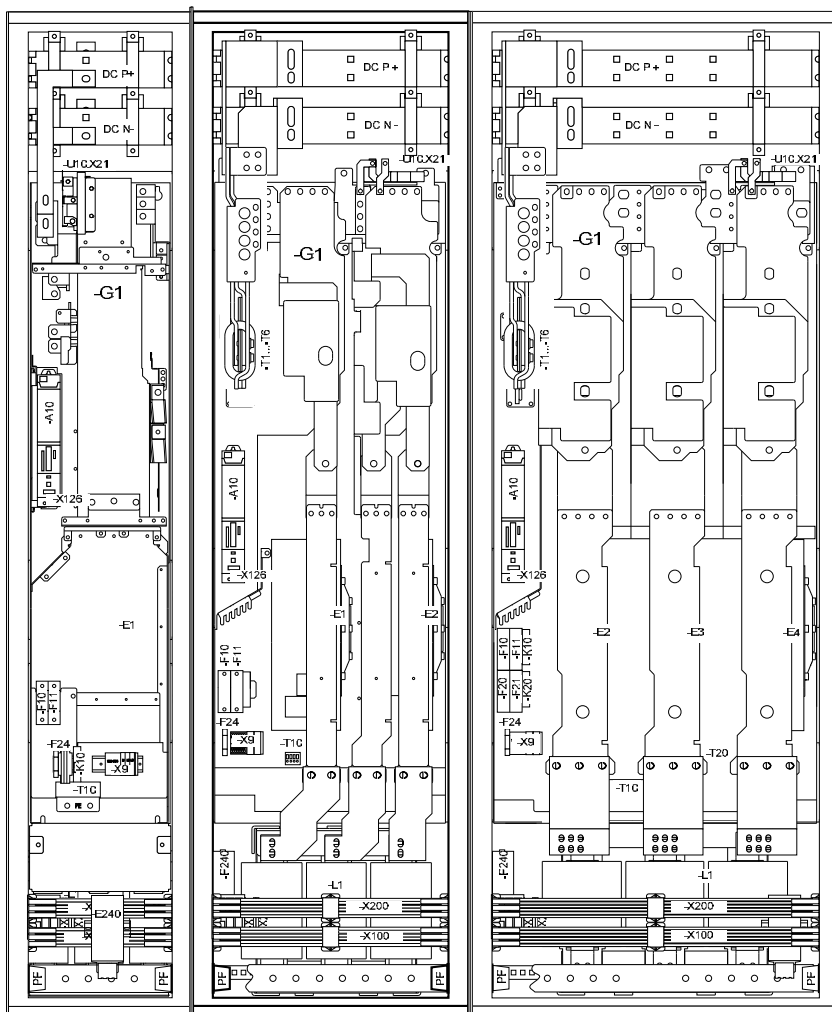
Order number assignment for BLMs

Please note that only Basic Line Modules with exactly the same output power rating can be connected in parallel. The potential for imbalances in current distribution means that current derating of 7.5 % must be applied and this must be taken into account when the modules are dimensioned.

Engineering Information

Design

The Smart Line Modules can be used in combination with Line Connection Modules. In this case, the two module types must be directly connected. The SLM cannot be installed at a remote location from the LCM. Possible combinations can be found in the section "Line Connection Modules".



A precharging circuit for the DC link capacitors is integrated into the units. The supply voltage for the precharging circuit is taken from the Line Connection Module in front of the contactor respectively circuit breaker. It is protected by separate fuses, which are also installed in the Line Connection Module. It is important to take into account that the precharging capacity of the precharging circuit responsible for the charging of the DC link capacitors has a unit-specific limit, which is between 4 times and 7.8 times higher than the DC link capacitance included in the Smart Line Module itself. Please refer to the section “Checking the maximum DC link capacitance” of the chapter “SINAMICS S120, General Information about Built-in and Cabinet Units”.

On the line side, either a contactor or a circuit breaker is absolutely essential for the Smart Line Module. With the selection of option L44 at the Line Connection Module these components are, harmonized with the Smart Line Module, installed in the Line Connection Module.

DC link fuses

Every Smart Line Module is equipped with DC link fuses. These fuses are located in the power unit of each Smart Line Module.

Parallel connections of Smart Line Modules

In order to be able to achieve higher output power ratings, it is possible to connect up to four Smart Line Modules with the same output power rating in parallel. As with other Line Modules, this parallel connection can be realized with separate Line Connection Modules or one common Line Connection Module for two of the Smart Line Modules.

For this compact design of parallel configurations Smart Line Modules with “mirrored” power connections are available, comparable to those of the Basic Line Modules. Smart Line Modules, which are mounted to the left of the Line Connection Module can be identified by the “C” at the last but one position of the order number e.g. 6SL3730-6TE41-1BC0.

A parallel connection with separate LCMs for each Smart Line Module can be realized with any units of the same power rating.

Rated power at 400 V [kW]	Smart Line Modules Order No.	
Supply voltage 380 V – 480 V 3AC (DC link voltage 500 V – 630 V)		
250	6SL3730-6TE35-5AA0	
355	6SL3730-6TE37-3AA0	
500	6SL3730-6TE41-1AA0	
500	6SL3730-6TE41-1BA0	For parallel configuration, mounted on the right of LCM
500	6SL3730-6TE41-1BC0	For parallel configuration, mounted on the left of LCM
630	6SL3730-6TE41-3AA0	
630	6SL3730-6TE41-3BA0	For parallel configuration, mounted on the right of LCM
630	6SL3730-6TE41-3BC0	For parallel configuration, mounted on the left of LCM
800	6SL3730-6TE41-7AA0	
800	6SL3730-6TE41-7BA0	For parallel configuration, mounted on the right of LCM
800	6SL3730-6TE41-7BC0	For parallel configuration, mounted on the left of LCM
Rated Power at 500 V resp. 690 V [kW]		
Supply voltage 500 V – 690 V 3AC (DC link voltage 650 V – 900 V)		
325 / 450	6SL3730-6TG35-5AA0	
510 / 710	6SL3730-6TG38-8AA0	
510 / 710	6SL3730-6TG38-8BA0	For parallel configuration, mounted on the right of LCM
510 / 710	6SL3730-6TG38-8BC0	For parallel configuration, mounted on the left of LCM
725 / 1000	6SL3730-6TG41-2AA0	
725 / 1000	6SL3730-6TG41-2BA0	For parallel configuration, mounted on the right of LCM
725 / 1000	6SL3730-6TG41-2BC0	For parallel configuration, mounted on the left of LCM
1015 / 1400	6SL3730-6TG41-7AA0	
1015 / 1400	6SL3730-6TG41-7BA0	For parallel configuration, mounted on the right of LCM
1015 / 1400	6SL3730-6TG41-7BC0	For parallel configuration, mounted on the left of LCM

Order number assignment for SLMs

Please note that parallel connections can only be made with Smart Line Modules of exactly the same power rating. The potential for imbalances in current distribution means that current derating of 7.5 % must be applied and this must be taken into account when the Modules are dimensioned. Furthermore, to balance the current of the parallel configuration, a line reactor with a relative short-circuit voltage of 4 % is required for every Smart Line Module. This is already integrated as standard.

Information on parallel configurations in the chapter “Fundamental Principles and System Description” and also on the use of DRIVE-CLiQ cables and how to install them in the sections “Information about equipment handling” and “DRIVE-CLiQ wiring” must be noted.

SINAMICS S120 Cabinet Modules

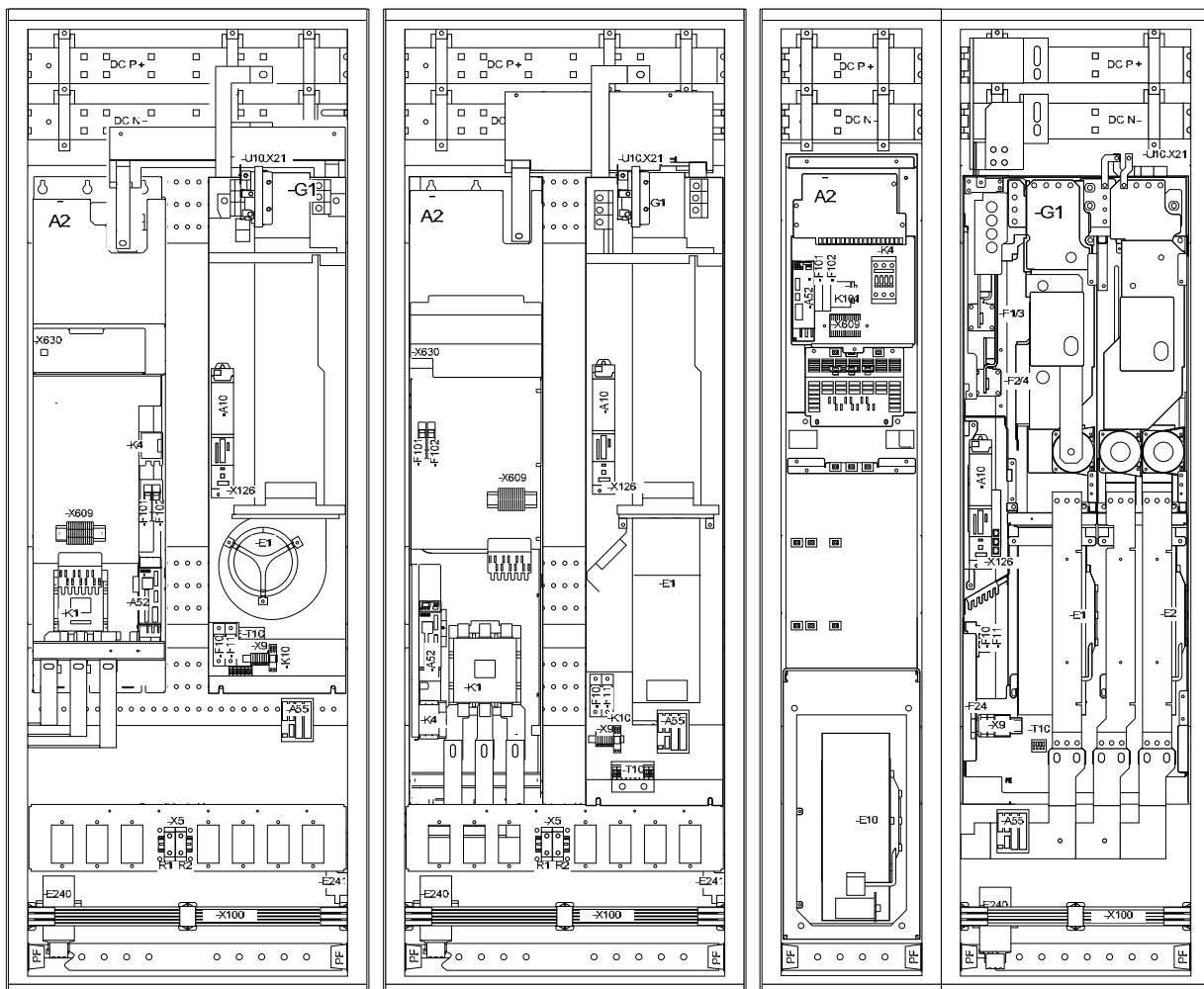
Engineering Information

Active Line Modules + Active Interface Modules

Design

Active Line Modules are available for S120 Cabinet Modules in the output power range of 132 to 900 kW at 400 V resp. 560 – 1400 kW at 690 V, and they can be operated only in combination with their associated Active Interface Modules.

Active Line Modules and their associated Active Interface Modules can be used in combination with Line Connection Modules. Active Line Modules and the associated Active Interface Modules must be directly connected to the Line Connection Module and they cannot be installed at a remote location from the LCM. Possible combinations can be found in the section "Line Connection Modules".



Configuration of Active Line Modules with associated Active Interface Modules in frame sizes FX+FI, GX+GI und HX+HI

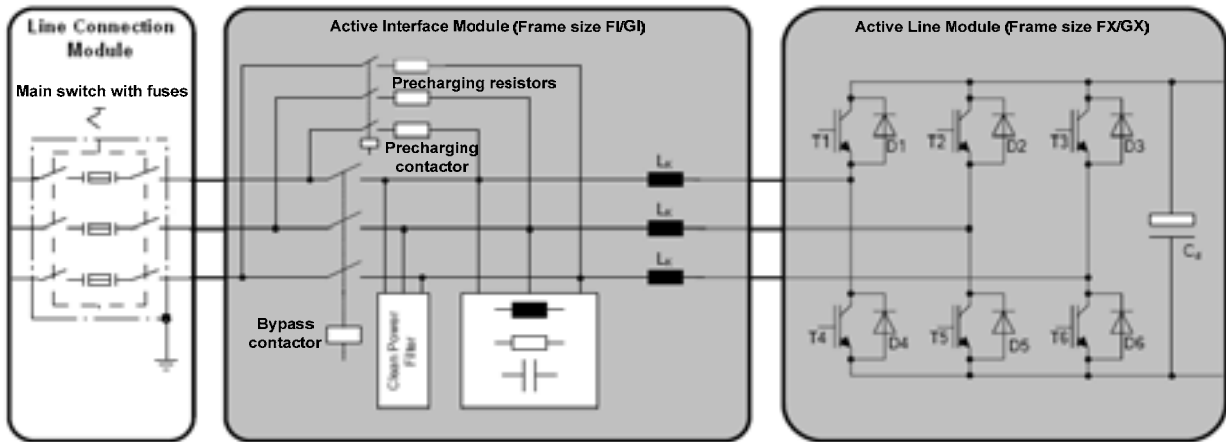
Active Line Modules (ALMs) can be delivered as S120 Cabinet Modules only in combination with the corresponding Active Interface Modules (AIMs) with one order number. Active Line Modules and Active Interface Modules in frame sizes FX+FI and GX+GI are built in the same cabinet unit. Active Line Modules and Active Interface Modules in frame sizes with higher output power ratings are built separately in individual cabinet units. An Active Line Module will not operate without the corresponding Active Interface Module. The cabinet unit consisting of ALM and AIM already contains all connections between the two types of units and thus the potential for wrong configuration is reduced.

Within the configuration of ALM and AIM the Voltage Sensing Module is located in the Active Interface Module. The associated DRIVE-CLiQ connection to the power unit is already included. The terminal block and the Control Unit CU320, which is available as an option, are installed in the Active Line Module.

SINAMICS S120 Cabinet Modules

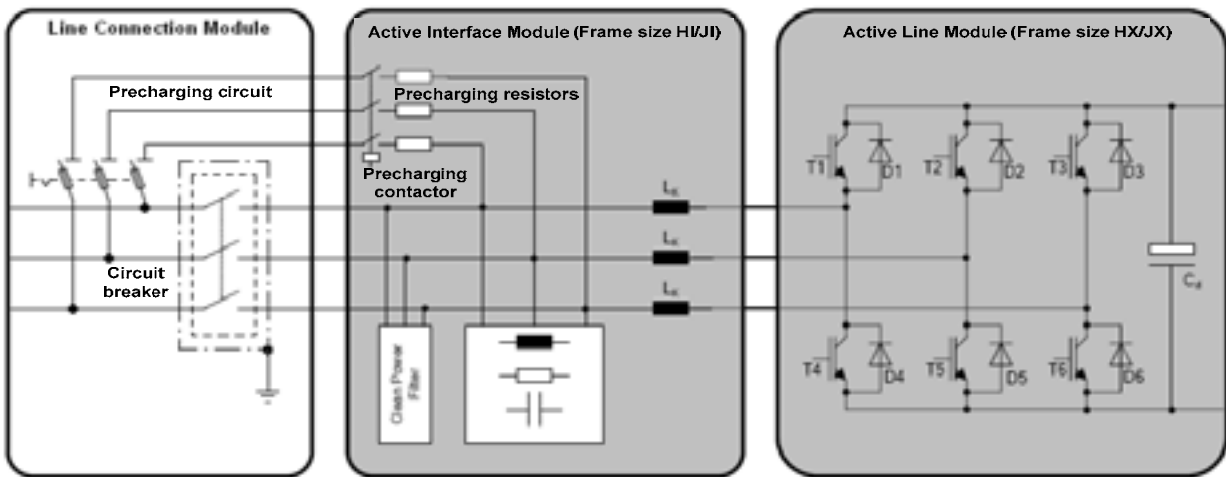
Engineering Information

The precharging circuit for the DC link capacitors is realized differently in the various frame sizes of Active Line Modules. With Active Infeeds consisting of Active Line Modules in frame sizes FX or GX and Active Interface Modules in frame sizes FI or GI the required Bypass contactor is located in the corresponding Active Interface Module. The supply voltage is taken from the Line Connection Module after the main switch.



Realization of the precharging circuit with Active Line Modules + Active Interface Modules in frame sizes FX+FI and GX+GI

With Active Infeeds consisting of Active Line Modules in frame sizes HX or JX and Active Interface Modules in frame sizes HI or JI the required Bypass contactor is not a part of the Active Interface Module. In this case it is located in the Line Connection Module as a circuit breaker. The supply voltage for the precharging circuit is taken from a separate fuse-protected switch in the Line Connection Module.



Realization of the precharging circuit with Active Line Modules + Active Interface Modules in frame sizes HX+HI and JX+JI

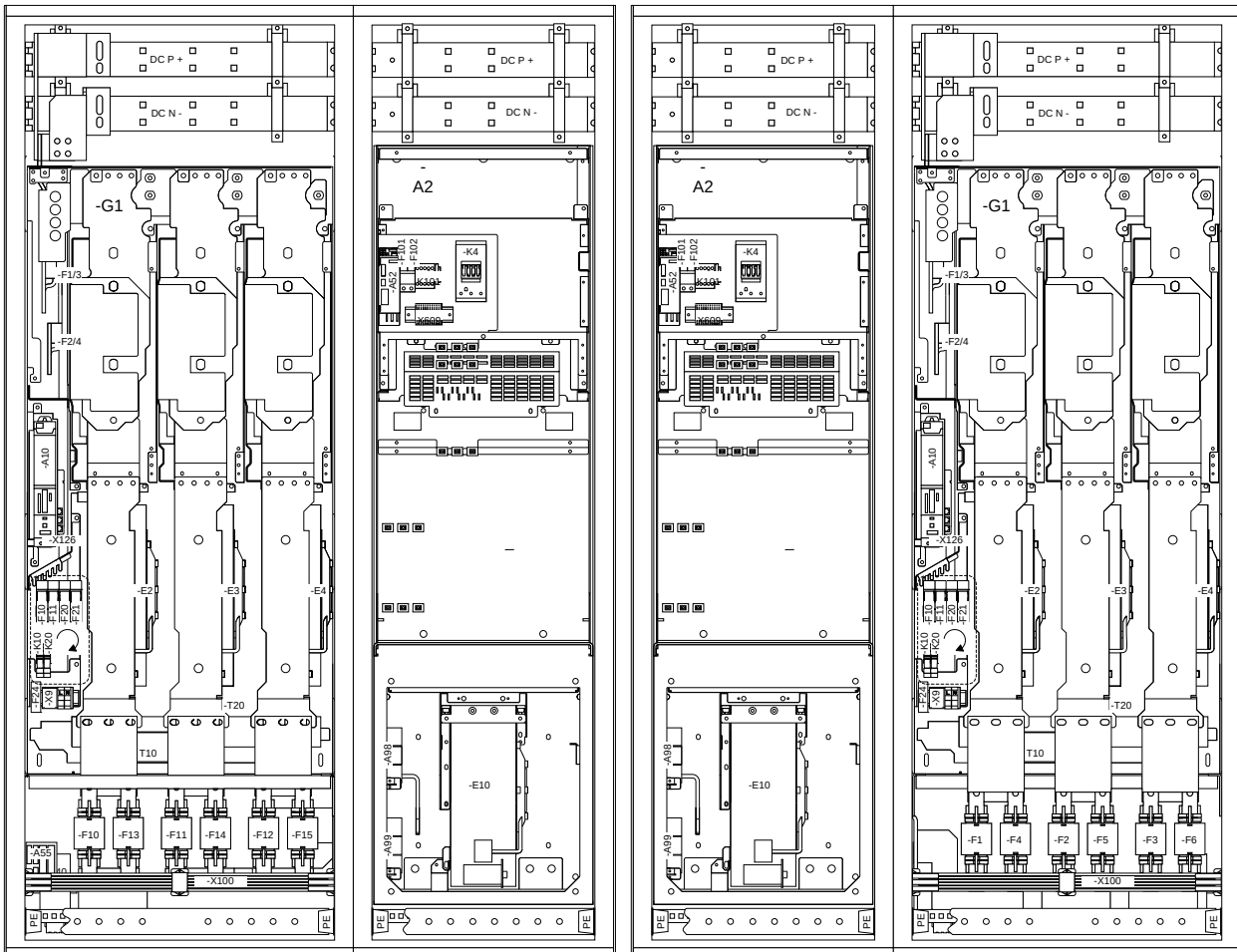
It is important to take into account that the precharging capacity of the precharging circuit responsible for the charging of the DC link capacitors has a unit-specific limit. Please refer to the section "Checking the maximum DC link capacitance" of the chapter "SINAMICS S120, General Information about Built-in and Cabinet Units".

The connections of the precharging circuit, as well as control cables from the Active Line Module to the circuit breaker are already included in the S120 Cabinet Modules and harmonized via option L42 with the corresponding LCM.

Engineering Information

Every Active Line Module is equipped with DC link fuses. These fuses are located in the power unit of each Module.

A parallel connection with separate LCMs can be realized with any units of the same power rating.



SINAMICS Engineering Manual – May 2008
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SINAMICS S120 Cabinet Modules

Engineering Information

Rated power at 400 V [kW]	Active Line Modules (incl. Active Interface Modules) Order No.	
Supply voltage 380 V – 480 V 3AC (DC Link Voltage 570 V – 720 V)		
132	6SL3730-7TE32-1BA0	
160	6SL3730-7TE32-6BA0	
235	6SL3730-7TE33-8BA0	
300	6SL3730-7TE35-0BA0	
380	6SL3730-7TE36-1BA0	
500	6SL3730-7TE38-4BA0	
630	6SL3730-7TE41-0BA0	
630	6SL3730-7TE41-0BC0	
900	6SL3730-7TE41-4BA0	For parallel connection, mounted on left of LCM (mirrored mounting)
900	6SL3730-7TE41-4BC0	
Rated power at 500 V resp. 690 V [kW]		
Supply voltage 500 V – 690 V 3AC (DC Link Voltage 750 V – 1035 V)		
400 / 560	6SL3730-7TG35-8BA0	
580 / 800	6SL3730-7TG37-4BA0	
580 / 800	6SL3730-7TG37-4BC0	For parallel connection, mounted on left of LCM (mirrored mounting)
800 / 1100	6SL3730-7TG41-0BA0	For parallel connection, mounted on left of LCM (mirrored mounting)
800 / 1100	6SL3730-7TG41-0BC0	
1015 / 1400	6SL3730-7TG41-3BA0	For parallel connection, mounted on left of LCM (mirrored mounting)
1015 / 1400	6SL3730-7TG41-3BC0	

Order Number assignment for Active Line Modules

Please note that parallel connections can only be made with Active Line Modules and the associated Active Interface modules of exactly the same power rating. The potential for imbalances in current distribution means that current derating of 5 % must be applied and this must be taken into account when the Modules are dimensioned.

Information on parallel configurations in the chapter "Fundamental Principles and System Description" and also on the use of DRIVE-CLiQ cables and how to install them in the sections "Information about equipment handling" and "DRIVE-CLiQ wiring" must be noted.

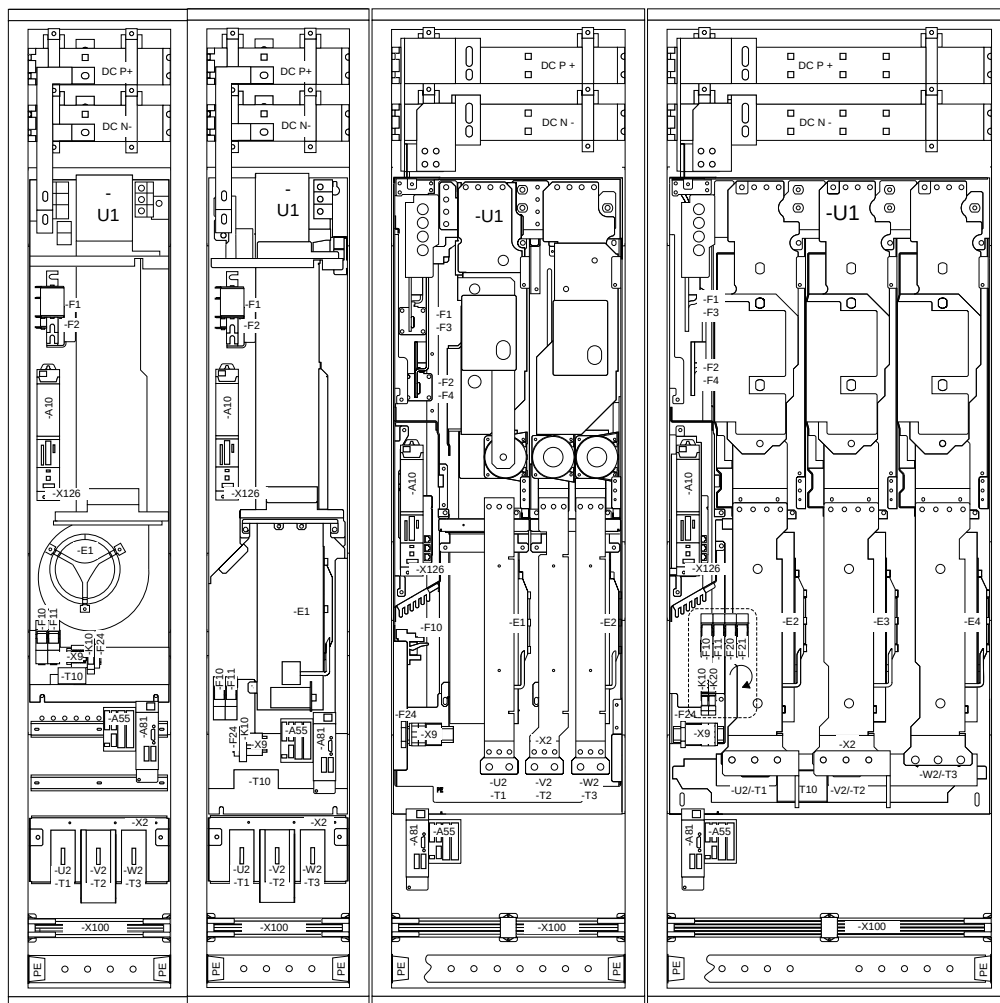
SINAMICS S120 Cabinet Modules

Engineering Information

Motor Modules

Design

Cabinet Modules in the Motor Modules variant offer the entire spectrum of chassis inverters. Options and connection concepts specially tailored to multi-motor configurations make these modules ideal for a wide range of applications.



Example configuration of Motor Modules in frame sizes FX, GX, HX, JX

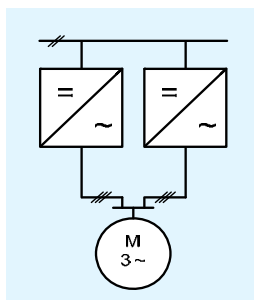
Apart from the variations in Power Units, the differences between the frame sizes are only very minor. The Motor Modules are designed for EMC compatibility with special measures. Even the air-flow guides and cable routes are specially constructed. Different approaches have been used to suit the individual structural features of the different module types.

Frame sizes FX and GX are also fitted with a special terminal area for connection of motor cables. With the frame sizes HX and JX the cables are connected directly to the Power Unit.

DC link fuses

DC link fuses are integrated in the power unit of every Motor Module. When a DC coupling (option L37) is installed, the fuses are integrated in the DC switch.

Parallel connections of Motor Modules



If two Motor Modules are connected in parallel, imbalances in the current distribution can occur despite the current compensation control. As a result, a derating factor of 5 % applies to parallel connections. Parallel connections may only include Motor Modules with identical voltage rating and identical output power rating.

For the purpose of decoupling, parallel-connected Motor Modules must be configured with the minimum cable lengths specified below. The specified power ratings are the values for a single Motor Module.

Motor Module			Motor supply cable	
Frame size	P _M at 400 V [kW]	I _{rated} [A]	Minimum length [m]	
Supply voltage 380 V - 480 V 3AC				
FX	110	210	30	
FX	132	260	27	
GX	160	310	20	
GX	200	380	17	
GX	250	490	15	
HX	315	605	13	
HX	400	745	10	
HX	450	840	9	
JX	560	985	8	
JX	710	1260	6	
JX	800	1405	5	
Motor Module			Motor supply cable	
Frame size	P _M at 500 V [kW]	I _{rated} [A]	Minimum length [m]	
Supply voltage 500 V - 600 V 3AC ¹				
FX	55	85	80	
FX	55	100	72	
FX	75	120	65	
FX	90	150	55	
GX	110	175	50	
GX	132	215	40	
GX	160	260	32	
GX	200	330	25	
HX	250	410	20	
HX	315	465	18	
HX	400	575	15	
JX	500	735	13	
JX	560	810	11	
JX	630	910	10	
JX	710	1025	8.5	
JX	900	1270	7	
Supply voltage 660 V - 690 V 3AC ¹				
FX	75	85	100	
FX	90	100	90	
FX	110	120	80	
FX	132	150	70	
GX	160	175	60	
GX	200	215	50	
GX	250	260	40	
GX	315	330	30	
HX	400	410	25	
HX	450	465	25	
HX	560	575	20	
JX	710	735	18	
JX	800	810	15	
JX	900	910	12	
JX	1000	1025	10	
JX	1200	1270	8	

Minimum motor cable length for parallel connection

A cross-connection of the motor terminal lugs between the individual modules is not available. Combined terminal lugs are available on request with an additional cabinet.

¹ These data relate to units with supply voltages of 500 V to 690 V 3AC (MLFB 6SL3720- 1TGxx-xAA0) and 660 V to 690 V 3AC (MLFB 6SL3720-1 THxx-xAA0).

SINAMICS S120 Cabinet Modules

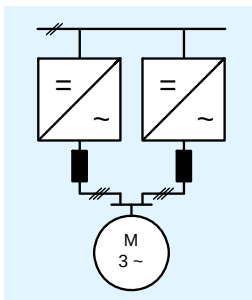
Engineering Information

Cable installation conditions

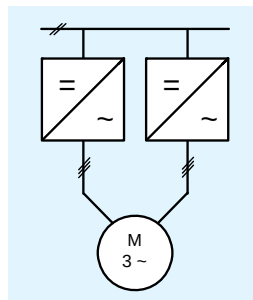
Three-wire or four-wire cables should be used where possible to connect Motor Modules in parallel for the purpose of increasing the output power rating. In this case, a specific clearance must be left between the cables of the individual subsystems. The minimum clearance required is 50 mm. A three-phase system (U2, V2, W2) must be connected to each 3-wire or 4-wire cable. Several motors can also be connected to one inverter output. However, as certain restrictions regarding cable design apply, configurations of this must be individually checked (see chapter "Fundamental Principles and System Description", section "Motor reactors").

If the application cannot accommodate the minimum required cable length specified above, an appropriate motor reactor must be installed. Alternatively, motors with two electrically isolated winding systems can be used.

The latter option should be preferred for drives with higher power outputs as the motor terminal boxes may be subject to current limitations in this case.



Use of motor reactors



Use of asynchronous motors with two electrically isolated winding systems

Please note the supplementary conditions applicable to parallel connections, such as the control of motors with only one common winding system. These are described in the section "Parallel connections of converters" of the chapter "Fundamental Principles and System Description".

■ Booksize Base Cabinet / Booksize Cabinet Kits

Design

Motor Modules in Booksize format are installed as Booksize Cabinet Kits into Booksize Base Cabinets in the factory and supplied as a complete unit together with the cabinet connection components. All Booksize Motor Modules are available in the version with internal air cooling and varnished modules.

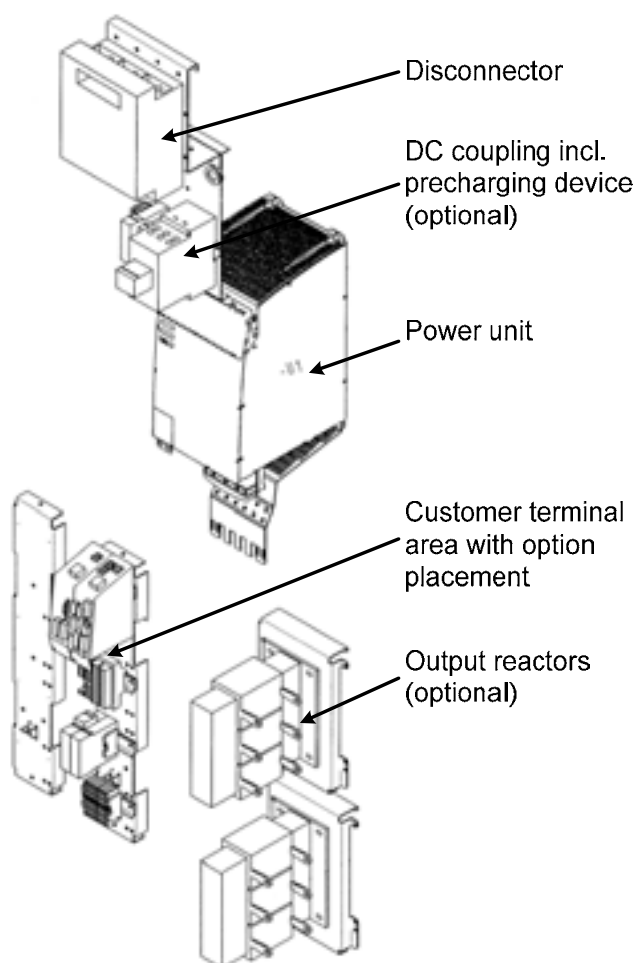
Booksize Base Cabinet

The Booksize Base Cabinet is the basis for a complete cabinet. This contains all the assembly plates required to accommodate the Booksize Cabinet Kits.

Booksize Base Cabinets are available in two standard cabinet widths, i.e. 800 mm and 1200 mm. In addition to the assembly plates, the cabinet also includes the PE bar and the auxiliary voltage busbar.

Booksize Cabinet Kits

Booksize Cabinet Kits are made to support an easy planning and equipping by virtue of their slot concept. A slot / Booksize Cabinet Kit has a specified cabinet width within which all the components required to operate a Booksize format SINAMICS S120 unit are arranged. The number of slots within a Base Cabinet is merely determined by the available width of the cabinet. Depending on the mounting width required for the relevant output, the number of Booksize Cabinet Kits which can be mounted in a Base Cabinet varies.



The basic version of the Booksize Cabinet Kit comprises the following components:

- Booksize format Motor Module
- Fuse switch-disconnector for each Motor Module installed
- Customer interface –X55 located in the terminal area of the Booksize Base Cabinet
- Shield connecting plate
- Complete electrical connection to the Base Cabinet interfaces

Each Booksize Cabinet Kit is connected to the DC busbar of the Cabinet Module separately via its own fuse switch-disconnector. The DC connecting rail integrated in the power units is not used to loop through the DC link voltage.

The optional DC coupling consists of a contactor assembly (see section "Options / Option L37") which is easy to replace by its pluggable interfaces.

When the optional Control Unit is installed (option K90/K91), the customer terminal block –A55 is also located in the cabinet terminal area. A DRIVE-CLiQ connection to the power unit of the Cabinet Kit is made in the factory.

Output reactors can be also installed within a Cabinet Kit as an option. When reactors are used, a separate motor connecting terminal is provided in the terminal area of the cabinet. For information about output reactors, please refer to section "Options / Option L08/ L09".

Example of a Booksize Cabinet Kit 200 mm

SINAMICS S120 Cabinet Modules

Engineering Information

The following Booksize Cabinet Kits are available:

Order No.	Rated power at 600 V DC link voltage [kW]	Rated output current I_{rated} [A]	Width Booksize Cabinet Kit [mm]
6SL3720-2TE13-0AB0	2 x 1.6	2 x 3	200
6SL3720-2TE15-0AB0	2 x 2.7	2 x 5	200
6SL3720-2TE21-0AB0	2 x 4.8	2 x 9	200
6SL3720-2TE21-8AB0	2 x 9.7	2 x 18	200
6SL3720-1TE13-0AB0	1.6	3	100
6SL3720-1TE15-0AB0	2.7	5	100
6SL3720-1TE21-0AB0	4.8	9	100
6SL3720-1TE21-8AB0	9.7	18	100
6SL3720-1TE23-0AB0	16	30	100
6SL3720-1TE24-5AB0	24	45	200
6SL3720-1TE26-0AB0	32	60	200
6SL3720-1TE28-5AB0	46	85	200
6SL3720-1TE31-3AB0	71	132	300
6SL3720-1TE32-0AB0	107	200	300

List of available Booksize Cabinet Kits

DC link fuses

SINAMICS power units in Booksize format feature integrated DC link fuses. These are not replaceable, however, but merely protect against hazards. For this reason, Booksize cabinets are fitted with switch-disconnectors with integrated fuses which are designed as standard to make the connection to the DC link busbar. The fuses are chosen according to selective criteria to ensure that the fuse in the switch-disconnector blows first in the event of a fault in the DC circuit.

Planning recommendations, special features

An equipping of the base Cabinets can be variably carried out with the Cabinet Kits without predefined mounting sequence or size assignment. The width of a Base Cabinet available for installing Cabinet Kits is calculated on the basis of a cabinet width of – 200 mm. The useful mounting widths available are therefore as follows:

Order number of Booksize Base Cabinet	Cabinet width [mm]	Useful mounting width [mm]
6SL3720-1TX38-0AA0	800	600
6SL3720-1TX41-2AA0	1200	1000

Assignment between cabinet width and useful mounting width

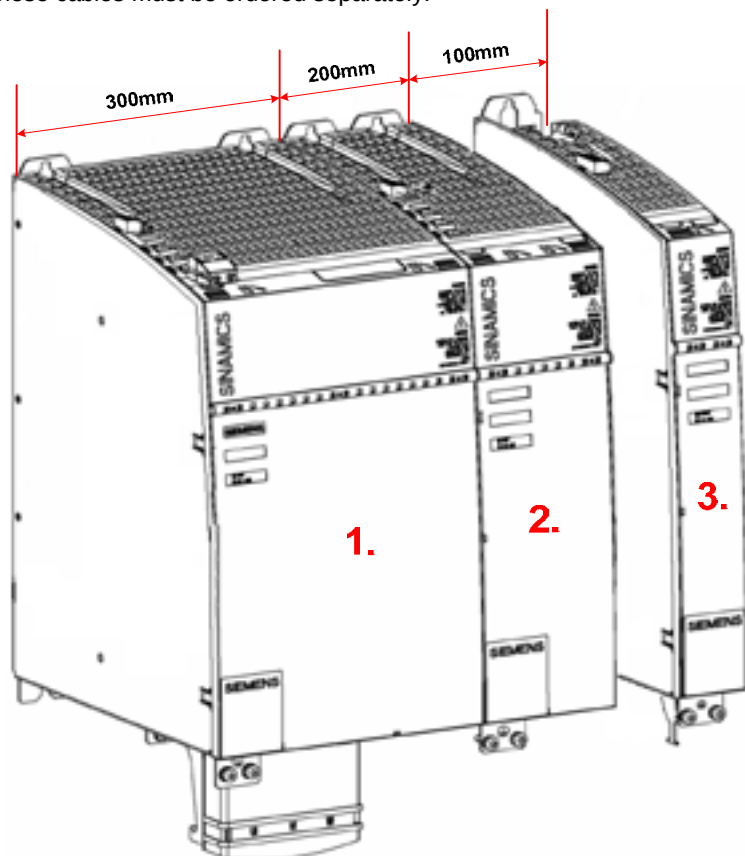
Booksize Cabinet Kits can only be ordered in combination with at least one Booksize Base Cabinet. It is not possible to order Booksize Cabinet Kits separately.

The components are arranged within a Cabinet Kit and within the Base Cabinet itself according to the zoning concept. The components are also likewise positioned in such a way that diagnostic elements are always freely accessible.

For an easy connection of external cables, Booksize cabinets are equipped with the customer terminal block –X55 as well as the customer terminal module –A55 in combination with a Control Unit (option K90/ K91). For further information, please refer to the sections on these specific components in this chapter.

The internal DRIVE-CLiQ wiring within a Cabinet Kit is installed in the factory. Cross-component connections, for example, from the Control Unit of Cabinet Kit >1< to the Motor Module of Cabinet Kit >2< cannot be standardized owing to the very wide variety of possible configurations. However, the required cable length can be calculated as being approximately 30 cm from the Control Unit to the relevant power unit + the width of the Booksize Cabinet Kit for the relevant power unit. If the power units will be connected in a "line topology" (power unit to power unit), then the cable length calculation must include the width of the Booksize cabinets + at least 10 cm to make allowance for the bending radii and connectors. Please note that this calculation applies to connections to the right. For connections to the left, the width of the adjacent Cabinet Kit must be used in the calculation.

These cables must be ordered separately.



Calculation of the DRIVE-CLiQ cable length in a Booksize module line-up

Example:

Three Booksize Cabinet Kits are installed in a Booksize Base Cabinet, as illustrated in the diagram above. A Control Unit has been assigned to the center kit (2) with option K91. The power unit of the first Cabinet Kit must be connected to the Control Unit and the power unit of the third Cabinet Kit to the power unit of the second.

The cable lengths required are calculated as follows:

1. No additional cable is needed to connect the power unit to which the Control Unit is assigned with option K91 (all components are provided within a Cabinet Kit).
2. The power unit of the first Cabinet Kit requires a cable of at least 300 mm (width of Cabinet Kit) + 300 mm (distance power unit 2 + 30 cm) = 600 mm.
3. The following cable is selected from the catalog: 6SL3060-4AU00-0AA0.
4. The power unit of the third Cabinet Kit requires a cable of at least 200 mm (width of adjacent Cabinet Kit + 100 mm (bending radius) = 300 mm.

The following is selected: 6SL3060-4AM00-0AA0 with a length of 360 mm.

Be aware that the cables must be properly secured.

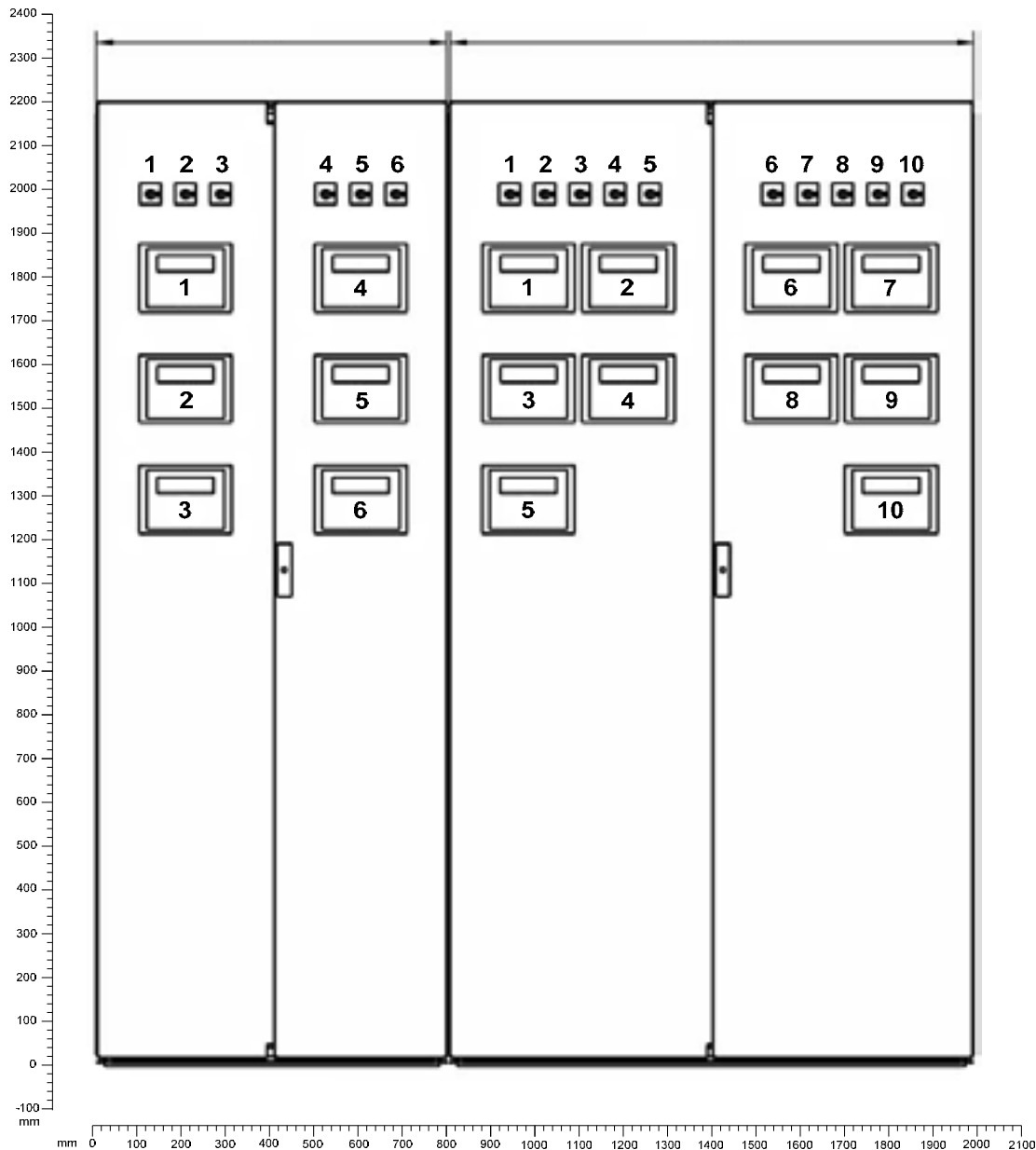
SINAMICS S120 Cabinet Modules

Engineering Information

The interfaces of the cabinet as a whole are designed to ensure that no additional auxiliary external wiring is required. All auxiliary voltage supplies are connected to the auxiliary voltage busbar with fuse protection.

A SITOP device is used for the 24 V power supply to meet the increased power requirement of combinations of individual Cabinet Kits. This is included as standard in every Booksize Base Cabinet and operates as the power supply for the entire cabinet.

The 24 V auxiliary power supply within a Base Cabinet has been configured in such a way that the failure of individual units/ Cabinet Kits does not impose any restrictions on other items of equipment. The internal auxiliary supply busbar of the Booksize devices is not used when a SITOP device is installed.



Booksize Base Cabinets with maximum equipment

With a maximum equipment complement, 6 Cabinet Kits can be mounted in the 800 mm wide Base Cabinet, and 10 Cabinet Kits in the 1200 mm wide Base Cabinet (applies to 100 mm wide Cabinet Kits in each case). The Base Cabinets feature defined slots which are equipped in the factory according to the order data. The ordered kits are not

SINAMICS S120 Cabinet Modules

Engineering Information

mounted in any specific sequence. If you wish the Booksize devices to be installed in the Base Cabinets in a particular order, please notify your Siemens contact.

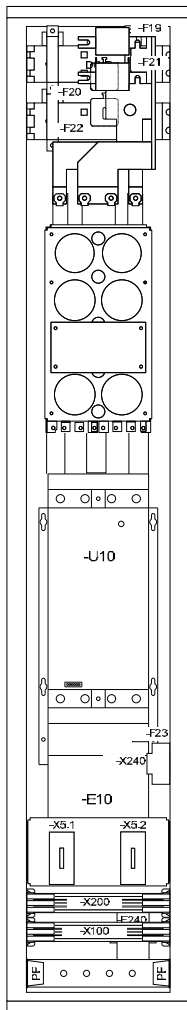
Booksize Base Cabinets are designed to function without a cabinet fan. When a protection class higher than IP21 is selected, thermostat-controlled fans to support efficient air circulation are fitted. The fan is supplied via the auxiliary supply busbar of the cabinet.

Please note the overload definitions applicable to units in Booksize format which differ to those for chassis power units. For further information, please refer to the SINAMICS S120 chassis units catalog.

Central Braking Modules

Design

Central Braking Modules are placed in a central position within the drive configuration built of S120 Cabinet Modules. With their high braking power they limit the DC link voltage if regenerative energy occurs in the DC link, which cannot be fed back into the supply system. This means that fault trips of the Motor Modules caused by DC link overvoltage can be avoided. Also a fast deceleration of the drives becomes possible.



If the DC link voltage of the DC busbar exceeds a certain limit in regenerative operation, an externally installed braking resistor is activated, which prevents a further increase of the DC link voltage. As a result, the regenerative energy is converted into heat.

The activation of the braking resistor is done by the Braking Unit, which is installed in the Cabinet Module. Central Braking Modules are an alternative to the optional Braking Modules (Option L61, L62 resp. L64, L65), particularly if very high braking power is required in a drive configuration. Central Braking Modules operate completely independently and only require a connection to the DC link. An external auxiliary supply voltage is not necessary.

The Braking Units can be used with all line supply types. The response threshold of the Braking Modules, i.e. the DC link voltage where they start to operate, can be adapted to the requirements on site using a switch in the Braking Module.

The units have an integrated temperature monitor. An internal fan provided as a standard supports the cooling of the Power Unit. Switching on and off of the fan is temperature-controlled. Thus continuous operation of the fan is avoided. The permissible ambient temperature for operation with rated power is 0°C - 40° C. At higher temperatures between 40°C and 50°C a power derating has to be taken into account in accordance with the formula:

$$P = [1 - 0.025 * (t - 40^{\circ}\text{C})] * P_N$$

The installation altitude can be up to 2000 m above sea level. For altitudes higher than 1000 m, a power derating has to be taken into account, which is 1.5% per 100 m.

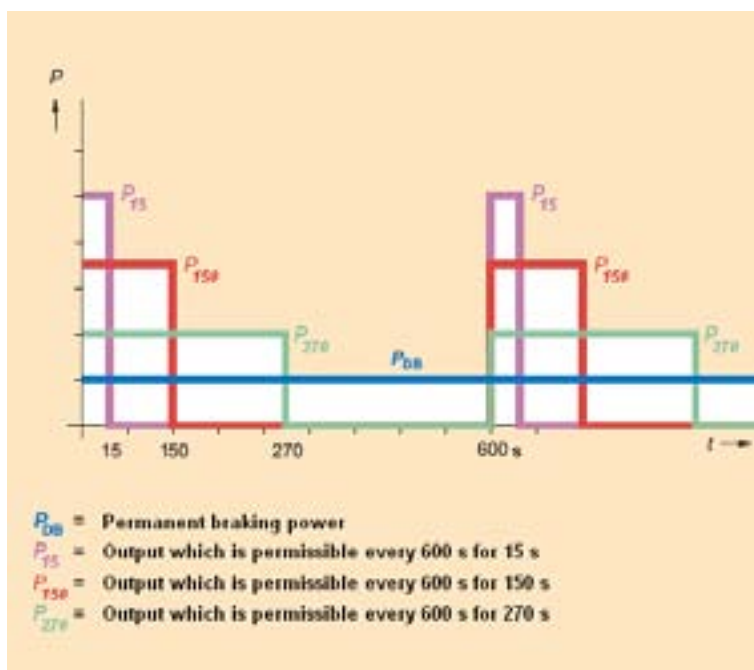
In addition to the temperature monitoring function, other protection measures are implemented such as overcurrent and overloads protection.

The Braking Units are also equipped with LEDs for optical indication of fault conditions and a control output, which is activated in case of a fault. The Braking Unit can be externally blocked using a control input.

Example configuration of a Central Braking Module

Example configuration of a Central Braking Module

In most applications, the Central Braking Modules are only used for occasional braking operation, but it is possible to use them for continuous braking operation. In this case, the load duty cycles shown in the following diagram must be taken into account.



Standard load duty cycles of Central Braking Modules

With the given standard load duty cycles, the following rated power outputs result, when the upper response threshold is selected and the Braking Units operate at the maximum possible DC link voltage:

Order number	Braking power of Central Braking Modules			
	P_{15}	P_{150}	P_{270}	P_{DB}
Supply voltage 380 V – 480 V 3AC / DC link voltage 500 V – 720 V DC				
6SL3700-1AE35-0AA1	730 kW	500 kW	300 kW	200 kW
6SL3700-1AE41-0AA1	1380 kW	1000 kW	580 kW	370 kW
Supply voltage 500 V – 600 V 3AC / DC link voltage 650 V – 900 V DC				
6SL3700-1AF35-5AA1	830 kW	550 kW	340 kW	220 kW
6SL3700-1AF41-1AA1	1580 kW	1050 kW	650 kW	420 kW
Supply voltage 660 V – 690 V 3AC / DC link voltage 850 V – 1035 V DC				
6SL3700-1AH36-3AA1	920 kW	630 kW	380 kW	240 kW
6SL3700-1AH41-2AA1	1700 kW	1200 kW	720 kW	460 kW

Braking power ratings for standard load duty cycles

Position in the DC link configuration

The Central Braking Modules must be positioned directly between the largest Power Units in the DC link configuration, preferably next to the Line Module. A sequence with several Central Braking Modules located directly next to one another in order to increase the braking power by parallel operation is not permissible. In this case it has to be ensured, that larger Motor Modules are installed between the Central Braking Modules.

If continuous braking operation is required, direct installation of Central Braking Modules next to small Motor Modules with small internal DC link capacitance should be avoided as the resulting DC link currents during braking operation can overload the DC link capacitors of the small Motor Modules and the Braking Unit itself. This can result in significantly reduced lifetime of these units.

Particular care should be taken to ensure that Power Units located next to the Central Braking Modules are not permanently disconnected from the DC link configuration by means of a DC switch (option 37). The disconnection is only allowed for a short time, e.g. for repair or maintenance purposes. If the disconnection is required for a longer time, the Central Braking Module should be deactivated.

SINAMICS S120 Cabinet Modules

Engineering Information

DC Link fuses

Every Central Braking Module has a DC link fuse. These are located in the bar between the Braking Unit and the DC link busbar.

Parallel configuration of Central Braking Modules

In order to increase the required braking power, Central Braking Modules can operate in parallel at a common DC link. The Braking Units are specially designed in that way that parallel operation is possible with good load distribution.

The parallel operation of the Braking Modules in the DC link configuration can be done without additional circuitry or communication between the units. However, the guidelines for positioning within the DC link configuration described on the previous page also apply here. In addition the following has to be taken in account:

- Every Central Braking Module must be connected to its own braking resistor
- Only Central Braking Modules of the same power rating can operate in parallel
- The braking power must be reduced by 10 % due to unsymmetrical load distribution depending on various system tolerances

Braking resistor

The regenerative energy of the drive configuration is converted into heat by the braking resistor. The braking resistor is directly connected to the Braking Module. The braking resistor must be installed outside of the cabinet units and can be located outside of the room where the drive cabinets are installed. Therefore, the resulting heat losses do not occur near to the drive cabinets which means that the air conditioning costs are reduced. A temperature switch protects the braking resistor against overheating. The isolated contact of the switch is opened when the temperature limit is exceeded. The tripping temperature is 120°C, which corresponds to a surface temperature of the resistor of approx. 400°C.

In contrast to the optional Braking Modules, which are mounted inside the Power units (options L61, L62, L64 L65), the braking resistors for the Central Braking Modules must be ordered separately. The degree of protection is IP21. The following resistors are available as standard:

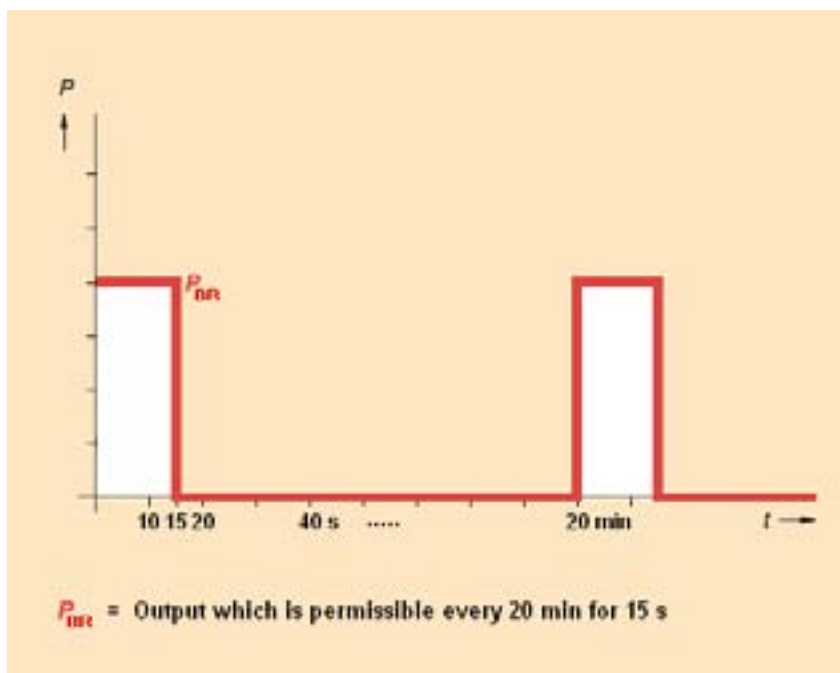
Central Braking Module Order number	Braking power P_{BR}	Corresponding braking resistor	Dimensions Width x Depth x Height [mm]
Supply voltage 380 V – 480 V 3AC / DC link voltage 500 V – 720 V DC			
6SL3700-1AE35-0AA1	500 kW	6SL3000-1BE35-0AA0	960 x 620 x 790
6SL3700-1AE41-0AA1	1000 kW	6SL3000-1BE41-0AA0	960 x 620 x 1430
Supply voltage 500 V – 600 V 3AC / DC link voltage 650 V – 900 V DC			
6SL3700-1AF35-5AA1	550 kW	6SL3000-1BF35-5AA0	960 x 620 x 1110
6SL3700-1AF41-1AA1	1050 kW	6SL3000-1BF41-1BA0	960 x 620 x 1430
Supply voltage 660 V – 690 V 3AC / DC link voltage 850 V – 1035 V DC			
6SL3700-1AH36-3AA1	630 kW	6SL3000-1BH36-3AA0	960 x 620 x 1110
6SL3700-1AH41-2AA1	1200 kW	6SL3000-1BH41-2AA0	960 x 620 x 1430

Braking resistor assignment table

The Braking Unit in the Central Braking Module can handle a higher peak braking power than that of the standard braking resistors.

The power of the braking resistors P_{BR} is harmonized with the braking power P_{150} of the Central Braking Modules. This power is, however, only permissible with a reduced load duty cycle duration of 20 minutes.

The braking resistors are dimensioned for occasional regenerative operation. In the case that the braking resistor is not sufficient to meet the demands of special applications, a suitable braking resistor must be designed individually.



In order to monitor the status of the temperature switch located at the braking resistor via the Control Unit CU320 or via a co-ordinating control, this contact, as well as the control output of the Central Braking Module, must be connected on site to the corresponding control devices. In order to guarantee thermal protection of the braking resistor, the following should be taken into consideration:

- The required braking power must not be exceeded.
- When the temperature switch in the resistor is opened, the following must be ensured:
 - Stop of the drives producing regenerative energy – integration of the temperature switch into the fault channel of the converters “External fault”
 - Control measures to prevent a re-start of the drives as long as the braking resistors is still overheated

A cable length of up to 100 m is permitted between the Central Braking Module and braking resistor. The cables must be laid in such a way that they are short-circuit and ground-fault proof.

The braking resistor must be installed as a free-standing component. Objects must not be deposited on or above the braking resistor. Ventilation space of 200 mm is required on each side of the braking resistor. Sufficient space must be maintained between the braking resistor and flammable objects. It has also to be ensured that the place of installation is able to dissipate the heat produced by the braking resistor. The installation should not be carried out near fire detectors as they could respond by the produced heat. When outdoor installation of the braking resistor is required protection against water must be ensured as the degree of protection of IP21 is not sufficient in this case.

SINAMICS S120 Cabinet Modules

Engineering Information

Options

Option G33 (Communication Board CBE20)

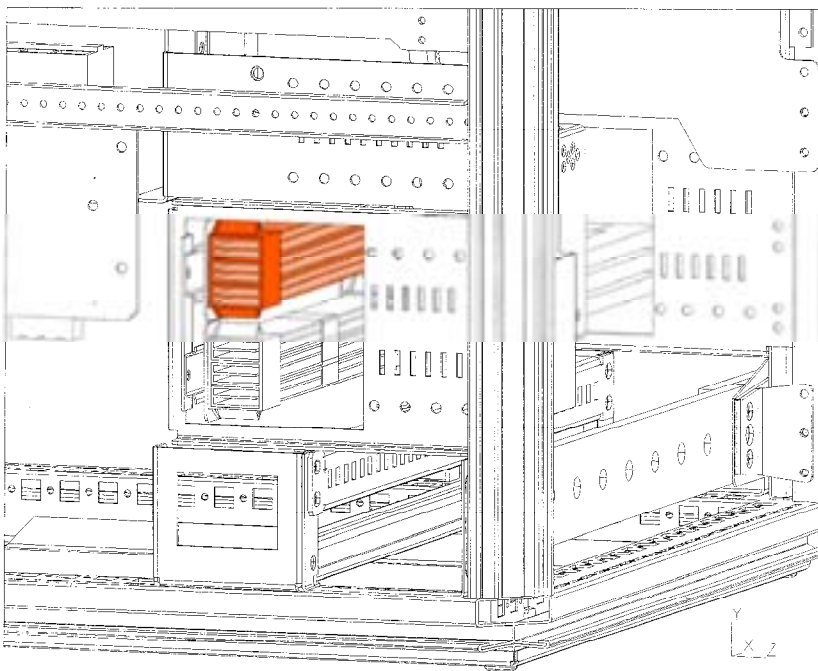
The interface module Communication Board CBE20 connects SINAMICS drives to the PROFINET. The CBE20 board allows to use PROFINET IO with IRT support and PROFINET IO with RT support. Mixed operation is not possible. PROFINET CBA is not supported. When a CBE20 board is used the SINAMICS S120 drive becomes an IO device.

The interface module Communication Board CBE20 is mounted in the option slot of the Control Unit CU320. Therefore it can be ordered as option G33 only in combination with Option K90/ K91 (Control Unit CU320).

Option K75 (Second auxiliary busbar)

If the application requires more supply voltages than can be provided by the auxiliary busbar system integrated in the basic model, additional auxiliary voltages for the Cabinet Modules can be obtained by installing the second auxiliary busbar option. The optional busbar system provides an additional six cable railway (divided into three times two levels).

The option is supplied as standard with three 2-pin connectors for each Cabinet Module which are designed to facilitate interconnection of individual Cabinet Modules.



Fitting of the optional auxiliary busbar system

The 6-pole busbars have the same properties as the standard bar.

Connectors for voltage pick-off and Infeed can be ordered by using the order number 5ST2545.

Option K82 (Terminal module for controlling the “Safe Torque Off” and “Safe Stop1” functions)

Before protection devices can be opened the safety functions „Safe Torque Off“ or „Safe Stop1“ must be activated.

The Safe Torque Off function prevents unexpected rotation of the connected motor at standstill. Before the Safe Stop1 function decelerates the motor in accordance to the deceleration ramp. These two safety functions are included as standard with S120 Cabinet Modules.

The following boundary conditions must be considered when using these safety functions:

- Simultaneous activation / deactivation at the Control Unit and the Power Unit.
- Supply with 24 V DC.
- According to EN 61800-5-1 and UL 508, only protective extra low voltage (PELV) must be connected to the control connections and control terminals.
- DC supply cables must not exceed a length of 10 m.
- Unshielded signal cables are permissible without additional measures up to a length of 30 m. For longer distances shielded cables must be used or appropriate measures against overvoltage must be installed.
- Maximum connection cross-sections: The connections of the components used with S120 Cabinet Modules are located at the Control Unit CU320 and, either on the power unit (Booksize Units) or on the CIB board (chassis units). Please refer to the chapter "General Engineering Information for SINAMICS", particularly to the section "Safety integrated, drive-integrated safety functions". The connection cross-section which can be connected is between 0.5mm (CU320) and 1.5mm (power unit / CIB).
- Due to the conditions inside the cabinet, the terminals are arranged at different positions in the cabinet.
- The unrestricted access to the terminals in the cabinet may be impeded by other components or covers for protection reasons.

Option K82 was especially developed to coordinate these limitations with the requirements and conditions on site.

This is done by using interface relays, the control of which is electrically isolated and variable with a wide voltage range of between 24 V and 230 V, DC and AC. The status information of the Safe Torque Off and Safe Stop1 safety functions is available by using an optional feedback path. This may be necessary for connection of an external control or external optical indication. The relays used have a second switch off path with which additional safety circuits can be connected. Using the relays also allows the use of an unshielded control cable with a length of more than 30 m. It is also possible to use option K82 in situations in which, due to long distances, no optimal equipotential bonding can be achieved.

All signals are passed to a customer interface. For the wiring to for the system environment on site only one terminal block is relevant which is always realized in the same way, despite its use in different modules. The maximum connection cross-section is always 2.5mm².

Operating Principles

Two independent channels of the integrated safety functions are controlled by two relays (K41, K42). The relay K41 controls the signal at the Control Unit required for the safety functions and relay K42 controls the corresponding signal at the Motor Module. Activation and deactivation must be carried out simultaneously. The unavoidable time delay caused by the mechanical switching of the relays can be adapted by parameters. The circuit is protected against wire breakage i.e. if the control voltage of the relays fails, the safety function becomes active. A check-back signal can be created from the series connection of the relay contacts for information, diagnoses or fault finding purposes.

The check-back signal can be used optionally and is not part of the safety concept. The check-back signal is not necessary to fulfill certified standards.

The activation of safety functions must be carried out with two independent channels. According to ISO 13850 / EN 418, a special switch with a forced opening contact according to IEC 60947-5-1, or another certified safety control system must be used.

The following maximum cable lengths can be connected for the control of the safety functions (valid for lead and return cable):

- AC (Cable capacitance: 330 pF/m):
 - 24 V: 5000 m
 - 110 V: 800 m
 - 230 V: 400 m

The values are valid for a frequency of 50 Hz. At 60 Hz the cable lengths must be reduced by 20 %.

- DC (min. cross-section = 0.75 mm²): 1500 m

SINAMICS S120 Cabinet Modules

Engineering Information

Furthermore, option K82 supports the concept of simplified cabling for the safety functions Safe Torque Off and Safe Stop 1 within coordinated drives. A well-planned arrangement of terminals and the associated cables connections allows a clear and optimised cable routing without cross connections. The arrangement of the modules has been taken into consideration for the design. The terminal can easily be reached in the lower part of the cabinet.

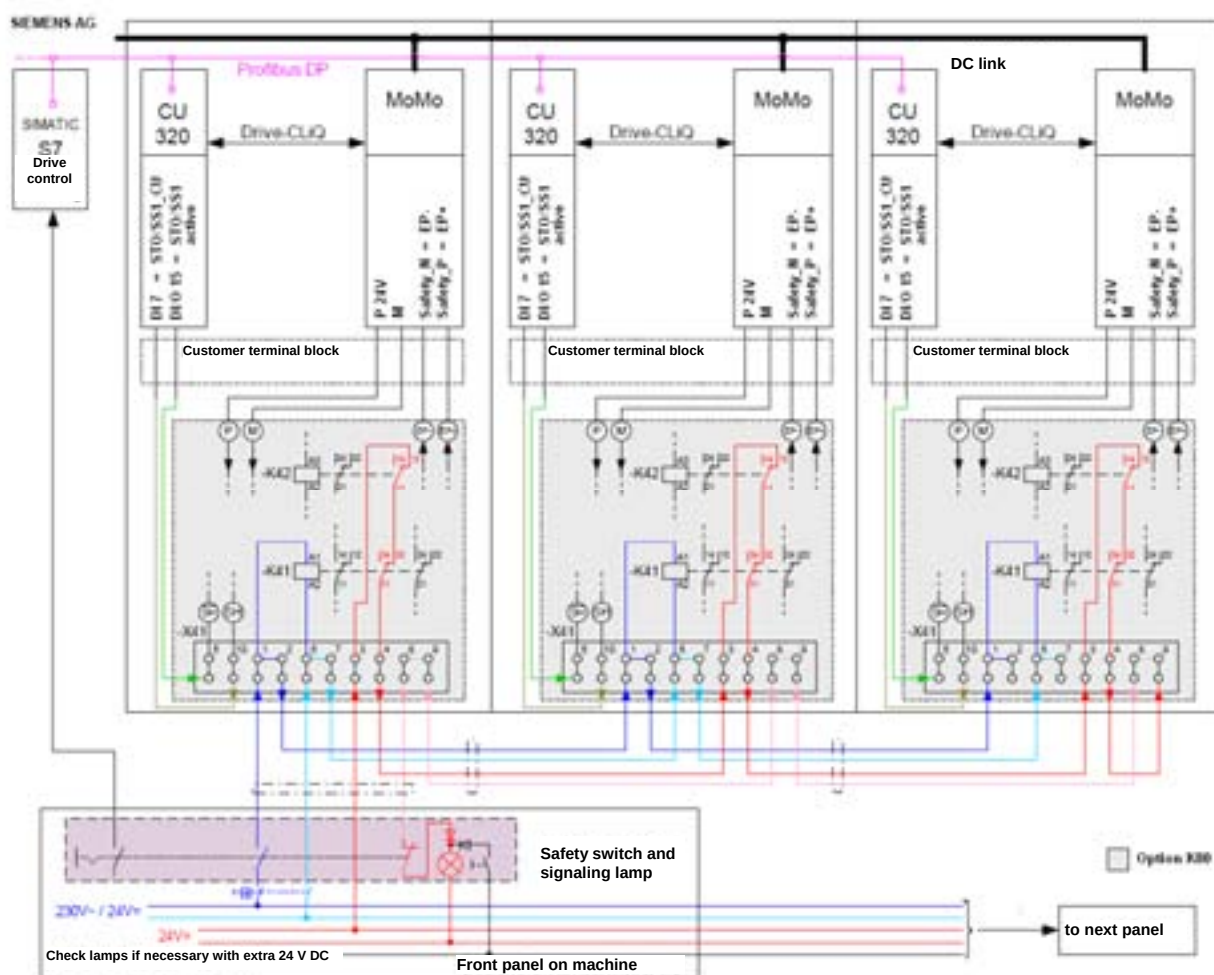
The voltage of the check-back signal paths can be up to 250 V DC / AC. The following rated operating currents must be observed when using check-back contacts (-X41: 5+6):

- AC-15 (according to IEC 60947-5-1): 24 V - 230 V = 3 A
- DC-13 (according to IEC 60947-5-1): 24 V = 1 A
110 V = 0.2 A
230 V = 0.1 A

Minimum switching capacity: DC 5 V, 1 mA with an error rate of 1 ppm.

Protection: Maximum 4 A (fuse for operation class gL/gG at $I_k \geq 1$ kA)

Examples



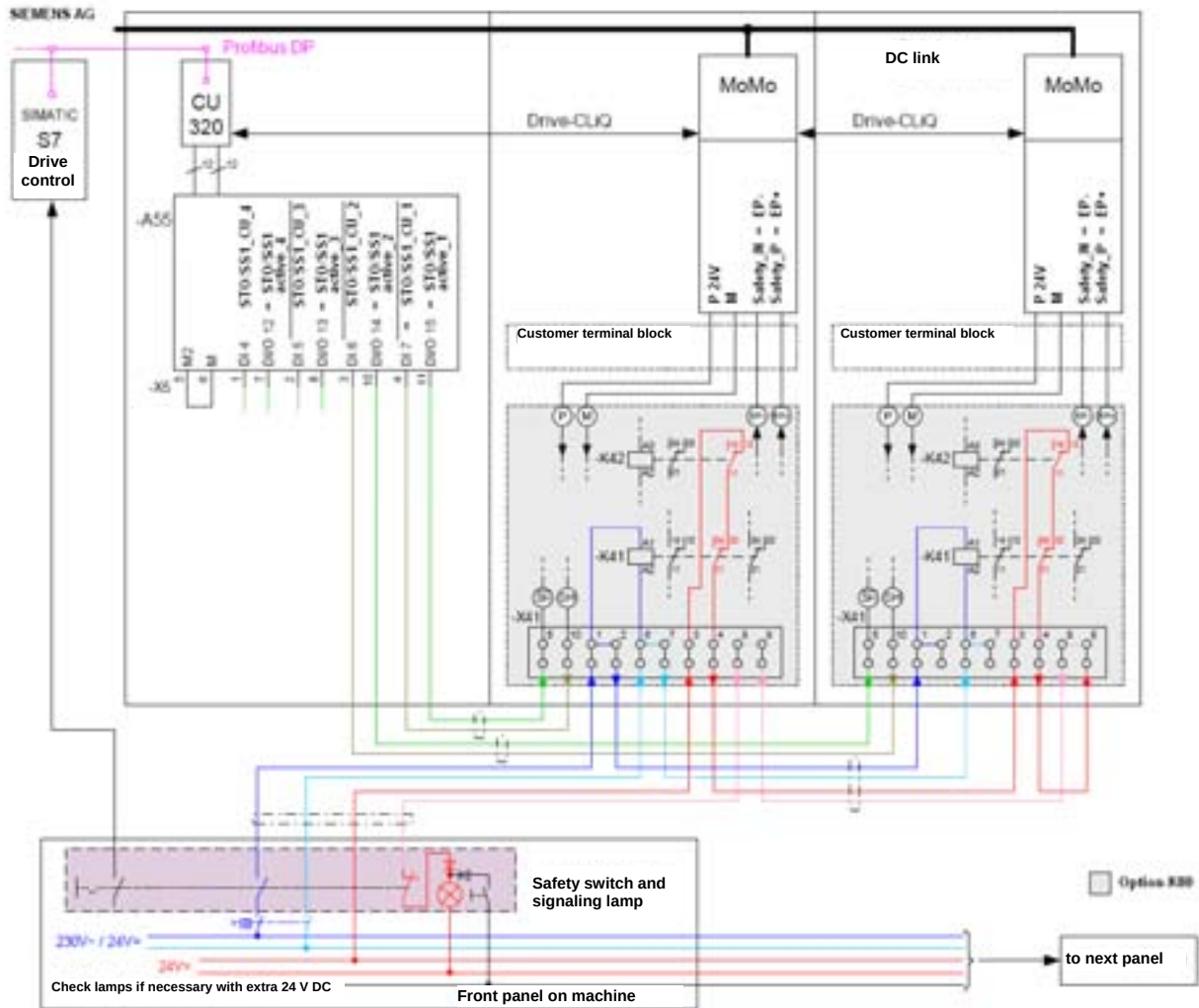
Example of the connection of option K82 with one CU320 per Motor Module with a central safety switch

The example shows how all Motor Modules in a safety group can be activated using a centrally-located safety switch. Due to the terminal configuration and arrangement only one cable must be routed between individual elements.

Inside a cabinet module all connections are pre-wired and the cabinet is therefore ready for connection. The SIMATIC S7 shown is not necessary and thus only demonstrates a possible connection variant.

SINAMICS S120 Cabinet Modules

Engineering Information



Example of the connection of option K82 with a separate CU320 for several Motor Modules

In this example, Motor Modules without their own separate CU320 are operated on the same safety switch shown in the previous diagram. They are driven by a central Control Unit which is also responsible for controlling the selected safety function. The interfaces are the same as in the previous diagram. The only difference is that signals must be taken to the externally mounted CU320.

Option K82 allows optimized hardware interfacing between the SINAMICS and the existing plant. Please note that it is essential to activate this firmware function during commissioning.

In combination with option K82, the requirements according to the machinery directive 98/37/EC and EN 60204-1 are fulfilled as well as the requirements according to DIN EN ISO 13849-1 (formerly the EN954-1) category 3 and Performance level d plus safety integrity level (SIL) 2 according to IEC 61508. The integrated firmware safety functions are already certified and the certification of option K82 is in preparation.

Please note the additional information on the safety functions Safe Torque Off and Safe Stop 1 in the chapter "General Engineering Information for SINAMICS" in the section "Safety-integrated, drive-integrated safety functions".

SINAMICS S120 Cabinet Modules

Engineering Information

Option K90 / 91 (Control Unit CU320)

A CU320 Control Unit which is capable of performing communication and open-loop/closed-loop control functions can be assigned to Line Modules and Motor Modules (incl. Booksize Cabinet Kits) with option K90 and K91 respectively.

The current firmware version including license is stored on the CompactFlash card.

The CompactFlash card for option K90 does not include a performance expansion. The computing capacity requirement increases in proportion to the number of connected modules and system components and in relation to the dynamic response required. The full computing capacity of the CU320 Control Unit is available only with performance expansion 1.

Performance expansion 1 is included with option K91 which supports wider combinations of equipment (see section "Dimensioning and selection information").

The performance expansion is supplied in the form of a license which is stored in the factory on the CompactFlash card as a license code. The expansion can also be enabled on-site, for example, if the performance expansions required are not known when the order is placed. The serial number of the CompactFlash card and the order number of the firmware option to be enabled are required for this purpose. With this information, the relevant license code can be purchased from a license database and the firmware option enabled.

The license code is only valid for the CompactFlash card declared and cannot be transferred to other CompactFlash cards.

The firmware version is encoded in the order number of the CompactFlash card supplied. This can be found on the CompactFlash card.

The firmware version is encoded as follows in the order number:

Order No.:		6SL3054-0 ■■0 ■-1AA0
Firmware version	1	B
	2	C
	3	D
	4	E
Version	.1	B
	.2	C
	.3	D
	.4	E
Without performance expansion		0
With performance expansion 1		1

Encoding of firmware version in the order number

Option L08 / L09 (Motor reactors)

Booksize Cabinet Kits can be supplied with optional output reactors. A maximum of two reactors can be installed for each Booksize Motor Module. Double Motor Modules can be combined as standard with one motor reactor.

The reactors are installed with shielding inside a Cabinet Kit according to the zoning principle. This does not, however, affect their accessibility. To facilitate the connection of motor cables, special terminals are included in the terminal area of the Booksize Base Cabinet. The same provision is also made for shield bonding where required. The cabinet is specially constructed for compliance with high standards of EMC. No extra wiring to the reactor or Motor Module is required.

Order number of Booksize Cabinet Kit	Rated output current of Motor Module [A]	Shielded cable Max. permissible cable length between motor reactor and motor with		Unshielded cable Max. permissible cable length between motor reactor and motor with	
		1 reactor/ Option L08 [m]	2 reactors/ Option L09 [m]	1 reactor/ Option L08 [m]	2 reactors/ Option L09 [m]
6SL3720-1TE13-0AB0	3	100	-	150	-
6SL3720-2TE13-0AB0	2*3	100	-	150	-
6SL3720-1TE15-0AB0	5	100	-	150	-
6SL3720-2TE15-0AB0	2*5	100	-	150	-
6SL3720-1TE21-0AB0	9	135	-	200	-
6SL3720-2TE21-0AB0	2*9	135	-	200	-
6SL3720-1TE21-8AB0	18	160	320	240	480
6SL3720-2TE21-8AB0	2*18	160	-	240	-
6SL3720-1TE23-0AB0	30	190	375	280	560
6SL3720-1TE24-5AB0	45	200	400	300	600
6SL3720-1TE26-0AB0	60	200	400	300	600
6SL3720-1TE28-5AB0	85	200	400	300	600
6SL3720-1TE31-3AB0	132	200	400	300	600
6SL3720-1TE32-0AB0	200	200	400	300	600

Possible cable lengths when motor reactors are used

The motor reactors are designed for a pulse frequency of 4 kHz. Higher pulse frequencies are not permissible. The maximum permissible output frequency when a motor reactor is used is 120 Hz. Motor reactors are approved for use only in conjunction with "Vector" and "V/f control" modes.

For further information about restrictions on motor cable lengths, please also refer to the section "Maximum connectable motor cable lengths" of the chapter "SINAMICS S120, General Information about Built-in and Cabinet Units".

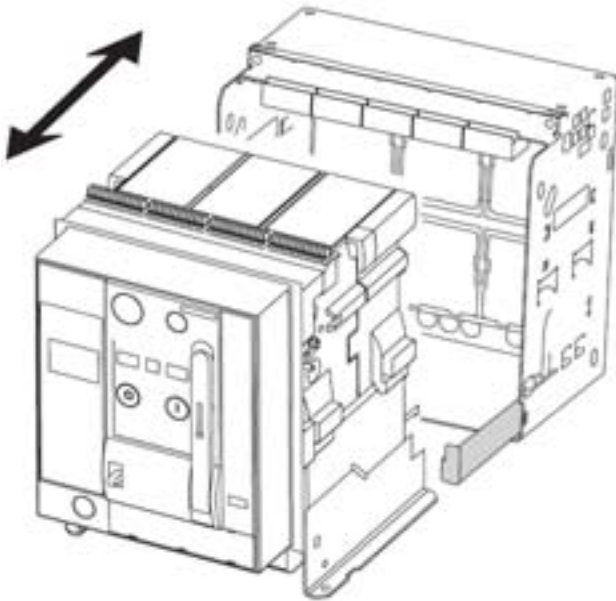
Option L25 (Withdrawable circuit breaker)

Line Connection Modules with an input current of >800 A are equipped as standard with fixed-mounted circuit breakers. With option L25, these circuit breakers are supplied as a withdrawable version so that the breakers can be implemented as a visible disconnection point.

The withdrawable breaker version should be used for applications which require a high level of plant availability or switching frequency. The advantage of the withdrawable version is that the breakers can be replaced quickly.

SINAMICS S120 Cabinet Modules

Engineering Information



Withdrawable version of circuit breaker

In addition to the standard functions/ options, the withdrawable version of the SENTRON WL circuit breaker features the following supplementary functions:

- Position indicator on the breaker front panel
- Captive crank handle for moving the withdrawable breaker
- Slide-in frame with guide rails for easier breaker handling
- Locking capability to prevent movement of breaker
- Withdrawable breaker cannot be moved when the breaker is closed
- Rated current coding between slide-in frame and withdrawable breaker to prevent insertion of incorrect breaker rating.

Option L34 (Circuit breaker on the output side)

Option L34 is a circuit breaker on the output side of the Motor Module and is designed for the purpose of disconnecting the Motor Module from the motor terminals. The disconnection can thus be carried out at full load.

Option L34 is required in the following applications with permanently-excited three-phase synchronous machines:

- Drives with a high moment of inertia, which require a long time for coming to standstill and which generate a voltage at the motor terminals during this time
- Mechanically-coupled auxiliary drives, which can be mechanically driven by the main drive
- Maintenance and repair at the converter, when the machine cannot, for example, be brought to a standstill by means of mechanical braking.
- Operation in the field weakening range in combination with a suitable limitation of the DC link voltage in the converter (e.g. a Braking Unit) which, in the event of a fault tripping of the inverter, effectively limits the DC link voltage until the circuit breaker is opened. For more detailed information, refer to the section "Drives with permanent-magnet three-phase synchronous motors" of the chapter "Drive Dimensioning".

A rotating, permanently magnetized synchronous machine produces a voltage at its terminals which is in proportion to the speed. The motor voltage is therefore present at the output terminals of the Motor Module as well as at the DC link and the components connected to it. For disconnection in the event of a fault or for maintenance work, the circuit breaker at the output is available as an option for S120 Cabinet Modules consisting of Motor Modules in chassis format.

Option L34 consists of a circuit breaker which is located in a separate, 600 mm-wide cabinet to the right of the Motor Module. It is controlled by the Motor Module via a terminal module, which, like the circuit breaker, is completely wired inside the Cabinet Module. Pre-defined BICO logic circuits based on the free function blocks support the commissioning process.

Circuit breakers are subject to limited load duty cycles. To increase their lifetime, they are not opened when the inverter receives an „OFF“ command (OFF1, OFF2, OFF3). Normally, the opening of the circuit breaker is initiated when the Motor Module trips or the auxiliary supply of option L34 fails or the „OFF“ button on the circuit breaker is pressed. When the „OFF“ button directly on the circuit breaker is pressed, the Motor Module will also be deactivated by disabling the pulses.

Option L37 (DC coupling)

The "DC coupling" option (L37) can be installed for applications where it is necessary to disconnect individual modules from the DC busbar and reconnect them again without having to power down the entire drive line-up. A disconnecter can be assigned to individual modules.

When the module is reconnected again, the DC link precharging circuit of the relevant module is activated automatically.

A manually operated switch disconnecter is used for power units of the chassis type. The switch provided with option L37 is extremely compact and features an innovative operating system which makes it particularly simple and reliable to operate.

A contactor assembly with the same operating system is provided for the Booksize Cabinet Kits.

Freely configurable switch-position signaling contacts make it easier to integrate the option's functions into the plant monitoring system. Switching operations can be monitored, but also configured to trigger other processes.

If a Control Unit (option K90/K91) is combined with option L37 and assigned to a module, the connection between the Control Unit and the switch disconnecter/contactor assembly for switching operation monitoring will be made in the factory. If the associated Control Unit is installed in a different transport unit, the connection must be made on site via the standard interface.

Operating principle

The option has an operating lever in the door which has three actuation levels with two switch positions.

- Switch position 0: OFF - switching contacts are open.
- Switch position 1: Precharging - precharging resistor is connected in.
The DC link is precharged in lever position 1.

When the ON command / pulse enable is issued for the chassis module, the switch automatically changes to the third level and the power unit is connected to the DC link. This is performed by a time relay on Booksize Cabinet Kits.

When the DC coupling is disconnected, the operating lever is switched directly from position 1 to 0, bypassing the precharging circuit. Operating errors are impossible.

To provide the greatest possible safety for operating personnel, the switch can be locked in position 0. A lock can be inserted in the specially provided recess for this purpose. With the switch disconnecter version, the cabinet door cannot be opened when the switch is in position 1, or opened only with an appropriate tool.

Option L37 also includes option M60 (additional shock-hazard protection) for optimized air-flow guidance.

The following options are not compatible with option L37:

- Option L61/L62 (braking units)

Option M59 (Cabinet door closed)

If the Cabinet Modules are erected on a false floor or duct which forms part of a forced ventilation system, the modules can be ordered with closed cabinet doors.

In this case, the customer must ensure that no dirt/dust or moisture can enter the Cabinet Module. If the area beneath the Cabinet Modules can be accessed, the customer must provide shock-hazard protection.

Cables must not be routed in such a way that they impede the air inlet through the cabinet floor opening. To ensure an adequate air-inlet cross-section, the units are shipped without the standard baseplates.

The cooling air requirements specified in the section "Dimensioning and selection information" must also be noted.

SINAMICS S120 Cabinet Modules

Engineering Information

Option Y11 (Factory assembly of Cabinet Modules into transport units)

Cabinet Modules can be ordered as factory-assembled transport units with a maximum width of up to 2400 mm. This option allows the modules to be assembled as quickly and simply as possible at their installation site.

The relevant modules are shipped as finished transport units which are interconnected both electrically and mechanically. No additional wiring need be installed between the units on site. Please note that this does not apply to the DRIVE-CLiQ connections between cabinets. These must be ordered separately as the customer's final implementation requirements cannot be determined from the order.

When DC busbars (options M80 to M87) for these "units" are selected, it must be ensured that identical busbars are installed within the transport unit and are compatible with all adjacent Cabinet Modules. Uninterrupted busbars are used in transport units to facilitate handling. This must be taken into account with respect to auxiliary voltage supplies. If the auxiliary voltage circuits are to be divided up, then separate transport units must be selected accordingly.

In a transport unit order, all the Cabinet Modules included in the unit and their installation sequence from left to right must be specified in plain text according to the syntax below:

Plain text required to order:	TE 1 - 1...6
Transport unit	
Serial number of transport unit	
Position of Cabinet Module within transport unit (from left to right)	

Option Y11 is particularly recommended for units comprising Line Connection Modules and Line Modules because the required precharging circuits and connection busbars, for example, can be incorporated in the transport unit for certain variants. Please refer to the assignment tables in the section "Line Connection Modules".

Example:

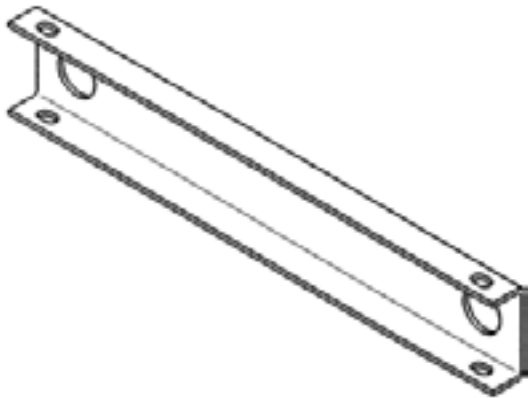
LCM1 BLM1 MM1 MM2 MM3 MM4 MM5 AUX1	Cabinet width [mm]
600 400 800 600 600 400 400 400	
600 1000 1800 2400 3000 3400 3800 4200	Total length [mm]
TE1 TE2 TE3	Assembly into transport units
2400 1000 800	Length of TE [mm]
TE1-1 TE1-2 TE1-3 TE1-4 TE2-1 TE2-2 TE3-1 TE3-2	Plain text info for option Y11

SINAMICS S120 Cabinet Modules

Engineering Information

In the line-up illustrated above, five Chassis Motor Modules are connected to a Basic Line Module. The Line Connection Module and the Auxiliary Power Supply Module are properly rated for the configuration. The first transport unit contains the Line Connection Module, the Basic Line Module plus two Motor Modules. These components require the maximum possible length of a transport unit (2.4 m). A standardized DC link busbar ordered with option M83 is installed in this unit. Mathematically speaking, the other modules with a remaining length of 1.8 m can be installed in another single transport unit. However, the requirement for a separate auxiliary voltage supply to Motor Module 5 means that a third transport unit is needed. A smaller DC busbar (for example, M80) can be selected for transport units 2 and 3 as their power requirement may be lower.

The parts needed to connect the individual transport units are included in the scope of supply. Please note that the auxiliary voltage busbar cannot be connected continuously when a separate auxiliary voltage Infeed is required, as described for the example above. In this case, the busbar segments (TE1+2 in the example) must be separately connected to the Auxiliary Power Supply Module.



The transport unit is shipped with a crane-hoisting transport rail which means that option M90 is not required.

Converter Cabinet Units SINAMICS S150

■ General information

SINAMICS S150 cabinets are ready-to-connect, high-output AC/AC converters in a standard cabinet. An extensive range of electrical and mechanical options means that they can be configured easily to meet individual requirements. They are designed for applications with high requirements to the control performance and feature a highly dynamic, pulsed, IGBT-based rectifier/regenerative unit for unrestricted 4Q operation (Active Infeed with AFE technology). The Clean Power Filter installed on the line side guarantees extremely "supply-friendly" operation with negligible harmonic effects.

SINAMICS S150 cabinets are especially suitable for use in drives with

- High dynamic requirements
- Frequent braking cycles and high braking energy

SINAMICS S150 cabinets are available for the line supply voltages and outputs listed in the table below:

Line supply voltage	Converter output
380 V – 480 V 3AC	110 kW - 800 kW at 400 V
500 V – 690 V 3AC	55 kW - 900 kW at 500 V 75 kW - 1200 kW at 690 V

Line supply voltages and output power ranges of SINAMICS S150 cabinets

Line and motor-side components as well as additional monitoring devices can be installed in the SINAMICS S150 cabinets.

They are available in widths from 1400 mm, which then increase in increments of 200 mm.

The standard model has degree of protection IP20, but further models with degrees of protection IP21, IP23, IP43 and IP54 are available as options.

SINAMICS S150 cabinets feature as standard the AOP30 Advanced Operator Panel for control, monitoring and commissioning tasks. It is mounted in the cabinet door.

The customer interface is provided in the form of a PROFIBUS interface on the CU320 Control Unit and the TM31 Terminal Module which adds a large number of analog and digital inputs/outputs.

The digital inputs and outputs on the CU320 Control Unit are used for internal purposes on S150 cabinets and are not therefore available for use as a customer interface. The TM31 Terminal Module must always be used for this purpose.

Rated data and continuous operation of the converters

Main applications

SINAMICS S150 cabinets are designed to meet high requirements in terms of dynamic response and control accuracy and operate with a high-quality vector control. Standard models are equipped with a sensorless vector control. SINAMICS S150 cabinets are also available with an optional speed encoder interface (SMC30) which allows operation with TTL/HTL incremental encoders (option K50).

They feature a highly dynamic, pulsed, IGBT-based rectifier/regenerative unit for 4Q operation. This regulates the DC link voltage and stabilizes it at a constant value irrespective of the level of line voltage fluctuation. The factory setting for the DC link voltage corresponds to 1.5 times the parameterized line supply voltage. These converters are therefore ideal for operation on unstable power supply systems with a high level of line voltage fluctuation.

The Clean Power Filter on the line side ensures minimum harmonic effects on the supply in operation. These units are therefore also ideal for applications which demand an extremely high standard of supply quality.

Line supply voltages

SINAMICS S150 cabinets are available for the following line supply voltages:

- 380 V – 480 V 3AC
- 500 V – 690 V 3AC

The permissible voltage tolerance is $\pm 10\%$ continuously and -15% for brief periods ($< 1\text{ min}$). Please note that the output voltage and thus the output power can be kept constant by virtue of the stabilized DC link voltage provided that sufficient line current reserves are available.

Usable output currents

The output currents specified in the selection and ordering data can be utilized over the entire frequency or speed setting range, i.e. even at very low output frequencies down to zero speed.

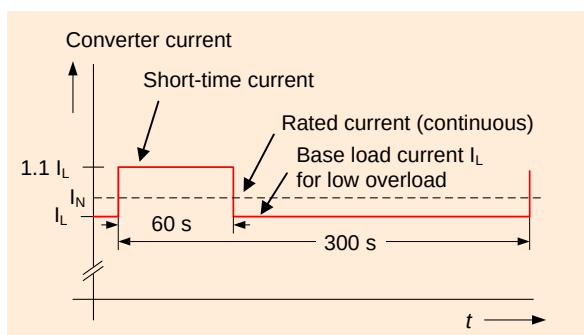
The specified rated output current is the maximum continuous thermally permissible output current. The units have no additional overload capacity when operating at this current.

Overload capability, load duty cycle definitions

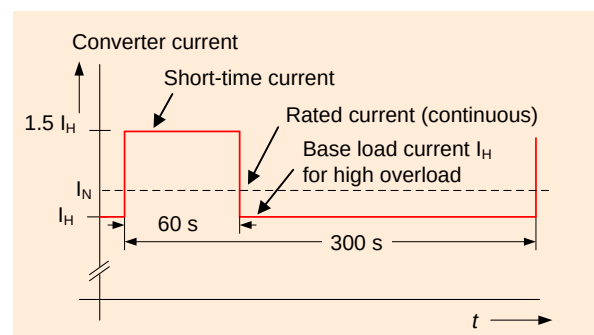
When a drive is required to overcome breakaway torques or is subjected to high surge loads, its configuration must take these factors into account. In such instances, it must be operated on the basis of a base load current which is lower than the rated output current. Overload reserves are available for this purpose. The load duty cycles for operation with low and high overloads are defined below.

- The base load current I_L for low overload is based on a load duty cycle of 110% for 60 s or 150% for 10 s.
- The base load current I_H for a high overload is based on a load duty cycle of 150% for 60 s or 160% for 10 s.

These overload values apply on condition that the converter is operated at its base load current before and after the period of overload on the basis of a load duty cycle duration of 300 s in each case.



Load duty cycle definition for low overload



Load duty cycle definition for high overload

Overload and overtemperature protection

SINAMICS S150 cabinets are equipped with effective overload and overtemperature protection mechanisms which protect them against thermal overloading.

Sensors at various locations in the converter (inlet air, control electronics, rectifier heatsink, inverter heatsink) measure the relevant temperatures and feed them into the so-called "Thermal model". This continuously calculates the temperature at critical positions on power components. In this way the converter is effectively protected against thermal overloads, whether they are caused by excessive current or high ambient temperatures. The so-called "I²t" monitoring circuit checks the level of utilization of the motor-side inverter. If the level of inverter utilization or the temperature at any point in the converter exceeds the upper tolerance limit, the converter responds by initiating an overload reaction parameterized in the firmware. It is possible to select whether the converter should react to overload by reducing the output frequency and output current or the pulse frequency. Immediate shutdown can also be parameterized.

Maximum output frequencies

The maximum output frequency for SINAMICS S150 cabinets is limited to either 160 Hz or 100 Hz due to the factory-set pulse frequency of either $f_{\text{pulse}} = 2.00 \text{ kHz}$ or $f_{\text{pulse}} = 1.25 \text{ kHz}$. Higher output frequencies can be obtained only through an increase in the pulse frequency. As the switching losses in the motor-end IGBT inverter increase in proportion to the pulse frequency, the output current must be reduced accordingly.

Permissible output current and maximum output frequency as a function of pulse frequency

Output power at 400 V / 690 V	Rated output current at pulse frequency of		Current derating-factor at pulse frequency of	
	2 kHz	1,25 kHz	4 kHz	2,5 kHz
380 V – 480 V 3AC				
110 kW	210 A	-	82 %	-
132 kW	260 A	-	83 %	-
160 kW	310 A	-	88 %	-
200 kW	380 A	-	87 %	-
250 kW	490 A	-	78 %	-
315 kW	-	605 A	-	72 %
400 kW	-	745 A	-	72 %
450 kW	-	840 A	-	79 %
560 kW	-	985 A	-	87 %
710 kW	-	1260 A	-	87 %
800 kW	-	1405 A	-	95 %
500 V – 690 V 3AC				
75 kW	-	85 A	-	89 %
90 kW	-	100 A	-	88 %
110 kW	-	120 A	-	88 %
132 kW	-	150 A	-	84 %
160 kW	-	175 A	-	87 %
200 kW	-	215 A	-	87 %
250 kW	-	260 A	-	88 %
315 kW	-	330 A	-	82 %
400 kW	-	410 A	-	82 %
450 kW	-	465 A	-	87 %
560 kW	-	575 A	-	85 %
710 kW	-	735 A	-	79 %
800 kW	-	810 A	-	95 %
900 kW	-	910 A	-	87 %
1000 kW	-	1025 A	-	86 %
1200 kW	-	1270 A	-	79 %

SINAMICS S150: Permissible output current as a function of pulse frequency

Pulse frequency	Maximum attainable output frequency
1.25 kHz	100 Hz
2.00 kHz	160 Hz
2.50 kHz	200 Hz
≥ 4.00 kHz	300 Hz

Maximum attainable output frequency as a function of pulse frequency

Current derating as a function of installation altitude

If the converters are operated at an **installation altitude > 2000 m** above sea level, the maximum permissible output current can be calculated using the following tables according to the degree of protection selected for the cabinet. To obtain these values, the air flow rate stipulated in the technical data tables must be provided. The specified values already include a permitted correction between installation altitude and ambient temperature (incoming air temperature at the inlet to the converter cabinet).

Installation altitude above sea level m	Current derating at an ambient temperature (inlet air temperature) of						
	20 °C	25 °C	30 °C	35 °C	40 °C	45 °C	50 °C
0 ... 2000	100 %					95.0 %	87.0 %
... 2500						96.3 %	91.4 %
... 3000	96.7 %			96.2 %	92.5 %	87.9 %	80.5 %
... 3500				92.3 %	88.8 %	84.3 %	77.3 %
... 4000	97.8 %	92.7 %	88.4 %	85.0 %	80.8 %	74.0 %	

Current derating as a function of ambient temperature (temperature of inlet air) and installation altitude for S150 cabinets with **degrees of protection IP20, IP21, IP23 and IP43**

Installation altitude above sea level m	Current derating at an ambient temperature (inlet air temperature) of						
	20 °C	25 °C	30 °C	35 °C	40 °C	45 °C	50 °C
0 ... 2000	100 %				95.0 %	87.5 %	80.0 %
... 2500					96.3 %	91.4 %	84.2 %
... 3000	96.7 %		96.2 %	92.5 %	87.9 %	81.0 %	74.1 %
... 3500			92.3 %	88.8 %	84.3 %	77.7 %	71.1 %
... 4000	97.8 %	92.7 %	88.4 %	85.0 %	80.8 %	74.7 %	68.0 %

Current derating as a function of ambient temperature (temperature of inlet air) and installation altitude, for S150 cabinets with **degree of protection IP54**

Voltage derating as a function of installation altitude

In addition to current derating, voltage derating as stipulated in the table below is applicable at installation altitudes of > 2000 m above sea level.

Installation Altitude above sea level m	Voltage derating at a rated input voltage of																			
	380 V	400 V	420 V	440 V	460 V	480 V	500 V	525 V	575 V	600 V	660 V	690 V								
0 ... 2000	100 %																			
... 2250													96 %							
... 2500													98 %						94 %	
... 2750													98 %						94 %	90 %
... 3000													95 %						91 %	88 %
... 3250		97 %	93 %	89 %	85 %															
... 3500	98 %	93 %	89 %	85 %	82 %															
... 3750	95 %	91 %	87 %	83 %	79 %															
... 4000	96 %	92 %	87 %	83 %	80 %	76 %	91 %	87 %	80 %	76 %										

Voltage derating as a function of installation altitude

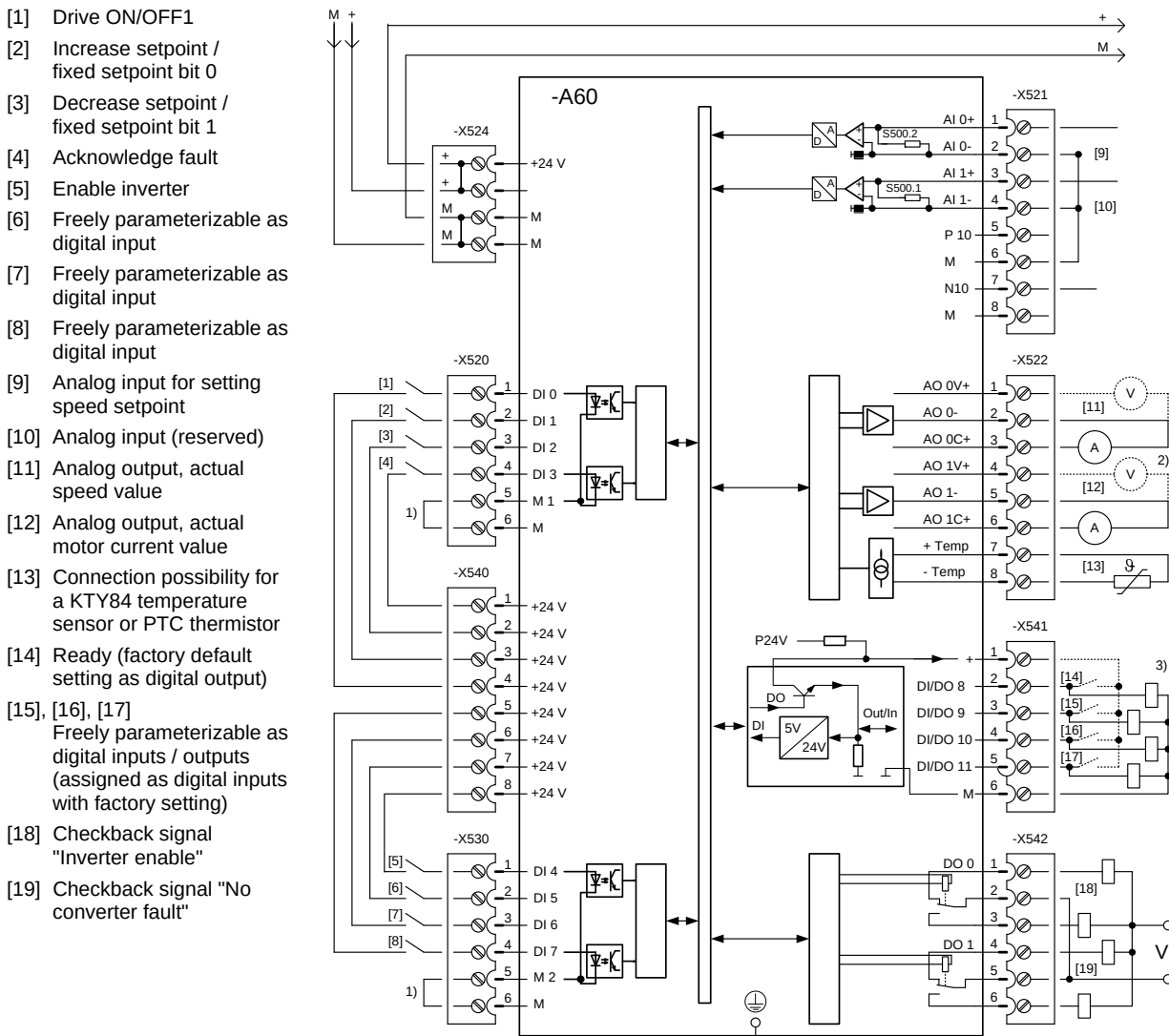
Factory settings (defaults) of customer interface on SINAMICS S150

A PROFIBUS interface on the CU320 Control Unit and the TM31 customer terminal block are available as standard interfaces to the control equipment in the customer's plant.

The customer terminal block can be used to connect the system to the higher-level controller using analog and digital signals, or to connect additional equipment.

The customer terminal block contains:

- 8 digital inputs (DI)
- 4 bidirectional inputs/outputs (DI/DO)
- 2 analog inputs (differential) (AI)
- 2 analog outputs (AO)
- 2 relay outputs (changeover contact) (DO)
- 1 input for KTY84 temperature sensor or PTC thermistor (temp.)
- Auxiliary voltage output ± 10 V for analog setpoint input
- Auxiliary voltage output +24 V for digital inputs



Customer terminal block

- 1) Jumpers must be inserted for this circuit example (M: internal ground, M1 or M2: External)
- 2) Parameterizable as current or voltage source
- 3) Individually parameterizable as digital input/output (factory setting: Assigned as output)

Terminal	No.	Type	Factory setting (default)	Comment
X540:1 - 8	P24	24 V DC supply voltage for the inputs D 0 to DI7 and DI/DO8 to DI/DO11		
X520:1	DI0	Digital input isolated via optocoupler	ON/OFF1	Inputs are freely parameterizable
X520:2	DI1		Increase setpoint / fixed setpoint bit 0	
X520:3	DI2		Decrease setpoint / fixed setpoint bit 1	
X520:4	DI3		Acknowledge fault	
X520:5	M1	Ground terminal for digital inputs DI0 to DI3		
X520:6	M (GND)	Ground terminal for P24 auxiliary voltage for digital inputs		
X530:1	DI4	Digital input isolated via optocoupler	Enable inverter	Converter is at standby and is waiting for enabling
X530:2	DI5			Inputs are freely parameterizable
X530:3	DI6			
X530:4	DI7			
X530:5	M2	Ground terminal for digital inputs DI4 to DI7		
X530:6	M (GND)	Ground terminal for P24 auxiliary voltage for digital inputs		
X541:1	P24	Non-isolated digital inputs/outputs	Ready (factory-set as digital output)	Inputs/outputs are freely parameterizable
X541:2	DI/DO8			Factory-set as input
X541:3	DI/DO9			Factory-set as input
X541:4	DI/DO10			Factory-set as input
X541:5	DI/DO11	Ground terminal of P24 and ground of digital inputs/outputs		
X541:6	M (GND)			
X521:1	AI 0 +	Analog inputs as differential inputs for the following ranges: -10 V To +10 V +4 mA To +20 mA -20 mA To +20 mA 0 mA To +20 mA The voltage/current input selection is made with switch S500	Speed setpoint Factory setting 0 to 20 mA	Positive differential input for voltage/current
X521:2	AI 0 -			Negative differential input for voltage/current
X521:3	AI 1 +		Reserved	Positive differential input for voltage/current
X521:4	AI 1 -			Negative differential input for voltage/current
X521:5	P10	Auxiliary voltage ± 10 V (10 mA) for the connection of a potentiometer for setpoint specification via an analog input		+10 V
X521:6	M (GND)			Ground terminal for ± 10 V
X521:7	N10			-10 V
X521:8	M (GND)			Ground terminal for ± 10 V
X522:1	AO 0V+	Analog outputs for the following ranges: -10 V To +10 V +4 mA To +20 mA -20 mA To +20 mA 0 mA To +20 mA	Speed actual value Factory setting 0 to 20 mA	Analog output voltage +
X522:2	AO 0 ref.			Common reference point for current/voltage
X522:3	AO 0A+			Analog output current +
X522:4	AO 1V+		Actual motor current value Factory setting 0 to 20 mA	Analog output voltage +
X522:5	AO 1 ref.			Common reference point for current/voltage
X522:6	AO 1A+			Analog output current +
X522:7	KTY+	KTY84 temperature sensor (0 to 200° C) or PTC ($R_{cold} \leq 1.5 \text{ k}\Omega$)		The sensor type must be parameterized
X522:8	KTY-			
X542:1	DO 0.NC	Relay output, changeover contact	Checkback: Enable inverter	NC contact
X542:2	DO 0.COM	Max. switching voltage: 250 V AC, 30 V DC		Common
X542:3	DO 0.NO	Max. switching capacity at 250 VAC: 2000 VA Max. switching capacity at 30 VDC: 240 W		NO contact
X542:4	DO 1.NC	Relay output, changeover contact	Checkback: No fault in converter	NC contact
X542:5	DO 1.COM	Max. switching voltage: 250 V AC, 30 V DC		Common
X542:6	DO 1.NO	Max. switching capacity at 250 VAC: 2000 VA Max. switching capacity at 30 VDC: 240 W		NO contact

Customer terminal block with factory settings

SINAMICS S150

Engineering Information

Cable cross-sections and connections on SINAMICS S150 cabinets

Recommended and maximum possible cable cross-sections for line and motor connections

The following tables show the recommended or maximum possible cable connections on the power supply and motor sides.

The recommended cross-sections are based on the catalog-listed fuses and single routing of the three-wire cables at an ambient temperature of 40 °C.

When the conditions differ from the above stated (cable routing, cable grouping, ambient temperature), the planning instructions for routing the cables must be taken into account.

Output		Converter	Wght.	Line connection					Motor connection					Cabinet earthing		Remarks
at 400 V or 600 V	at 480 V (60 Hz)		(standard version)	Recommended cross-section		Maximum conductor cross-section		Mounting screw M12	Recommended cross-section		Maximum conductor cross-section		Mounting screw M12	Mounting screw M12		
kW	hp	Type	kg	DIN VDE mm ²	AWG/ MCM	DIN VDE mm ²	AWG/ MCM	(No. of holes)	DIN VDE mm ²	AWG/ MCM	DIN VDE mm ²	AWG/ MCM	(No. of holes)	(No. of holes)		
6SE3710 ...																
380 V to 480 V																
110	150	-7LE32-1AA0	708	2x70	2x(000)	4x240	4x800	(2)	2x70	2x(000)	2x150	2x(400)	(2)	(2)		
132	200	-7LE32-6AA0	708	2x95	2x(4/0)	4x240	4x800	(2)	2x95	2x(4/0)	2x150	2x(400)	(2)	(2)		
160	250	-7LE33-1AA0	892	2x120	2x(300)	4x240	4x800	(2)	2x120	2x(300)	2x150	2x(400)	(2)	(2)		
200	300	-7LE33-8AA0	980	2x120	2x(300)	4x240	4x800	(2)	2x120	2x(300)	2x150	2x(400)	(2)	(2)		
250	400	-7LE35-0AA0	980	2x185	2x(500)	4x240	4x800	(2)	2x185	2x(500)	2x240	2x(600)	(2)	(2)		
315	500	-7LE36-1AA0	1716	2x240	2x(600)	4x240	4x800	(2)	2x240	2x(600)	4x240	4x(600)	(2)	(2)		
400	600	-7LE37-5AA0	1731	3x185	3x(500)	4x240	4x800	(2)	2x240	2x(600)	4x240	4x(600)	(2)	(10)	Cu rail	
450	700	-7LE38-4AA0	1778	4x150	4x(400)	8x240	8x(600)	(4)	4x150	4x(400)	4x240	4x(600)	(2)	(10)	Cu rail	
560	800	-7LE41-0AA0	2408	4x185	4x(500)	8x240	8x(600)	(4)	4x185	4x(500)	6x240	6x(600)	(3)	(18)	Cu rail	
710	900	-7LE41-2AA0	2408	4x240	4x(600)	8x240	8x(600)	(4)	4x240	4x(600)	6x240	6x(600)	(3)	(18)	Cu rail	
800	1000	-7LE41-4AA0	2408	6x185	6x(500)	8x240	8x(600)	(4)	6x185	6x(500)	6x240	6x(600)	(3)	(18)	Cu rail	
600 V to 800 V																
75	-	-7LH28-5AA0	708	50	(00)	4x240	4x800	(2)	50	(00)	2x70	2x(000)	(2)	(2)		
90	-	-7LH31-0AA0	708	50	(00)	4x240	4x800	(2)	50	(00)	2x150	2x(400)	(2)	(2)		
110	-	-7LH31-2AA0	708	70	(000)	4x240	4x800	(2)	70	(000)	2x150	2x(400)	(2)	(2)		
132	-	-7LH31-5AA0	708	95	(4/0)	4x240	4x800	(2)	95	(4/0)	2x150	2x(400)	(2)	(2)		
160	-	-7LH31-8AA0	892	120	(300)	4x240	4x800	(2)	120	(300)	2x150	2x(400)	(2)	(2)		
200	-	-7LH32-0AA0	892	2x70	2x(000)	4x240	4x800	(2)	2x70	2x(000)	2x150	2x(400)	(2)	(2)		
250	-	-7LH32-6AA0	892	2x95	2x(4/0)	4x240	4x800	(2)	2x95	2x(4/0)	2x185	2x(500)	(2)	(2)		
315	-	-7LH33-3AA0	892	2x120	2x(300)	4x240	4x800	(2)	2x120	2x(300)	2x240	2x(600)	(2)	(2)		
400	-	-7LH34-1AA0	1716	2x185	2x(500)	4x240	4x800	(2)	2x185	2x(500)	4x240	4x(600)	(2)	(2)		
450	-	-7LH34-7AA0	1716	2x185	2x(500)	4x240	4x800	(2)	2x185	2x(500)	4x240	4x(600)	(2)	(2)		
560	-	-7LH35-8AA0	1716	2x240	2x(600)	4x240	4x800	(2)	2x240	2x(600)	4x240	4x(600)	(2)	(2)		
710	-	-7LH37-1AA0	2300	3x185	3x(500)	8x240	8x(600)	(4)	3x185	3x(500)	6x240	6x(600)	(3)	(18)	Cu rail	
800	-	-7LH38-1AA0	2408	4x150	4x(400)	8x240	8x(600)	(4)	4x150	4x(400)	6x240	6x(600)	(3)	(18)	Cu rail	
900	-	-7LH38-8AA0	2408	4x150	4x(400)	8x240	8x(600)	(4)	4x150	4x(400)	6x240	6x(600)	(3)	(18)	Cu rail	
1000	-	-7LH41-0AA0	2408	4x185	4x(500)	8x240	8x(600)	(4)	4x185	4x(500)	6x240	6x(600)	(3)	(18)	Cu rail	
1200	-	-7LH41-3AA0	2408	4x240	4x(600)	8x240	8x(600)	(4)	4x240	4x(600)	6x240	6x(600)	(3)	(18)	Cu rail	

Required cable cross-sections for line and motor connections

It is always advisable to use shielded, symmetrical, 3-wire three-phase cables or to connect several cables of this type in parallel if necessary. There are basically two reasons for this choice of cable:

This is the only way in which the high IP55 degree of protection can be achieved for the motor terminal box without problems because the cables enter the terminal box via glands and the number of possible glands is limited by the geometry of the terminal box. Therefore single cables are less suitable.

With symmetrical, 3-wire, three-phase cables, the summed ampere-turns over the cable outer diameter are equal to zero and they can be routed in conductive, metal cable ducts or racks without any significant currents (ground current or leakage current) being induced in these conductive, metal connections. The danger of induced leakage currents and thus of increased cable shield losses increases with single-wire cables.

The required cable cross-section depends on the amperage which flows through the cable. The permissible current loading of cables is defined e.g. in DIN VDE 0298 Part 2/DIN VDE 0276-1000. It depends on ambient conditions such as the temperature, but also on the routing method. It depends whether cables are routed singly and therefore relatively well ventilated, or whether groups of cables are routed together. In the latter instance, the cables heat one another and are therefore far less well ventilated. Reference should be made to the corresponding reduction factors for such conditions as specified in DIN VDE 0298 Part 2 / DIN VDE 0276-1000. With an ambient temperature of 40 °C, the cross-sections of copper cables can be based on the following table.

Cross-section of 3-wire cables mm ²	With single routing A	With several cables on a common cable rack A
50	138	95
70	176	121
95	212	146
120	245	169
150	282	194
185	323	222
240	380	261
300	418	289

Current-carrying capacity according to DIN VDE 0298 Part 2 at 40° C

With higher amperages, cables must be connected in parallel.

Note:

The recommendations for the North American market in AWG or MCM must be taken from the appropriate NEC (National Electrical Code)/CEC (Canadian Electrical Code) standards.

Grounding and PE conductor cross-section

The PE conductor must be dimensioned to meet the following requirements:

- In the case of a ground fault, no impermissibly high contact voltages resulting from voltage drops on the PE conductor caused by the ground fault current may occur (< 50 VAC or < 120 VDC, EN 50 178 Subsection 5.3.2.2, IEC 60 364, IEC 60 543).
- The PE conductor should not be excessively loaded by any ground fault current it carries.
- If it is possible for continuous currents to flow through the PE conductor when a fault occurs in accordance with EN 50 78 Subsection 8.3.3.4, the PE conductor cross-section must be dimensioned for this continuous current.
- The PE conductor cross-section should be selected according to EN 60 204-1, EN 60 439-1, IEC 60 364.

Cross-section of phase conductor mm ²	Minimum cross-section of the external PE conductor mm ²
Up to 16	Minimum phase conductor cross-section
16 to 35	16
35 and above	Minimum half the phase conductor cross-section

Note:

The recommendations for the North American market in AWG or MCM must be taken from the appropriate NEC (National Electrical Code)/CEC (Canadian Electrical Code) standards.

- Switchgear systems and motors are usually grounded via a separate local ground connection. In the case of a ground fault with this configuration, the ground fault current is divided and flows through the ground connections in parallel. With this grounding system, no impermissible contact voltages can occur, despite the PE conductor cross-sections used in the above table.

Based on experience with different grounding configurations, however, we recommend that the ground wire from the motor should be routed directly back to the converter. For EMC reasons and to prevent bearing currents, symmetrical, three-wire, three-phase cables should be used in this case rather than four-wire cables. The ground connection (PE) must be routed separately or must be arranged symmetrically in the motor cable. The symmetry of the PE conductor is achieved using a conductor surrounding all phase conductors or using a cable with a symmetrical arrangement of the three phase conductors and three ground conductors. For further information, please refer to the sections "Bearing currents caused by steep voltage edges on the motor" and "Line filters" of the chapter "Fundamental Principles and System Description".

- Through their controllers, the converters limit the load current (motor and ground fault currents) to an rms value corresponding to the rated current. We therefore recommend the use of a PE conductor cross-section analogous to the phase conductor cross-section for grounding the converter cabinet.

■ Load-side components and cables

Motor reactor

The fast switching of the IGBTs in the inverter causes high voltage rate of rise dv/dt at the inverter output. If long motor cables are used, these voltage gradients increase the current load on the converter output due to capacitive charge/discharge currents. The length of cable which may be connected is therefore limited.

The high voltage rate of rise and the resulting voltage spikes at the motor terminals, increase the voltage stress at the motor winding in comparison to direct line operation. In conjunction with the connected cable capacitances, the motor reactors (option L08) reduce the capacitive charge/discharge currents in the motor cables and, as a function of the motor cable length, limit the voltage rate of rise dv/dt and the voltage peaks V_{PP} at the motor terminals.

For a more detailed description, please refer to the section "Motor reactors" of the chapter "Fundamental Principles and System Description".

dv/dt filter plus VPL

The dv/dt filter plus VPL (option L10) consists of two components, the dv/dt reactor and the voltage limiting network (Voltage Peak Limiter), which limits voltage peaks and returns the energy back to the DC link.

The dv/dt filter plus VPL must be used for motors for which the withstand voltage of the insulation system is unknown or insufficient. Motors in the 1LA and 1LG ranges require this type of filter only when they are connected to a supply voltage exceeding 500 V +10 % and no special insulation is used on the motor.

The dv/dt filter plus VPL limits the voltage rate of rise to values $< 500 \text{ V}/\mu\text{s}$ and the typical voltage spikes at the motor to the values below:

- V_{PP} (typically) $< 1000 \text{ V}$ for $V_{Line} < 575 \text{ V}$
- V_{PP} (typically) $< 1250 \text{ V}$ for $660 \text{ V} < V_{Line} < 690 \text{ V}$

For a more detailed description, please refer to the section "dv/dt filters plus VPL" of the chapter "Fundamental Principles and System Description".

Sine-wave filter

Sine-wave filters are LC low-pass filters and constitute the most sophisticated filter solution. They are significantly more effective than dv/dt filters plus VPL in reducing the voltage rate of rise dv/dt and peak voltages V_{PP} , but operation with sine-wave filters imposes substantial restrictions in terms of the possible pulse frequency settings and voltage and current utilization of the motor-side inverter (voltage and current derating).

For a more detailed description and for the derating data, please refer to the section "Sine-wave filters" of the chapter "Fundamental Principles and System Description".

Maximum connectable motor cable lengths

The table shows the maximum connectable motor cable lengths. The values apply to the motor cable types recommended in the tables as well as to all other types of motor cable.

Line supply voltage	Output power at 400 V resp. 690 V	Maximum permissible motor cable length	
		Shielded cable e.g. Protodur NYCWY	Unshielded cable e.g. Protodur NYY
Without reactor or filter			
380 V – 480 V 3AC	110 kW - 800 kW	300 m	450 m
500 V – 690 V 3AC	75 kW - 1200 kW	300 m	450 m
With one motor reactor (option L08)			
380 V – 480 V 3AC	110 kW - 800 kW	300 m	450 m
500 V – 690 V 3AC	75 kW - 1200 kW	300 m	450 m

Permissible motor cable lengths for SINAMICS S150

SINAMICS S150

Engineering Information

Line supply voltage	Output power at 400 V resp. 690 V	Maximum permissible motor cable length	
		Shielded cable e.g. Protodur NYCWY	Unshielded cable e.g. Protodur NYY
With dv/dt filter plus VPL (option L10)			
380 V – 480 V 3AC	110 kW - 800 kW	300 m	450 m
500 V – 690 V 3AC	75 kW - 1200 kW	300 m	450 m
With sine-wave filter (option L15)			
380 V – 480 V 3AC	110 kW - 250 kW	300 m	450 m
500 V – 690 V 3AC	110 kW - 132 kW	300 m	450 m

Permissible motor cable lengths for SINAMICS S150 (continued)

When two motor reactors are connected in series, the permissible cable lengths can be increased even further to 525 m with shielded cables and 787 m with unshielded cables.

A second motor reactor is not a standard option and may require an additional cabinet. A second motor reactor is therefore available only on request.

Drive Dimensioning

Drives with quadratic load torque

Drives with a quadratic load torque ($M \sim n^2$), such as pumps and fans, require full torque at rated speed. Increased starting torques or high load peaks usually do not occur. It is therefore not necessary to provide a higher overload capability for the converter.

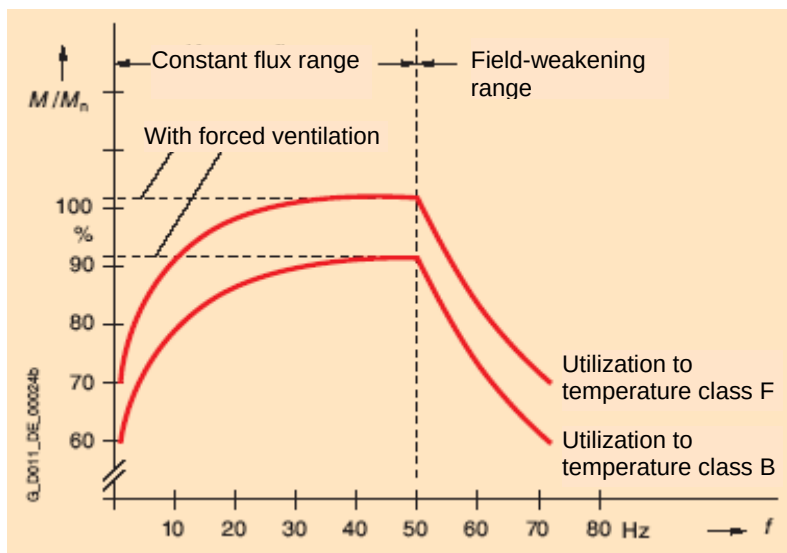
The following applies to selection of a suitable converter or Motor Module for drives with a quadratic load torque:

The rated current of the converter or Motor Module must be at least as high as the motor current at full torque in the required load point.

When Siemens standard asynchronous motors are used, these can be loaded with the full rated power even in converter-fed operation. They are then utilized according to temperature class F.

However, if the motors may only be used according to temperature class B, the motor output must be derated by 10 %. For motor types 1LA8 and 1PQ8 the derating is 15 %.

Selection of suitable motors and converters for a specific application is supported by the SIZER configuration tool.



Typical characteristic of the permissible torque with self-cooled motors
at a rated frequency of 50 Hz

Drives with constant load torque

The self-cooled motors cannot produce their full rated torque over the entire speed range in continuous operation. The continuous permissible torque decreases as the speed decreases because of the reduced cooling effect (see diagram above).

Depending on the speed range, the torque - and thus the output power - must be derated for self-cooled motors.

In the case of forced-ventilated motors, it is not necessary to reduce the output power, or only by a relatively small amount, depending on the speed range.

In the case of frequencies above rated frequency f_{rated} (50 Hz in the diagram), the motors are driven in the field weakening range. The useful torque drops approximately in proportion to the frequency ratio f_{rated}/f in case of asynchronous motors operating in this range. The output power remains constant.

It must be ensured that there is a sufficient margin of $\geq 30\%$ between the required torque and breakdown torque which decreases in proportion to the ratio $(f_{\text{rated}}/f)^2$. This applies particularly in V/f control mode.

The base load current of the converter or Motor Module should be selected at least as high as the motor current at full torque in the required load point.

Permissible motor-converter combinations

Rated motor current higher than the rated current of the converter or Motor Module

If the motor used has a higher rated current than the rated current of the converter or Motor Module, the motor will only be able to operate under partial load. The following limit applies:

The maximum possible short-time current of the converter or Motor Module (short-time current = $1.5 \cdot$ base load current) should be greater than or equal to the rated current of the connected motor.

It is important to observe this guideline, as very high, modulation-related current spikes caused by the low leakage inductance of large motors could otherwise occur. These can lead either to shutdown on over-current or, if the total RMS value of the motor current increases too far due to the high "current ripple", to a continuous reduction in output power as a result of limits imposed by internal protection mechanisms (overload reaction triggered by I^2t monitoring or thermal monitoring model).

Rated motor current significantly lower than the rated current of the converter or Motor Module

In typical applications with vector control (with or without speed encoder), the rated motor current should equal at least 25 % of the rated current of the converter or Motor Module. The greater the difference between the rated currents of motor and converter, the less accurate will be the actual current sensing circuit and the lower the quality of the vector control. For applications with very high control requirements which use a speed encoder and demand a very accurate vector control, it is advisable to select a motor rated current which equals at least 50 % of the rated current of the converter or Motor Module.

No restrictions of this type apply to V/f control mode. Motors with very low rated currents can operate on the converter. This applies, for example, to roller drive applications in which up to 100 small motors are supplied by a single converter in extreme cases.

Drives with permanent-magnet three-phase synchronous motors

With SINAMICS converters permanent-magnet, three-phase synchronous motors can also be used alongside three-phase asynchronous motors. These motors are available as motor series HT-direct 1FW4 as high-torque motors with high number of poles. They are designed for use with SINAMICS converters as low-speed direct drives and can replace favorably conventional motor-gearbox combinations. In addition to the motors of series HT-direct 1FW4, permanent-magnet synchronous motors made by other manufacturers can also be used with SINAMICS converters.

Closed-loop control of permanent-magnet synchronous motors

SINAMICS converters of type G130, G150, S120 and S150 have a closed-loop control function for permanent-magnet synchronous motors implemented in their firmware.

- SINAMICS G130 and G150 are designed for sensorless vector control. With these converters, regenerative energy cannot be returned to the supply system. For this reason, these drives are suitable only for standard applications with low requirements regarding dynamic performance and accuracy. If the drive has to be capable of flying restart, i.e. switching onto a rotating motor, a Voltage Sensing Module (VSM) must be integrated in the converter instead of an encoder module.
- SINAMICS S120 and S150 are designed for both, sensorless vector control and vector control with speed encoders. In addition, the servo control mode is available. With these converters, regenerative energy can be returned to the supply system. These drives are therefore suitable for use with demanding applications with the highest requirements in terms of dynamic performance and accuracy. Sensorless vector control is possible for simple, standard applications. Vector control with speed encoder is always required when high dynamic performance and accuracy are needed. The highest dynamic performance is achieved using the servo control mode.

Important current derating factors applicable to the converter

Pulse frequency derating

It is essential that SINAMICS converters, when used with permanent-magnet synchronous motors, must be operated with relatively high pulse frequency due to the eddy current losses in the magnets. Therefore, the factory-set pulse frequency of 1.25 kHz resp. 2.0 kHz must be increased, which causes a derating of the output current. The derating factors can be found in the corresponding tables of the unit-specific chapters.

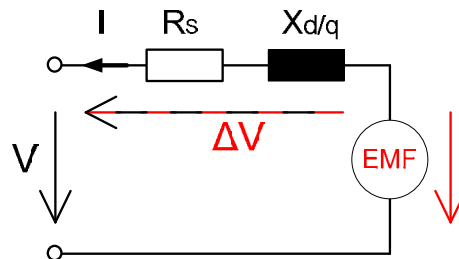
Synchronous motors of the series HT-direct 1FW4 require a pulse frequency of at least 2.5 kHz. Synchronous motors produced by other manufacturers often require even higher pulse frequencies of up to 4 kHz.

Derating in crawling mode with low speed resp. low converter output frequency

Water-cooled and externally-ventilated synchronous motors of series 1FW4 can be used for up to three hours in crawl mode with speeds close to zero. At these operating conditions, the converter can only deliver 50 % of its rated output current. If a higher current is required, the converter must be oversized.

Operation in the field weakening range

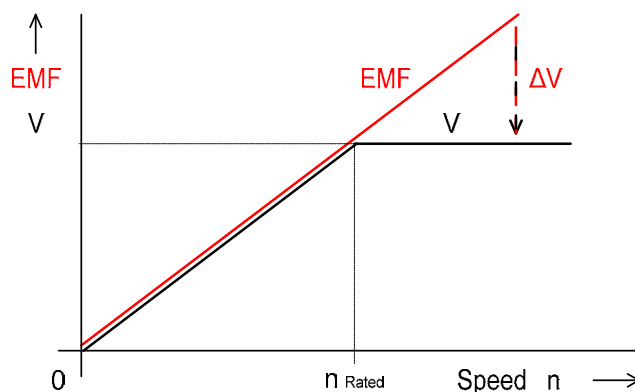
Permanent-magnet synchronous motors have a permanent magnetic field as a result of the magnets in the rotor. Thus, the motors produce a voltage, as soon as the rotor starts to turn. The EMF (Electro-Magnetical Force) induced in the stator winding as a result of the rotation of the rotor increases in proportion to the rotor speed. The following diagram shows the electrical circuit diagram (one phase) of a permanent-magnet synchronous motor.



Electrical diagram of a permanent-magnet synchronous motor

In the base speed range up to rated speed n_{Rated} , the output voltage V of the converter increases in proportion to the speed. As the EMF produced by the permanent magnets in the motor also increases in proportion to the speed, a balance exists between the output voltage V of the converter and the EMF of the motor.

From the rated speed n_{Rated} of the motor, the converter output voltage V remains constant because, with SINAMICS converters, it is limited to the value of the line supply voltage connected to the converter input. The EMF of the motor, however, still increases in proportion to the speed. In order to restore the balance between the constant converter output voltage V and the correspondingly higher EMF of the motor in the field-weakening range, a supplementary reactive current I must be delivered to the stator winding by the converter, in addition to the active current which produces the torque. This is to weaken the field induced by the rotor and to restore the voltage balance in the motor by producing the voltage drop ΔV . The higher the speed in field-weakening range, the larger the field-weakening reactive current must be. This reactive current must be considered at the dimensioning of the drive. At operation in high field-weakening range, a clear over-dimensioning of the drive may be required.



Converter output voltage V and EMF of the motor dependent on the speed

If the converter trips during operation in the field-weakening range, the reactive current I in the stator, which weakens the rotor field, is no longer present and therefore also the voltage drop ΔV . The voltage V at the motor terminals and at the converter output thus increases within a few 10 ms to the value of the EMF depending on the field-weakening speed of the motor. As a result, the DC link is charged via the freewheeling diodes of the inverter to the amplitude of the EMF of the motor.

Protection measures in the field-weakening range

In order that the maximum permissible DC link voltage is not exceeded and the DC link capacitors are not damaged in the event of a trip of the converter during operation in the field-weakening range, either the motor speed must be limited, or other suitable measures must be taken to ensure that the maximum permissible DC link voltage is not exceeded, e.g. by the use of an appropriately dimensioned Braking Module.

1. Limitation of the speed in the field-weakening range

With SINAMICS G130, G150, S120 (Chassis and Cabinet Modules) and S150 operating in vector control mode, the speed in the field-weakening range is limited to the value $n_{\max}$ by factory settings, in order to protect the converter.

$$n_{\max} = n_{\text{Rated}} \cdot \sqrt{\frac{3}{2} \cdot \frac{V_{\text{DC max}} \cdot I_{\text{Rated}}}{P_{\text{Rated}}}}$$

Key to abbreviations:

- $n_{\max}$ Maximum permissible speed in the field-weakening range for the protection of the converter
- n_{Rated} Rated motor speed
- I_{Rated} Rated motor current
- P_{Rated} Rated motor output power
- $U_{\text{DC max}}$ Maximum permissible DC link voltage of the converter or inverter in dependency on the line supply voltage:
 - 820 V for units with a line supply voltage of 380 V – 480 V 3AC
 - 1022 V for units with a line supply voltage of 500 V – 600 V 3AC
 - 1220 V for units with a line supply voltage of 660 V – 690 V 3AC

With synchronous motors of the series HT-direct 1FW4, the maximum permissible field-weakening speed is limited to 1.2 times the rated speed. Thus it lies within the limit defined in the given formula. With synchronous motors of other manufacturers, often much higher field-weakening speeds are permissible.

2. Use of a Braking Module

Until the introduction of firmware version V2.4 the maximum permissible speed $n_{\max}$ according to the above given formula was not changeable by means of parameterization. Since the introduction of firmware version V2.5, it is possible to increase the limit speed. However, the essential requirement for this is, that the drive is equipped with an appropriately dimensioned Braking Module in order to limit the DC link voltage in the event of a trip of the drive. With the implementation of this measure, field-weakening speeds up to 2.5 times faster than the rated speed can be achieved.

Protection concept

Since permanent-magnet synchronous motors with a rotating rotor are an active voltage source generating a voltage in proportion to the speed, it is not safe simply to disconnect the converter from the supply system and wait for the DC link to discharge before starting with maintenance or repair work. Additional measures must be taken to ensure that the rotating synchronous motor is not generating any voltage at the converter output. This can be achieved either by blocking the motor mechanically or, in cases where the type of application means that rotary movement of the motor cannot be completely precluded, by disconnecting the converter from the motor by a switch at the output side of the converter.

It is generally not safe to perform any maintenance or repair work on the motor terminal box or the motor cable, until measures have been taken to preclude any risk of rotor movement, the supplying converter is reliably disconnected from the supply system and the converter DC link is discharged.

Guide for selecting a drive system comprising an HT-direct motor and a SINAMICS converter

The following example explains all the individual steps which must be taken to design a drive system:

1st step	Technical requirements of the motor (example data)		Further notes and alternatives
Determine the required product profile This is, for example:	Torque in continuous duty ($M_{cont.}$)	16 000 Nm	
	Short-time overload torque ($M_{overload}$)	18 000 Nm	$M_{overload} / M_{cont.} < 1.5$: Rated torque = $M_{cont.}$ $M_{overload} / M_{cont.} > 1.5$: Rated torque = $M_{overload} / 1.5$ Higher overloads on request.
	Mode of operation	S1	When, instead of S1 duty, load duty cycles must be taken into account: Average torque is calculated from the root of the square of the required torques multiplied by the time divided by the total time: e.g. 140 %, 10 seconds, then 80 %, 30seconds, results in an average 98.5 % of the rated torque: $\sqrt{[(1.40^2 \times 10 + 0.80^2 \times 30) / 40]} = 0.985$
	Utilization	Temperature Class 155 (previously temperature class F)	In case of use according to temperature class 130 (previously temperature class B), the motor must be designed for a torque 20 % higher: (e.g. $M_{cont.} = 1.2 \times 16\,000 = 19\,200$ Nm)
	Rated voltage	690 V	Alternatively 400 V or 460 V
	Max. speed in continuous operation	765 rpm	Rated speed according to catalog D86.2: 800 rpm, max. permissible speed 20 % higher ($800 \times 1.2 = 960$ rpm)
	Cooling	Water with max. inlet temperature 25°C	Allowance must be made for higher cooling-water inlet temperatures using derating factors when the rated torque is determined: e.g. for 35°C: $16\,000 / 0.95 = 16\,840$ Nm See catalog D86.2 / page 30 for derating factors.
	Construction type	IM B3	
2nd step	Environmental requirements of the motor		Further notes and alternatives
Determine the installation conditions	Ambient temperature	-20 to +40 °C	At ambient temperatures up to +40°C, derating factors are not required for water-cooled motors. At higher ambient temperatures in combination with cooling-water inlet temperatures above 25 °C, the derating factors in catalog D86.2 / page 30 apply. For air-cooled motors, the derating factors defined in catalog D86.2 / Chapter 3 must be applied.
	Installation altitude	< 1000 m	For water-cooled motors, the installation altitude is not relevant with respect to derating factors. For installation altitudes > 1000 m above sea level, the conditions of the converter must however be taken into account. For air-cooled motors, the derating factors defined in catalog D86.2 / Chapter 3 must be applied.
3rd step	Motor selection		Further notes and alternatives
Determine the motor Order No.	1FW4453-1HF70-1AA0		See "Selection and ordering data" catalog D86.2 / Chapter 2. Due to the current-carrying capability of the motor terminal box (max. 1230 A), the motor is designed with two terminal boxes and two electrically isolated winding systems.
4th step	Option selection		Further notes and alternatives
Complete the motor Order No.	Define options for special versions and tests.		See "Special versions" catalog D86.2 / Chapter 2.

Drive Dimensioning

Engineering Information

5th step	Motor current calculation		Further notes and alternatives
Motor currents	Motor rated current for torque of 16 000 Nm in continuous duty at 690 V	1416 A	See "Selection and ordering data" catalog D86.2 / Chapter 22. $(16\,500/16\,000) \times 1416 = 1460\text{ A}$
	Required motor current for max. torque of 18 000 Nm (brief overload torque)	1593 A	$(18\,000 / 16\,000) \times 1416 = 1593\text{ A}$
6th step	Selection of the converter or the S120 Motor Module		Further notes and alternatives
Select the SINAMICS S120 system	Rated output current I_{rated}	$\geq 1593\text{ A}$	
	Due to the amperage of 1593 A, the current must be distributed between two Motor Modules.	797 A per Motor Module	$1593/2 = 797\text{ A}$
	Derating factor for two parallel Motor Modules	0.95	See section "Parallel connections of converters" in this engineering manual
	Current required per Motor Module	840 A	$797/0.95 = 840\text{ A}$
	Intermediate result for Motor Module selection	910A, 900 kW	
	Derating factor for increasing the pulse frequency to 2.5 kHz for the 900 kW Motor Module	0.87	The derating factors are dependent on the converter type and converter output. They can be found in the chapters on specific unit types in this engineering manual.
	Max. output current of both Motor Modules	1504 A (too low, because 1593 A is needed!)	$2 \times 910\text{ A} \times 0.95 \times 0.87 = 1504\text{ A}$
	Selection of the next largest Motor Module	1025 A, 1000 kW	
	Derating factor for increasing the pulse frequency to 2.5 kHz for the 1000 kW Motor Module	0.86	The derating factors are dependent on the converter type and converter output. They can be found in the chapters on specific unit types in this engineering manual.
	Max. output current of both Motor Modules	1675 A (sufficient)	$2 \times 1025\text{ A} \times 0.95 \times 0.86 = 1675\text{ A}$
	SINAMICS S120 Vector Control: 2 Single Motor Modules Order No. 6SL3320-1TH41-0AA0		The relevant Infeed must be selected as well.
	SINAMICS S120 Cabinet Modules: 2 Motor Modules Order No. 6SL3720-1TH41-0AA0		The relevant Infeed must be selected as well.

7th step	Definition of the protection system	Further notes and alternatives
A protection system must be defined when work has to be carried out on the converter and/or cables after power OFF when the rotor is still revolving.	The protection system depends on the operating conditions and application.	See above or catalog D86.2 / Chapter 1: "Converter-fed operation"

Guide for designing a drive with an HT-direct motor and a SINAMICS converter

Motors

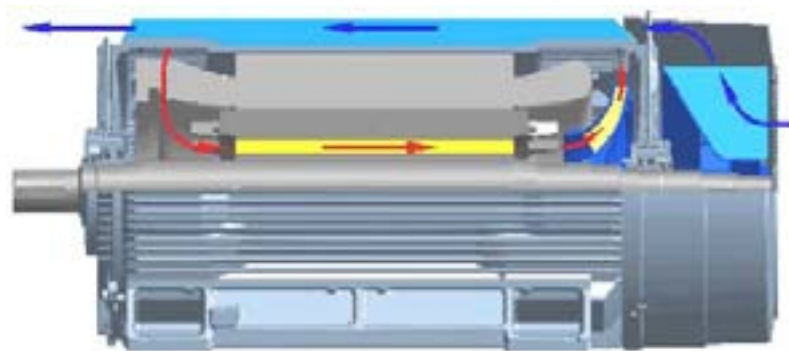
Engineering Information

Motors

We generally recommend the use of the successful Siemens standard asynchronous motors of types 1LA and 1LG for standard applications. For more detailed information about motor series 1LG4/1LG6 and 1LA8, please refer to catalog D81.1.

1LG4/1LG6 and 1LA8 self-cooled asynchronous motors

1LG4/1LG6 and 1LA8 asynchronous motors are self-cooled motors with IP55 degree of protection. They are designed with an internal and an external cooling system. Both the internal and external fans (which are fitted in each motor) are permanently coupled to the shaft. The cooling effect is therefore directly dependent on the motor speed.



Internal and external cooling circuits on self-cooled motors of type 1LG4/1LG6 and 1LA8

1PH7/ 1PL6 compact asynchronous motors

In addition to the 1LA and 1LG motors, it is also possible to use 1PH7/1PL6 compact asynchronous motors in the voltage range up to 415 V. These are recommended for applications at

- wide speed ranges with high maximum speeds
- limited mounting space.

1PH7/1PL6 motors with the same rated power are on average 1 to 2 shaft heights smaller than comparable standard asynchronous motors.

With converter chassis units SINAMICS G130 and converter cabinet units SINAMICS G150 it is only possible to use the Sensor Module SMC30. Therefore, only TTL/HTL incremental encoders can be used when these motors are operated by SINAMICS G130 and G150.

1FW3 / 1FW4 three-phase synchronous motors (high-torque motors with permanent magnets)

In addition to the three-phase asynchronous motors, three-phase synchronous motors of types 1FW3 and 1FW4 are also available as high-torque motors with permanent magnets for converter-fed operation on SINAMICS units. These are recommended for applications with

- high torques
- low speeds
- low-maintenance operation

which require

- a compact design
- high availability

and

- high efficiency
- rugged design
- low noise generation

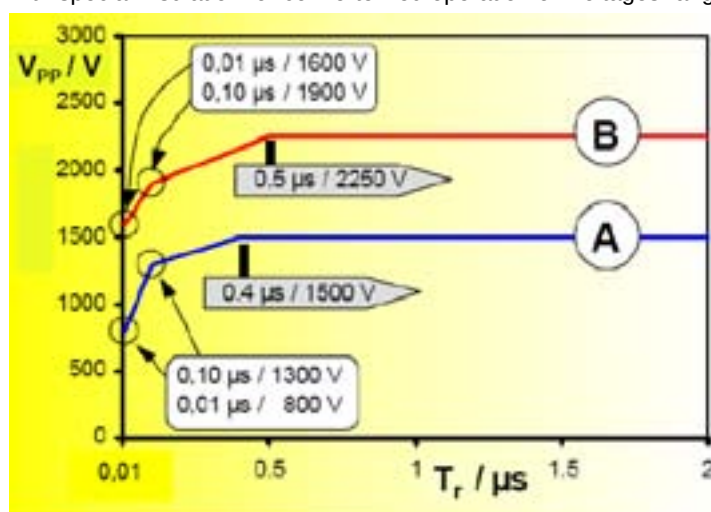
Special insulation for line supply voltages > 500 V in converter-fed operation

The standard insulation of the 1LA and 1LG motors is designed such that unrestricted operation on a SINAMICS converter is possible only on line supply voltages up to 500 V +10 %. Motors operating on higher line supply voltages require stronger insulation. Alternatively, filters such as the dv/dt filter or sine-wave filter must be provided at the converter output.

Asynchronous motors of types 1LA8 / 1PQ8 and 1LG6 are also available with special insulation for converter-fed operation on line supply voltages from > 500 V to 690 V, which means that no filters need to be provided at the converter output. These motors are identified by an "M" in the 10th position of the order number, e.g. 1LA8315-2PM80.

Synchronous motors of type 1FW4 are designed specifically for converter operation and therefore feature special insulation as standard.

The diagram and the table below show the permissible voltage limits for motors with standard insulation and for those with special insulation for converter-fed operation on voltages ranging from > 500 V to 690 V.



Permissible limit values V_{PP} for Siemens insulation systems:

- A: Standard insulation
B: Special insulation

Winding insulation	Line supply voltage V_{Line}	Phase-to-phase V_{PP} permissible	Phase-to-earth V_{PE} permissible	DC link voltage V_{DCLink} permissible
A = standard insulation	≤ 500 V	1500 V	1100 V	750 V +10 %
B = special insulation	> 500 V to 690 V	2250 V	1500 V	1125 V +10 %

Permissible voltage limits for Siemens low-voltage motors with round-wire windings up to 690 V

In comparison to standard insulation, the ratio between insulation material and copper within a single slot is less favorable with the special insulation, causing a slight reduction in the rated output of motors with special insulation.

Bearing currents

The fast-switching IGBTs in the inverter cause steep voltage edges which generate bearing currents in the motor. Under unfavorable conditions, these currents can reach relatively high values, cause damage to the bearing and therefore reduce its lifetime.

To prevent damage caused by bearing currents, it is advisable to provide an insulated bearing at the non-drive end (NDE) of motors operating on a converter supply. The insulated NDE bearing is standard on all 1LA8 motors that are designated as suitable for converter operation (9th position of order no. = "P", e.g. 1LA8315-2PM80). Insulated NDE bearings are available for 1LG4/1LG6 motors of frame size 225 and above as option L27. The use of this option is highly recommended at converter operation.

In systems with speed encoders, it must be ensured that the encoder is not installed in such a way that it bridges the bearing insulation, i.e. the encoder mounting must be insulated or an encoder with insulated bearings must be used.

For further information, please refer to the section "Bearing currents caused by steep voltage edges on the motor" of the chapter "Fundamental Principles and System Description".

Motors

Engineering Information

Motor protection

The motor can be protected against overloading by the I^2t monitoring function integrated in the SINAMICS firmware. This prevents operation at excessive motor currents.

More precise motor protection, which also takes into account the influence of the ambient temperature, is possible using direct temperature detection with KTY84 sensors or PTC thermistors in the motor winding.

To order the KTY84 sensors for motors of type 1LA8/1LA4 and 1LG4/1LG6, motor option A23 must be specified in the order. The sensors are fitted as standard in 1PH7 and 1PL6 motors.

If PTC thermistors are required, option A11 (for tripping) or A12 (for alarm) must be specified in the order for motors of type 1LG4/1LG6. With 1LA8/1PQ8 motors, the sensors are fitted as standard.

An evaluation unit for the KTY84 and/or PTC sensors can be connected to the customer terminal block in cabinets G150 and S150. The connection must be made to terminal –X41 of the Power Module of G130 Chassis.

PT100 temperature sensors (resistance thermometers) for monitoring the motor winding temperature are available as an alternative for 1LA8 and 1LG4/1LG6 motors. In this case, option A60 (3 x PT100) or A61 (6 x PT100) must be selected in the motor order.

A separate evaluation unit is available (option L86) for evaluation of the PT100 temperature sensors in the SINAMICS G150 and S150 cabinets.

With 1MJ flameproof motors, PTB-approved PTC thermistors and tripping devices are absolutely mandatory. These are available for SINAMCS G150 and S150 cabinets as option L83 (for alarm) and L84 (for shutdown).

Operation of explosion proof motors with type of protection "d"

Siemens 1MJ asynchronous motors can be connected as explosion-proof motors with flameproof enclosure EEx de IIC both to the mains supply and the converter.

The relevant directives specify that 1MJ motors must be equipped with PTC thermistors.

If 1MJ motors are connected to converters, their maximum permissible torque must be reduced, depending on the load characteristic, for utilization according to temperature class B, in exactly the same way as 1LA motors with the same output.

1MJ motors have a terminal box with "increased safety" EEx e II as standard.

For detailed motor data, please refer to catalog D81.1.

Dimension Drawings

Engineering Information

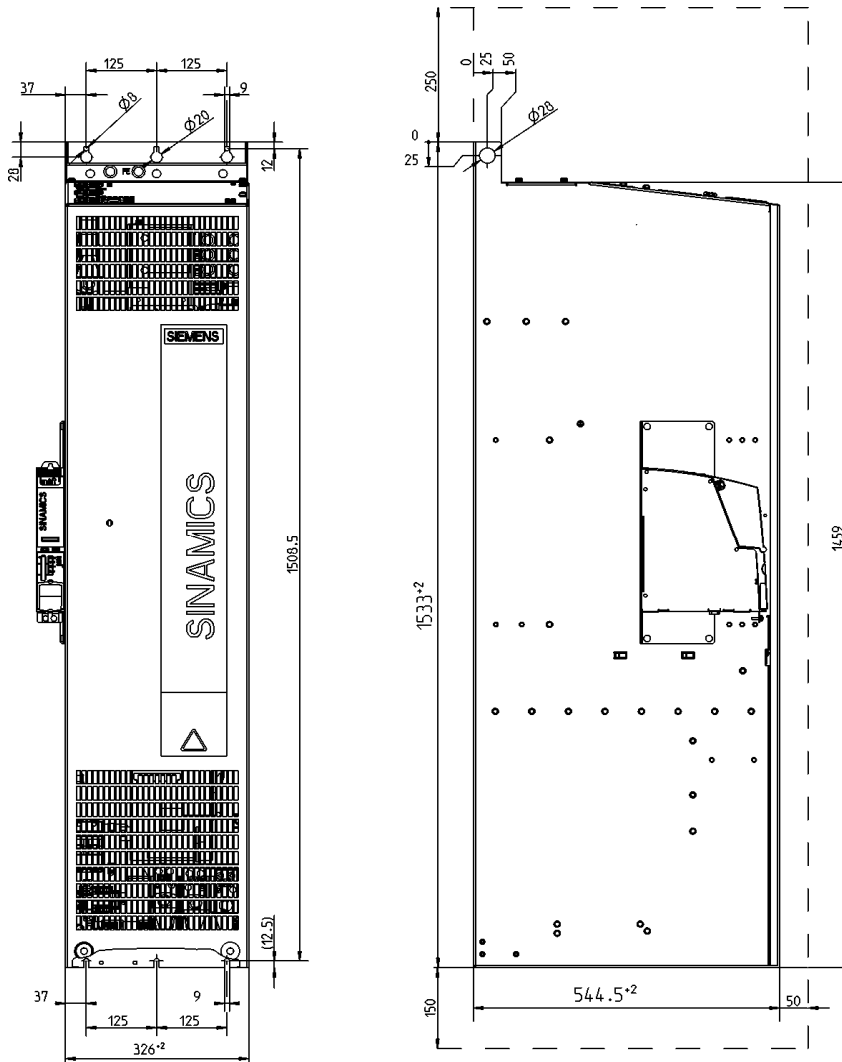
SINAMICS G130, continued

Dimension drawing 2, frame size GX:

380 V to 480 V 160 – 250 kW

500 V to 600 V 110 – 200 kW

660 V to 690 V 160 – 315 kW



Front view

Side view

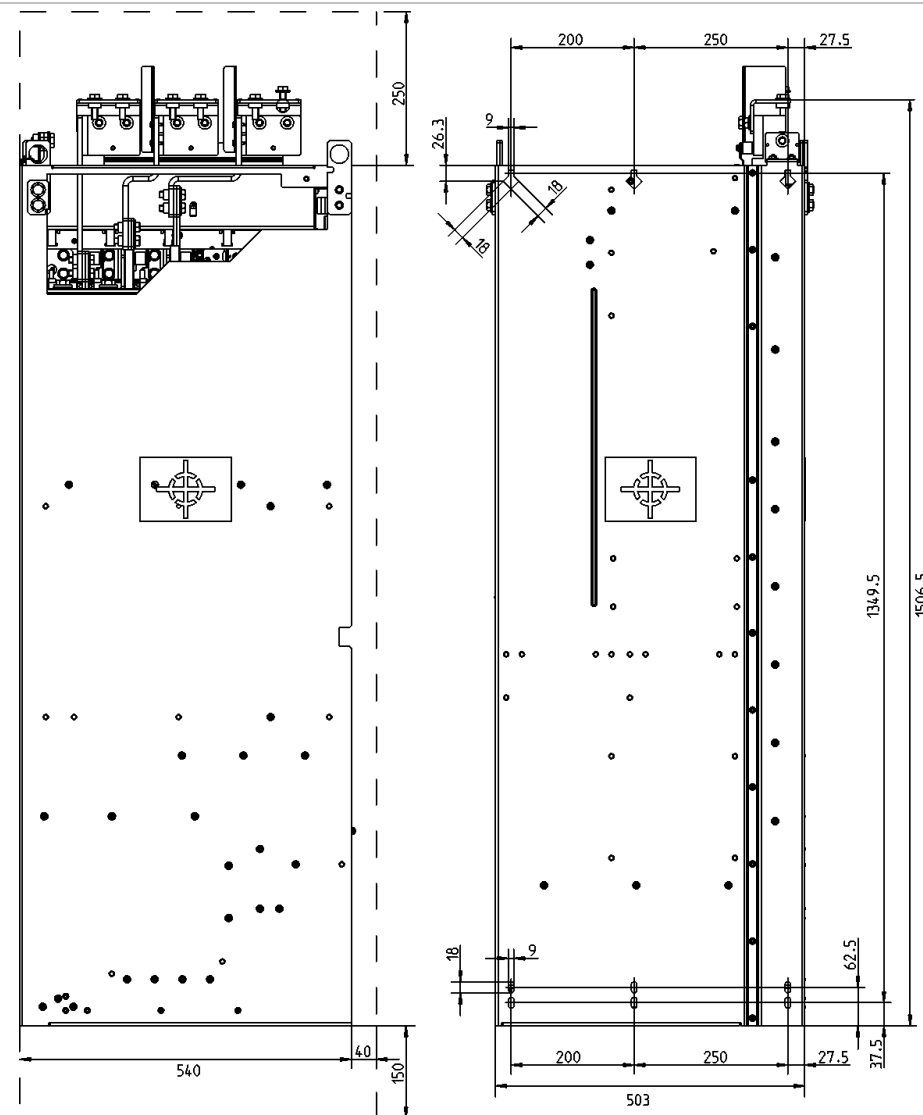
Required clearance for ventilation - - - - -

Line supply connection			Motor connection			Grounding			
Max. connection cross-section		M10 screw	Max. connection cross-section		M10 screw		Max. connection cross-section		M10 screw
DIN VDE mm²	NEC, CEC AWG/MCM	(No. of holes)	DIN VDE mm²	NEC, CEC AWG/MCM	(No. of holes)		DIN VDE mm²	NEC, CEC AWG/MCM	(No. of holes)
2 x 240	2 x 500 MCM	(1)	2 x 240	2 x 500 MCM	(1)	PE1	2 x 240	2 x 500 MCM	(2)
						PE2	2 x 240	2 x 500 MCM	(2)

SINAMICS G130, continued

Dimension drawing 3, frame size HX:

380 V to 480 V	315 - 450 kW
500 V to 600 V	250 - 400 kW
660 V to 690 V	400 - 560 kW



Side view

Rear view

Required clearance for ventilation - - - - -

Line supply connection			Motor connection			Grounding			
Max. connection cross-section		M12 screw	Max. connection cross-section		M12 screw		Max. connection cross-section		M12 screw
DIN VDE mm²	NEC, CEC AWG/MCM	(No. of holes)	DIN VDE mm²	NEC, CEC AWG/MCM	(No. of holes)		DIN VDE mm²	NEC, CEC AWG/MCM	(No. of holes)
4 x 240	4 x 500 MCM	(2)	4 x 240	4 x 500 MCM	(2)	PE1	2 x 240	2 x 500 MCM	(1)
						PE2	4 x 240	4 x 500 MCM	(2)

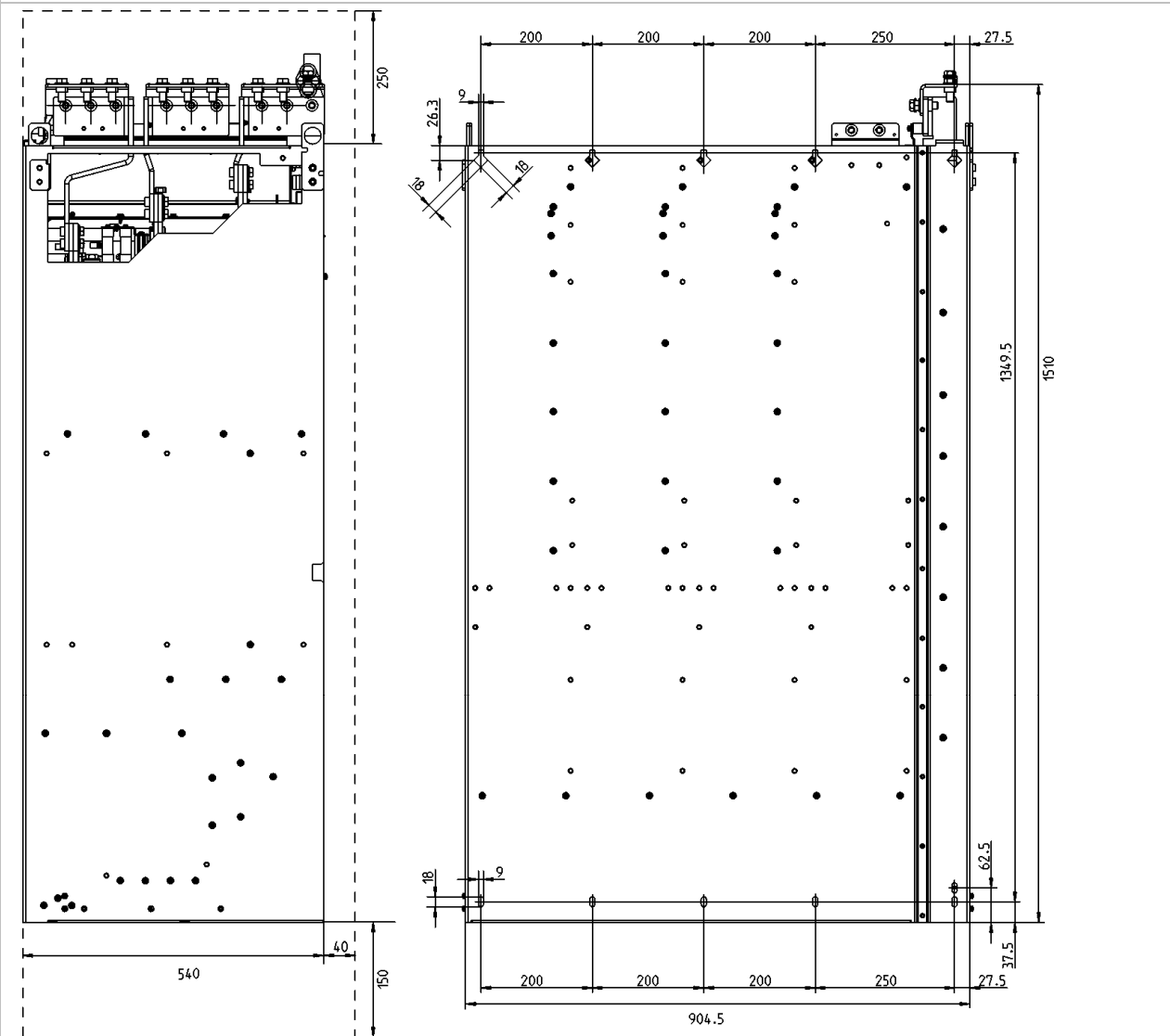
Dimension Drawings

Engineering Information

SINAMICS G130, continued

Dimension drawing 4, frame size JX:

380 V to 480 V 560 kW
 500 V to 600 V 500 - 560 kW
 660 V to 690 V 710 - 800 kW



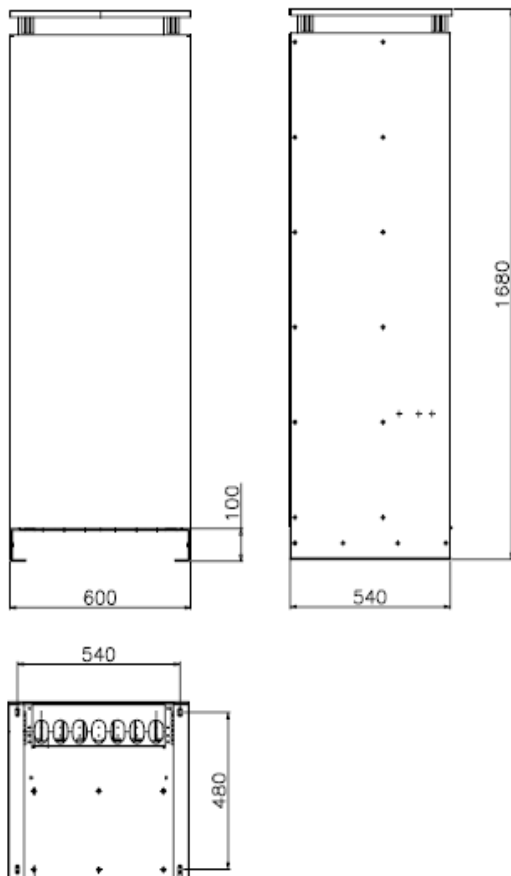
Side view				Rear view					
Required clearance for ventilation - - - - -									
Line supply connection				Motor connection			Grounding		
Max. connection cross-section		M12 screw	Max. connection cross-section		M12 screw		Max. connection cross-section		M12 screw
DIN VDE mm²	NEC, CEC AWG/MCM	(No. of holes)	DIN VDE mm²	NEC, CEC AWG/MCM	(No. of holes)		DIN VDE mm²	NEC, CEC AWG/MCM	(No. of holes)
6 x 240	6 x 500 MCM	(3)	6 x 240	6 x 500 MCM	(3)	PE1	4 x 240	4 x 500 MCM	(2)
						PE2	6 x 240	6 x 500 MCM	(3)

SINAMICS Line Harmonics Filter

Dimension drawing 1:

380 V to 480 V
500 V to 690 V

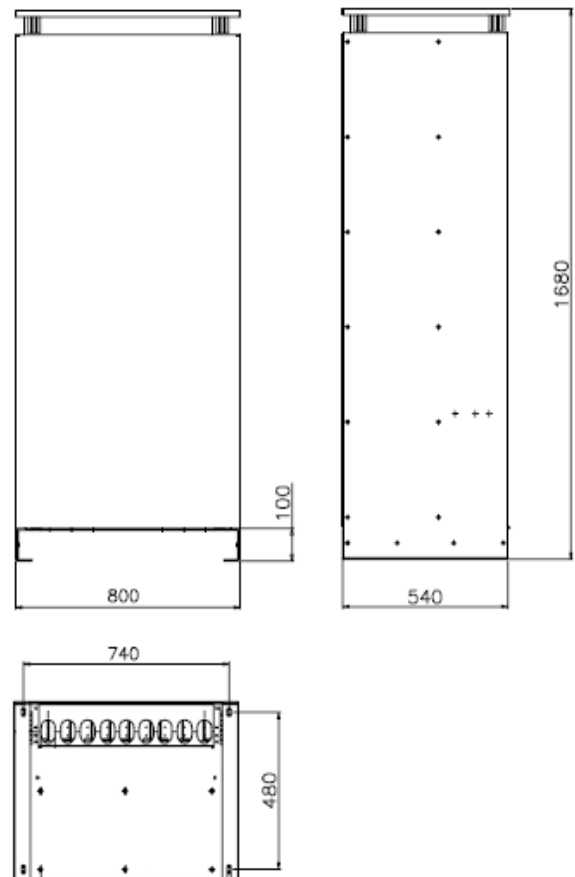
315 kW
315 kW



Dimension drawing 2:

380 V to 480 V
500 V to 690 V

450 kW
450 kW



Line supply connection			Motor connection			Grounding	
Max. connection cross-section		M12 screw	Max. connection cross-section		M12 screw	Fastening bolt M12	
DIN VDE mm ²	NEC, CEC AWG/MCM	(No. of holes)	DIN VDE mm ²	NEC, CEC AWG/MCM	(No. of holes)	(No. of bolts)	
2 x 240	2 x 500 MCM	(2)	2 x 240	2 x 500 MCM	(2)	(3)	

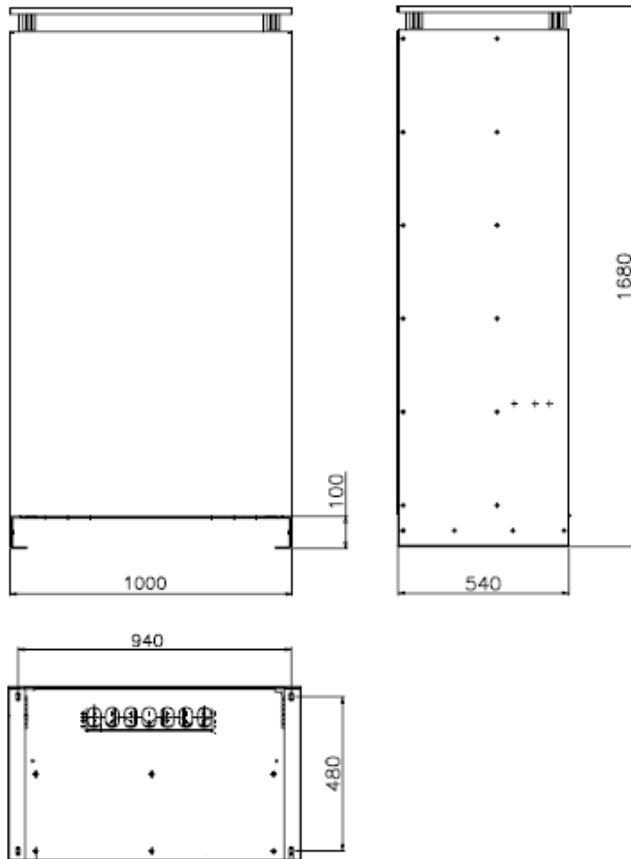
Dimension Drawings

Engineering Information

SINAMICS Line Harmonics Filter, continued

Dimension drawing 3:

380 V to 480 V 560 kW
500 V to 690 V 560 - 800 kW



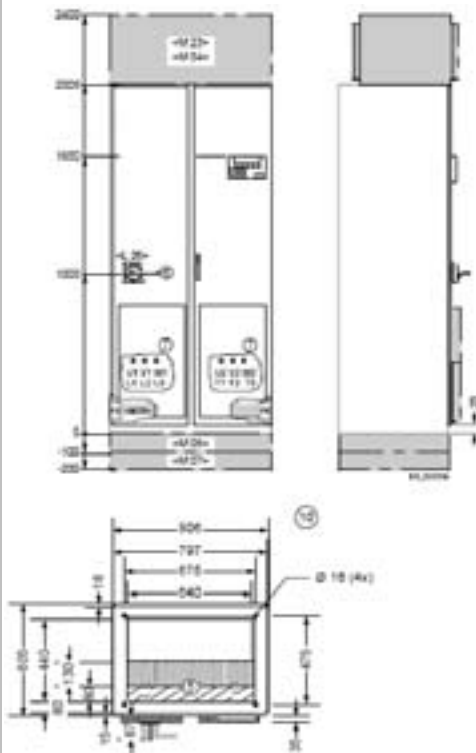
Line supply connection			Motor connection			Grounding	
Max. connection cross-section		M12 screw	Max. connection cross-section		M12 screw	Fastening bolt M12	
DIN VDE mm ²	NEC, CEC AWG/MCM	(No. of holes)	DIN VDE mm ²	NEC, CEC AWG/MCM	(No. of holes)	(No. of bolts)	
2 x 240	2 x 500 MCM	(2)	2 x 240	2 x 500 MCM	(2)	(3)	

SINAMICS G150 (type A)

Dimension drawing 1:

380 V to 480 V	110 - 160 kW
500 V to 600 V	110 - 200 kW
660 V to 690 V	75 - 315 kW

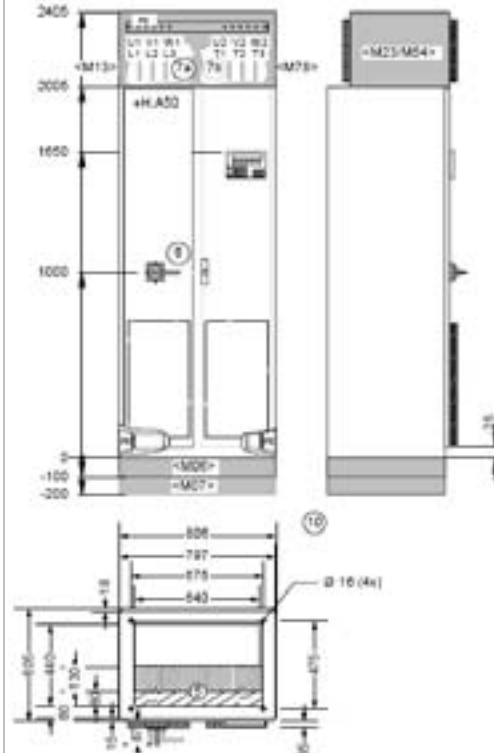
Power supply connection from below, motor connection from below



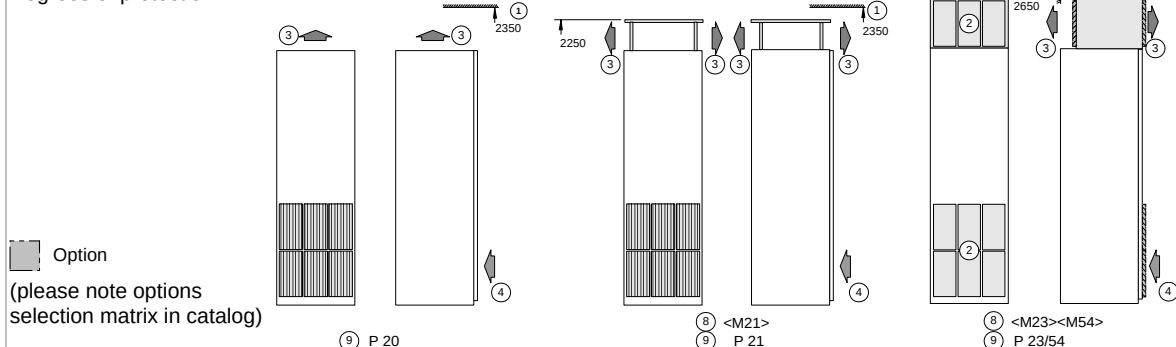
Dimension drawing 2:

380 V to 480 V	110 - 160 kW
500 V to 600 V	110 - 200 kW
660 V to 690 V	75 - 315 kW

Power supply connection from above, motor connection from above



Degrees of protection:



Legend:

- Minimum ceiling height for wall mounting
- Ventilation grid
- Air outlet area
- Air inlet area
- Cables can enter from below within hatched area
- Main circuit breaker, can be secured by padlock (option)
- Power connection (7a: power supply, 7b: motor)
- Degree of protection option
- Degree of protection IP20

IP21	Option <M21>
IP23	Option <M23>
IP43	Option <M43>
IP54	Option <M54>
- Transport unit

Dimension Drawings

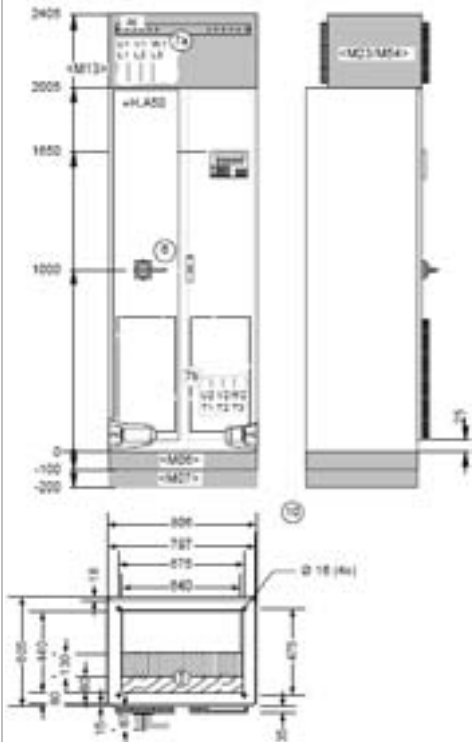
Engineering Information

SINAMICS G150 (type A), continued

Dimension drawing 3:

380 V to 480 V 110 - 160 kW
 500 V to 600 V 110 - 200 kW
 660 V to 690 V 75 - 315 kW

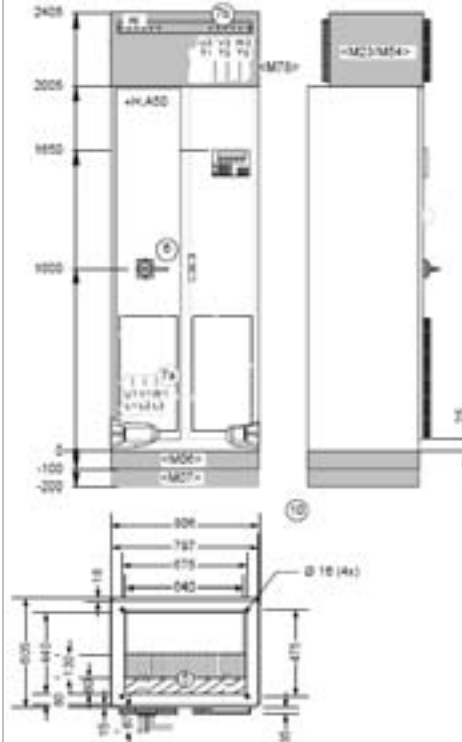
Power supply connection from above, motor connection from below



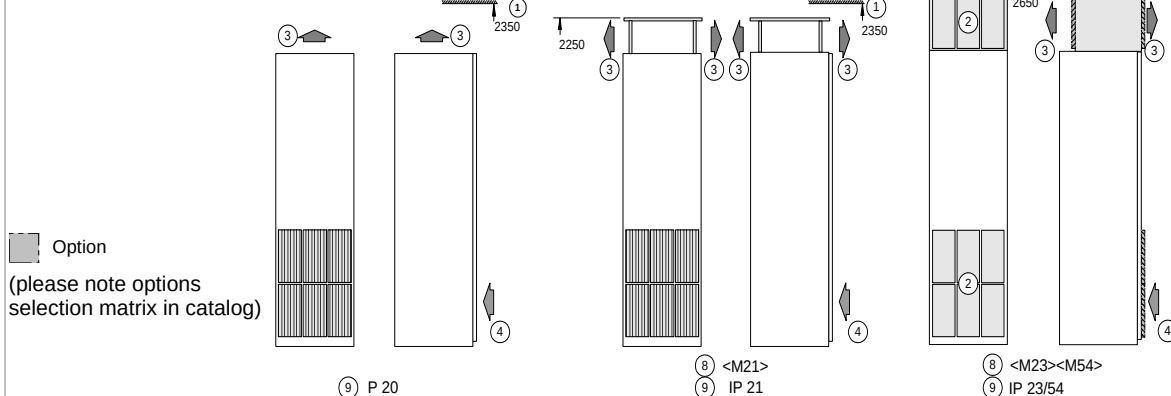
Dimension drawing 4:

380 V to 480 V 110 - 160 kW
 500 V to 600 V 110 - 200 kW
 660 V to 690 V 75 - 315 kW

Power supply connection from below, motor connection from above



Degrees of protection:



Legend:

1. Minimum ceiling height for wall mounting	7. Power connection (7a: power supply, 7b: motor)
2. Ventilation grid	8. Degree of protection option
3. Air outlet area	9. Degree of protection IP20
4. Air inlet area	IP21 Option <M21>
5. Cables can enter from below within hatched area	IP23 Option <M23>
6. Main circuit breaker, can be secured by padlock (option)	IP43 Option <M43>
	IP54 Option <M54>
	10. Transport unit

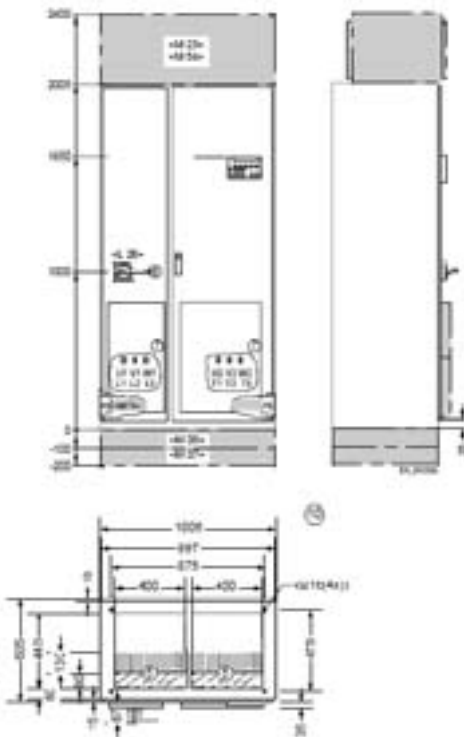
SINAMICS G150 (type A), continued

Dimension drawing 5:

380 V to 480 V

200 - 250 kW

Power supply connection from below, motor connection from below

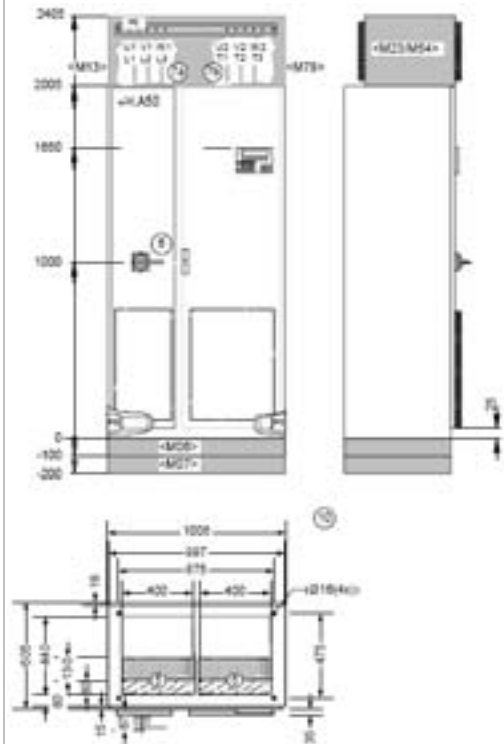


Dimension drawing 6:

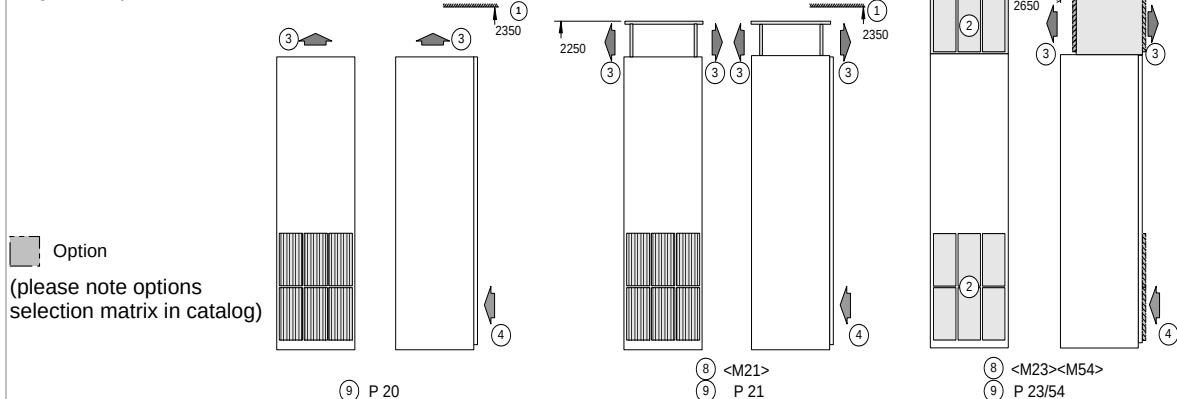
380 V to 480 V

200 - 250 kW

Power supply connection from above, motor connection from above



Degrees of protection:



Legend:

1. Minimum ceiling height for wall mounting	7. Power connection (7a: power supply, 7b: motor)
2. Ventilation grid	8. Degree of protection option
3. Air outlet area	9. Degree of protection IP20
4. Air inlet area	IP21 Option <M21>
5. Cables can enter from below within hatched area	IP23 Option <M23>
6. Main circuit breaker, can be secured by padlock (option)	IP43 Option <M43>
	IP54 Option <M54>
	10. Transport unit

Dimension Drawings

Engineering Information

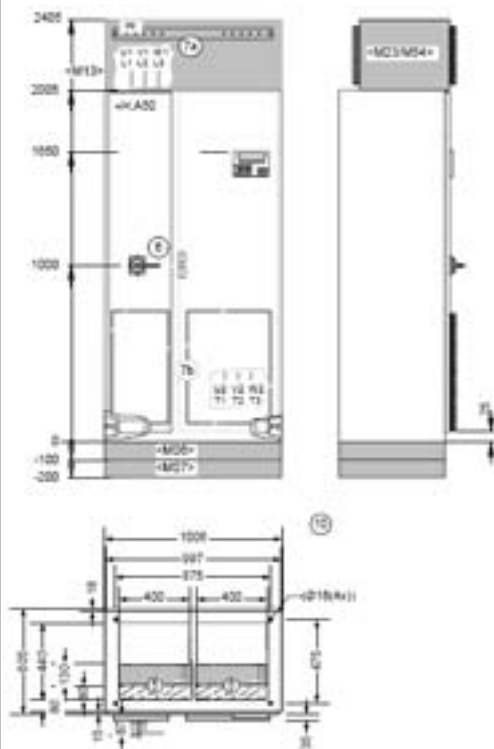
SINAMICS G150 (type A), continued

Dimension drawing 7:

380 V to 480 V

200 - 250 kW

Power supply connection from above, motor connection from below

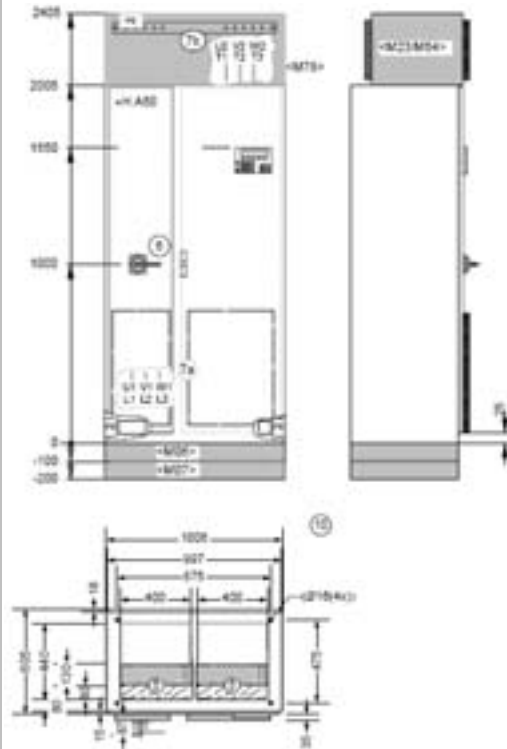


Dimension drawing 8:

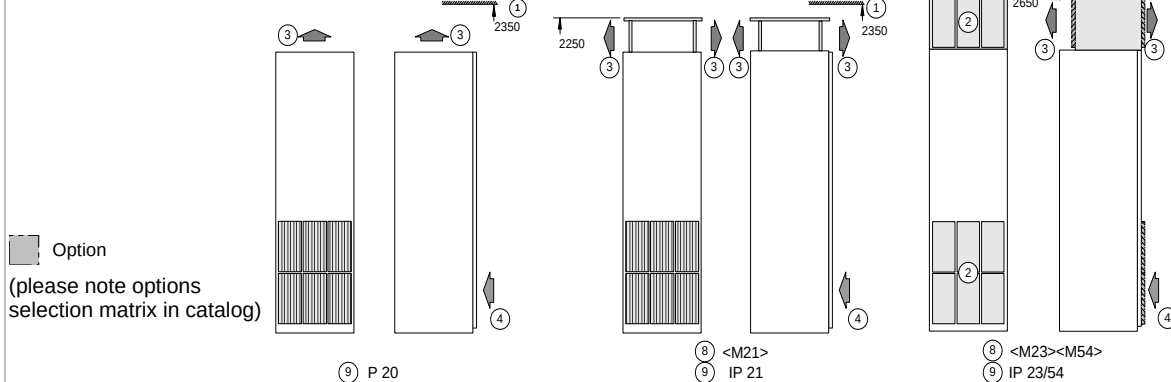
380 V to 480 V

200 - 250 kW

Power supply connection from below, motor connection from above



Degrees of protection:



Legend:

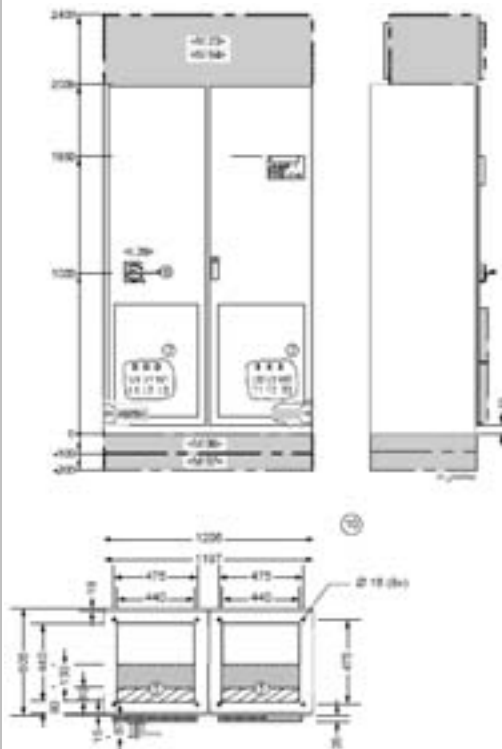
1. Minimum ceiling height for wall mounting	7. Power connection (7a: power supply, 7b: motor)
2. Ventilation grid	8. Degree of protection option
3. Air outlet area	9. Degree of protection IP20
4. Air inlet area	IP21 Option <M21>
5. Cables can enter from below within hatched area	IP23 Option <M23>
6. Main circuit breaker, can be secured by padlock (option)	IP43 Option <M43>
	IP54 Option <M54>
	10. Transport unit

SINAMICS G150 (type A), continued

Dimension drawing 9:

380 V to 480 V 315 kW
 500 V to 600 V 250 - 400 kW
 660 V to 690 V 400 - 560 kW

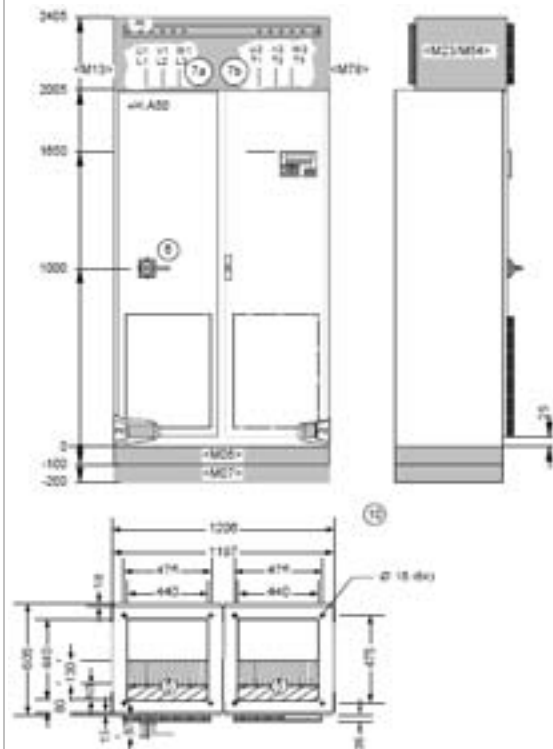
Power supply connection from below, motor connection from below



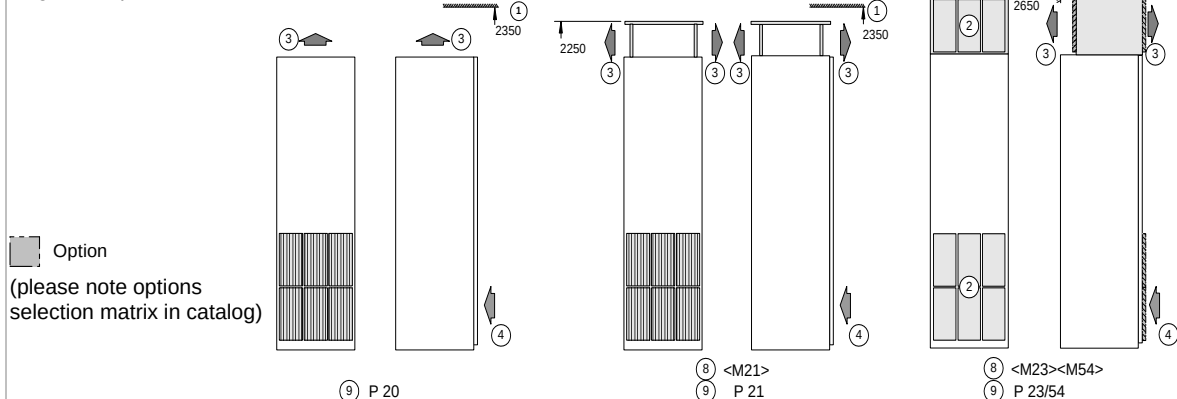
Dimension drawing 10:

380 V to 480 V 315 kW
 500 V to 600 V 250 - 400 kW
 660 V to 690 V 400 - 560 kW

Power supply connection from above, motor connection from above



Degrees of protection:



Legend:

1. Minimum ceiling height for wall mounting	7. Power connection (7a: power supply, 7b: motor)
2. Ventilation grid	8. Degree of protection option
3. Air outlet area	9. Degree of protection IP20
4. Air inlet area	Option <M21>
5. Cables can enter from below within hatched area	IP21
6. Main circuit breaker, can be secured by padlock (option)	IP23
	Option <M23>
	IP43
	Option <M43>
	IP54
	Option <M54>
	10. Transport unit

Dimension Drawings

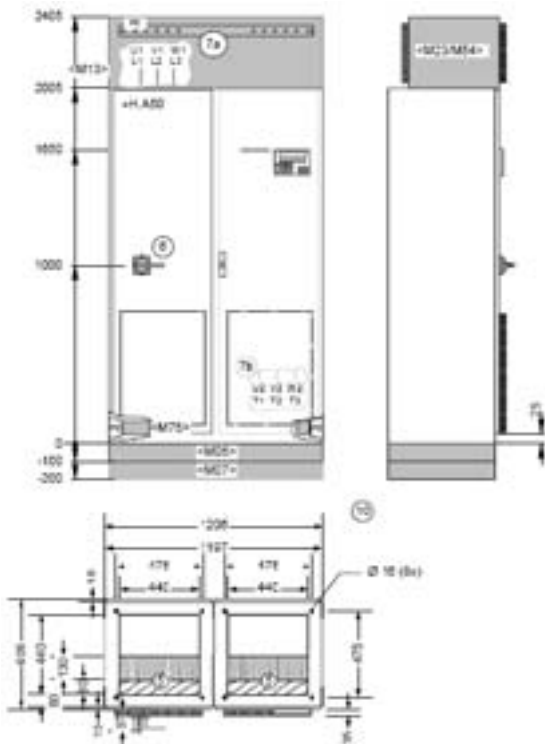
Engineering Information

SINAMICS G150 (type A), continued

Dimension drawing 11:

380 V to 480 V 315 kW
 500 V to 600 V 250 - 400 kW
 660 V to 690 V 400 - 560 kW

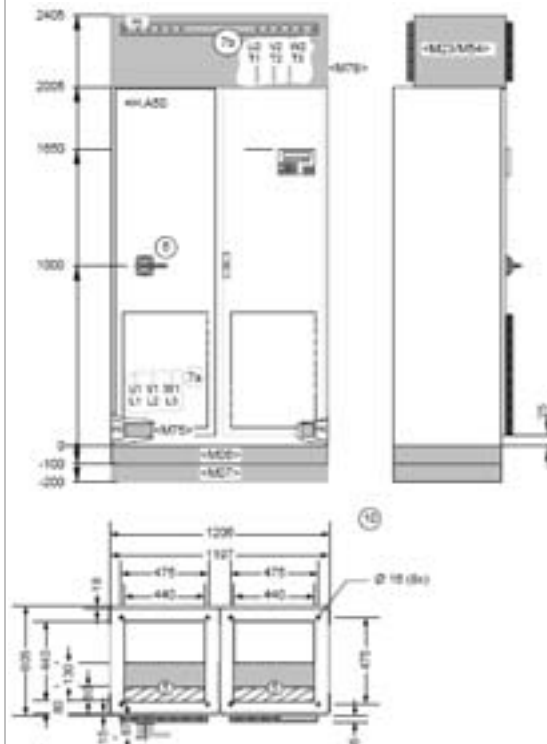
Power supply connection from above, motor connection from below



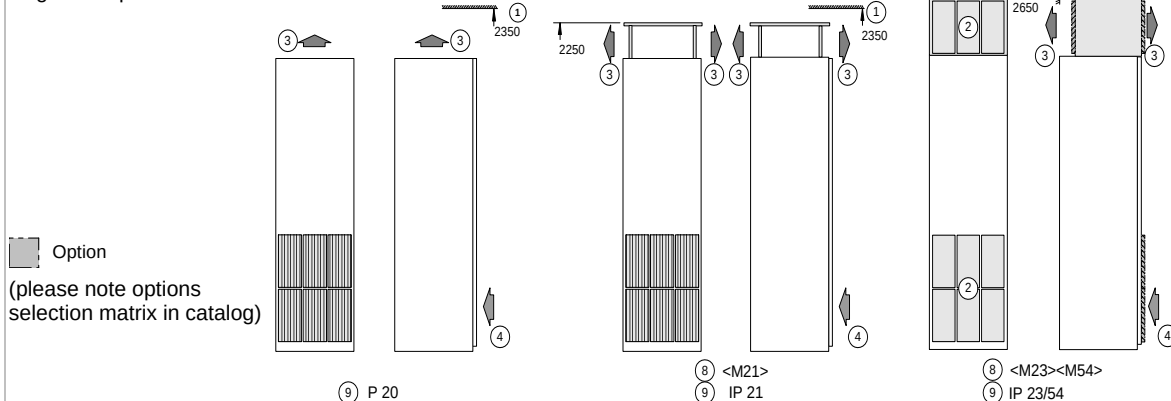
Dimension drawing 12:

380 V to 480 V 315 kW
 500 V to 600 V 250 - 400 kW
 660 V to 690 V 400 - 560 kW

Power supply connection from below, motor connection from above



Degrees of protection:



Legend:

- Minimum ceiling height for wall mounting
- Ventilation grid
- Air outlet area
- Air inlet area
- Cables can enter from below within hatched area
- Main circuit breaker, can be secured by padlock (option)
- Power connection (7a: power supply, 7b: motor)
- Degree of protection option
- Degree of protection IP20
 IP21 Option <M21>
 IP23 Option <M23>
 IP43 Option <M43>
 IP54 Option <M54>
- Transport unit

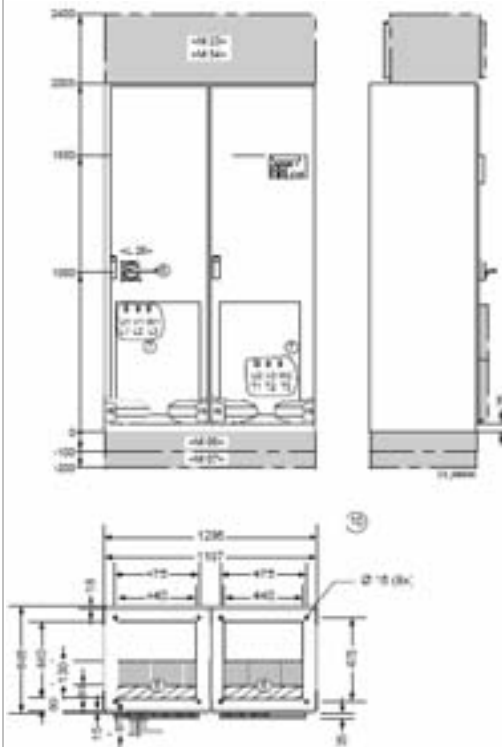
SINAMICS G150 (type A), continued

Dimension drawing 13:

380 V to 480 V

400 - 450 kW

Power supply connection from below, motor connection from below

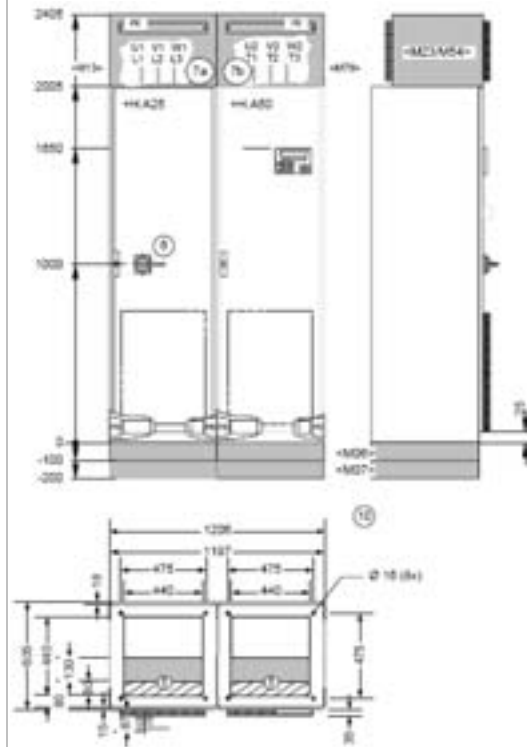


Dimension drawing 14:

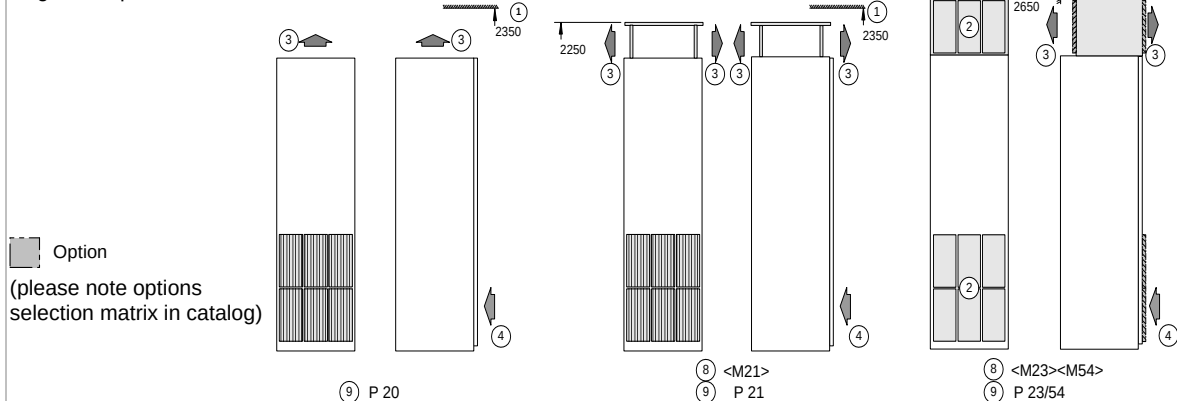
380 V to 480 V

400 - 450 kW

Power supply connection from above, motor connection from above



Degrees of protection:



Legend:

1. Minimum ceiling height for wall mounting	7. Power connection (7a: power supply, 7b: motor)
2. Ventilation grid	8. Degree of protection option
3. Air outlet area	9. Degree of protection IP20
4. Air inlet area	IP21 Option <M21>
5. Cables can enter from below within hatched area	IP23 Option <M23>
6. Main circuit breaker, can be secured by padlock (option)	IP43 Option <M43>
	IP54 Option <M54>
	10. Transport unit

Dimension Drawings

Engineering Information

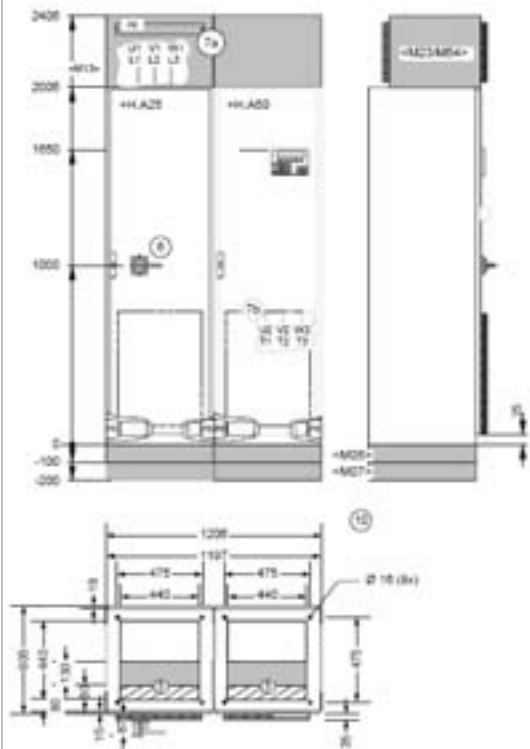
SINAMICS G150 (type A), continued

Dimension drawing 15:

380 V to 480 V

400 - 450 kW

Power supply connection from above, motor connection from below

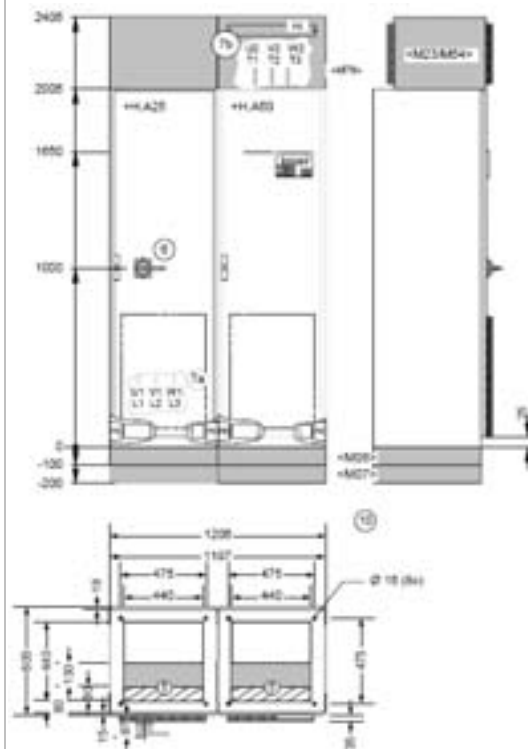


Dimension drawing 16:

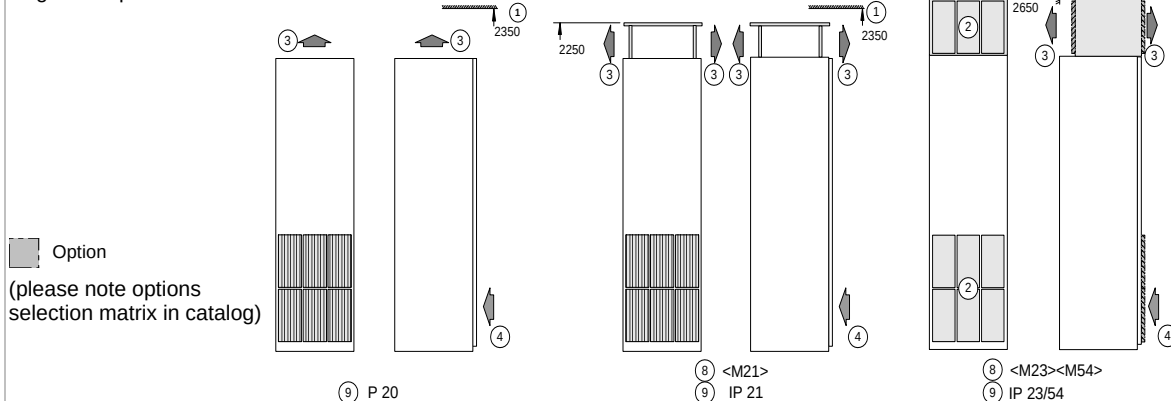
380 V to 480 V

400 - 450 kW

Power supply connection from below, motor connection from above



Degrees of protection:



Legend:

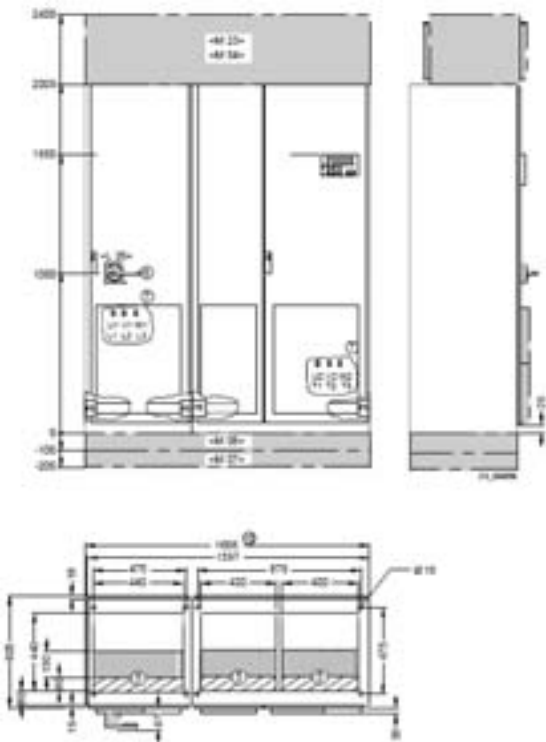
1. Minimum ceiling height for wall mounting	7. Power connection (7a: power supply, 7b: motor)
2. Ventilation grid	8. Degree of protection option
3. Air outlet area	9. Degree of protection IP20
4. Air inlet area	IP21
5. Cables can enter from below within hatched area	IP23
6. Main circuit breaker, can be secured by padlock (option)	IP43
	IP54
	Option <M21>
	Option <M23>
	Option <M43>
	Option <M54>
	10. Transport unit

SINAMICS G150 (type A), continued

Dimension drawing 17:

380 V to 480 V 560 kW
 500 V to 600 V 500 - 560 kW
 660 V to 690 V 710 - 800 kW

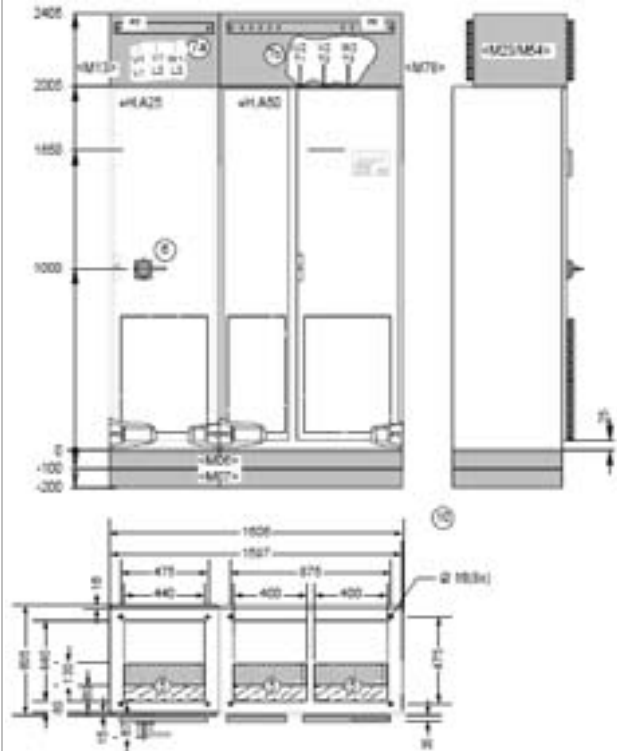
Power supply connection from below, motor connection from below



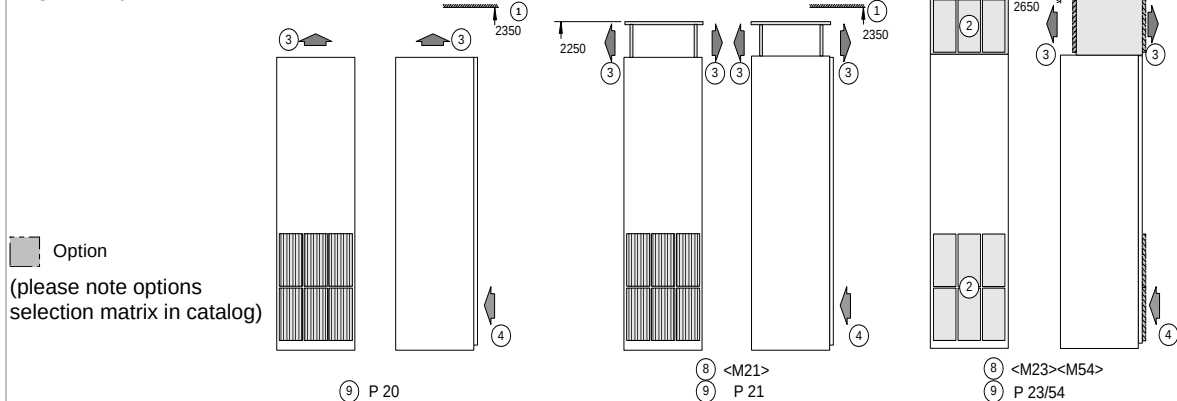
Dimension drawing 18:

380 V to 480 V 560 kW
 500 V to 600 V 500 - 560 kW
 660 V to 690 V 710 - 800 kW

Power supply connection from above, motor connection from above



Degrees of protection:



Legend:

1. Minimum ceiling height for wall mounting	7. Power connection (7a: power supply, 7b: motor)
2. Ventilation grid	8. Degree of protection option
3. Air outlet area	9. Degree of protection IP20
4. Air inlet area	IP21 Option <M21>
5. Cables can enter from below within hatched area	IP23 Option <M23>
6. Main circuit breaker, can be secured by padlock (option)	IP43 Option <M43>
	IP54 Option <M54>
	10. Transport unit

Dimension Drawings

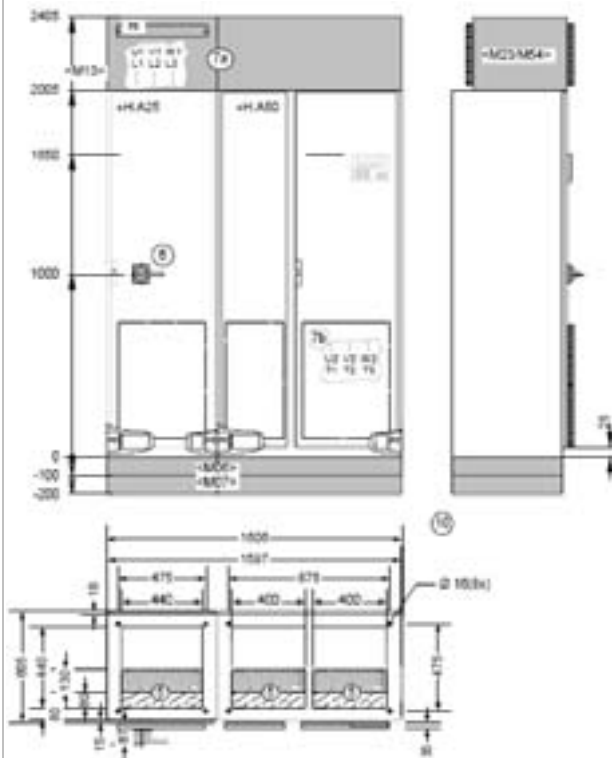
Engineering Information

SINAMICS G150 (type A), continued

Dimension drawing 19:

380 V to 480 V 560 kW
 500 V to 600 V 500 - 560 kW
 660 V to 690 V 710 - 800 kW

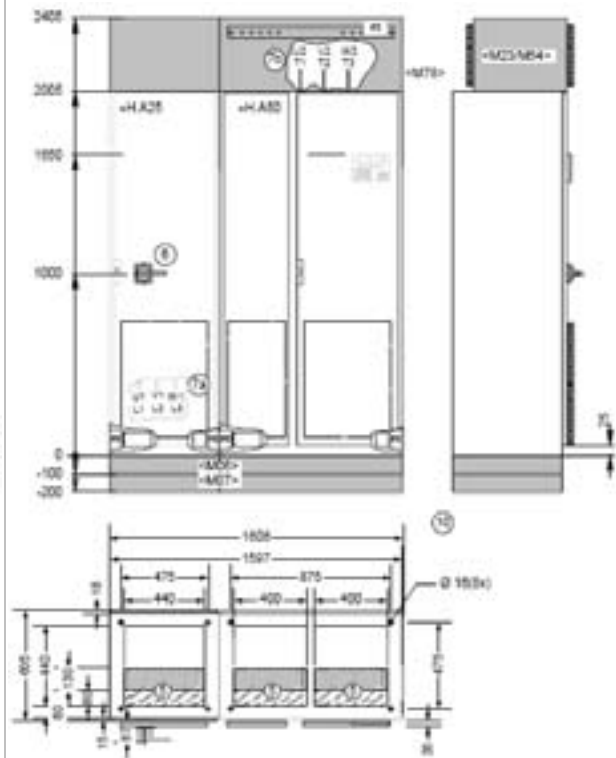
Power supply connection from above, motor connection from below



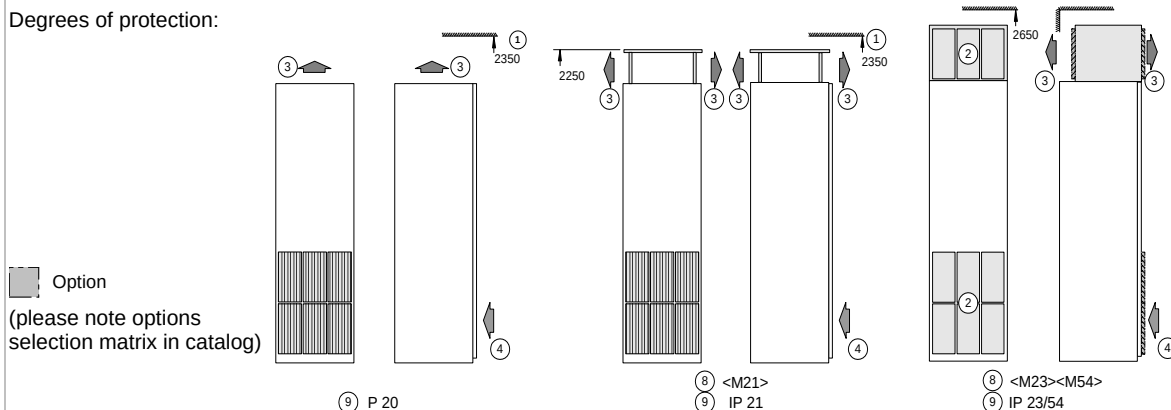
Dimension drawing 20:

380 V to 480 V 560 kW
 500 V to 600 V 500 - 560 kW
 660 V to 690 V 710 - 800 kW

Power supply connection from below, motor connection from above



Degrees of protection:



Legend:

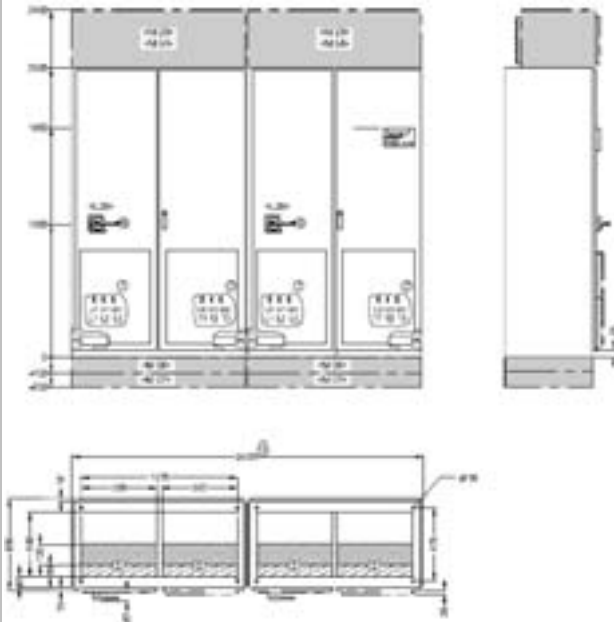
1. Minimum ceiling height for wall mounting	7. Power connection (7a: power supply, 7b: motor)
2. Ventilation grid	8. Degree of protection option
3. Air outlet area	9. Degree of protection IP20
4. Air inlet area	IP21 Option <M21>
5. Cables can enter from below within hatched area	IP23 Option <M23>
6. Main circuit breaker, can be secured by padlock (option)	IP43 Option <M43>
	IP54 Option <M54>
	10. Transport unit

SINAMICS G150 (type A), continued

Dimension drawing 21:

380 V to 480 V 630 kW
 500 V to 600 V 630 - 710 kW
 660 V to 690 V 1000 kW

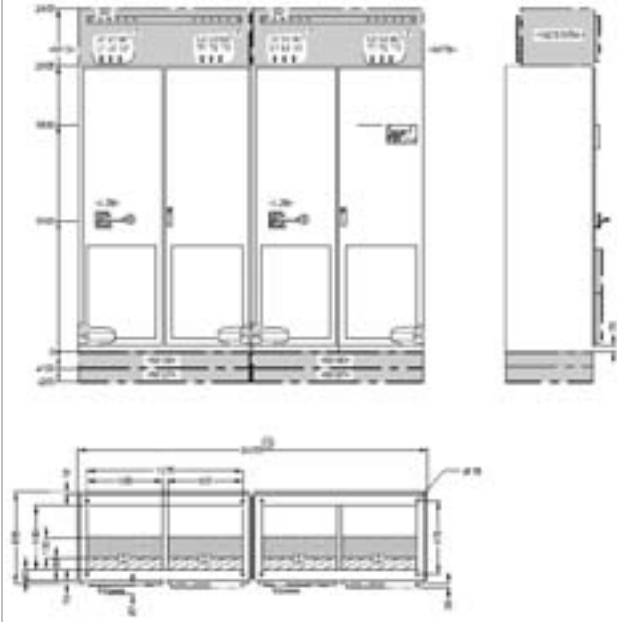
Power supply connection from below, motor connection from below



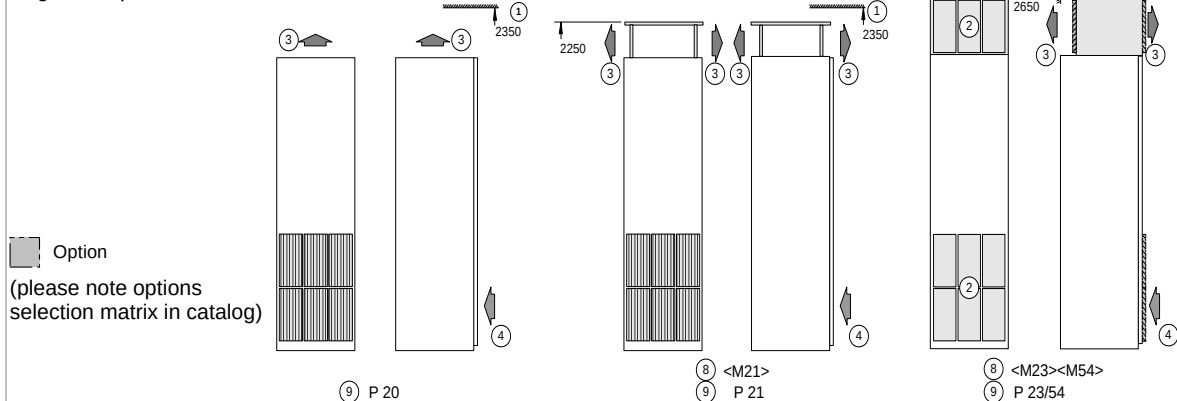
Dimension drawing 22:

380 V to 480 V 630 kW
 500 V to 600 V 630 - 710 kW
 660 V to 690 V 1000 kW

Power supply connection from above, motor connection from above



Degrees of protection:



Legend:

- Minimum ceiling height for wall mounting
- Ventilation grid
- Air outlet area
- Air inlet area
- Cables can enter from below within hatched area
- Main circuit breaker, can be secured by padlock (option)
- Power connection (7a: power supply, 7b: motor)
- Degree of protection option
- Degree of protection IP20
- 2 transport units, each 1200 mm

Dimension Drawings

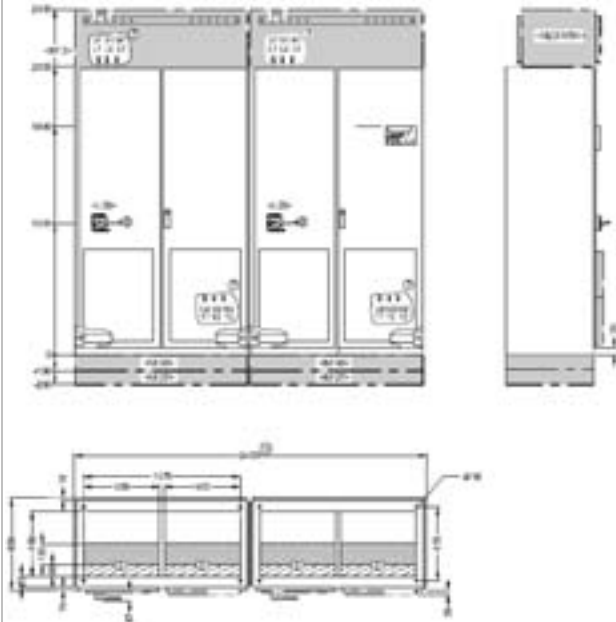
Engineering Information

SINAMICS G150 (type A), continued

Dimension drawing 23:

380 V to 480 V 630 kW
 500 V to 600 V 630 - 710 kW
 660 V to 690 V 1000 kW

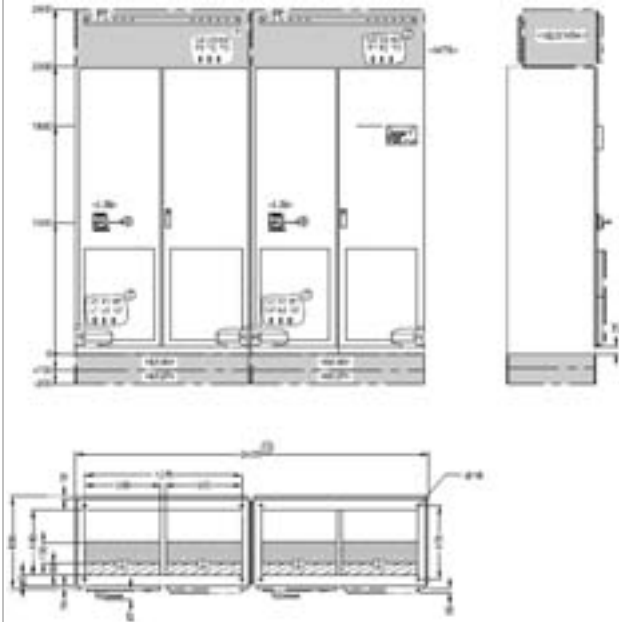
Power supply connection from above, motor connection from below



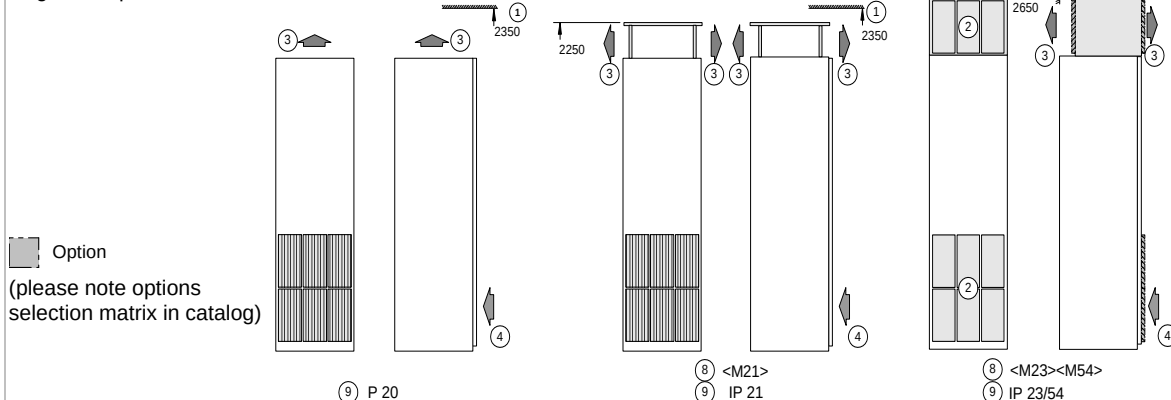
Dimension drawing 24:

380 V to 480 V 630 kW
 500 V to 600 V 630 - 710 kW
 660 V to 690 V 1000 kW

Power supply connection from below, motor connection from above



Degrees of protection:



Legend:

1. Minimum ceiling height for wall mounting
2. Ventilation grid
3. Air outlet area
4. Air inlet area
5. Cables can enter from below within hatched area
6. Main circuit breaker, can be secured by padlock (option)

7. Power connection (7a: power supply, 7b: motor)
8. Degree of protection option
9. Degree of protection IP20

IP21	Option <M21>
IP23	Option <M23>
IP43	Option <M43>
IP54	Option <M54>
10. 2 transport units, each 1200 mm

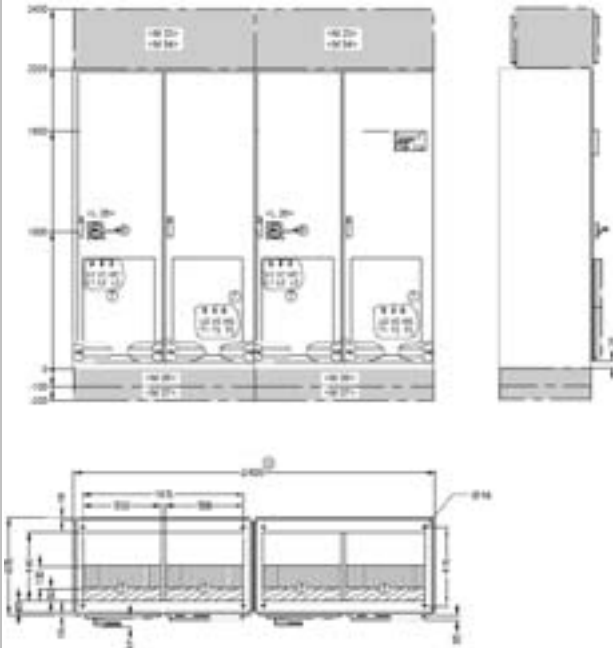
SINAMICS G150 (type A), continued

Dimension drawing 25:

380 V to 480 V

710 - 900 kW

Power supply connection from below, motor connection from below

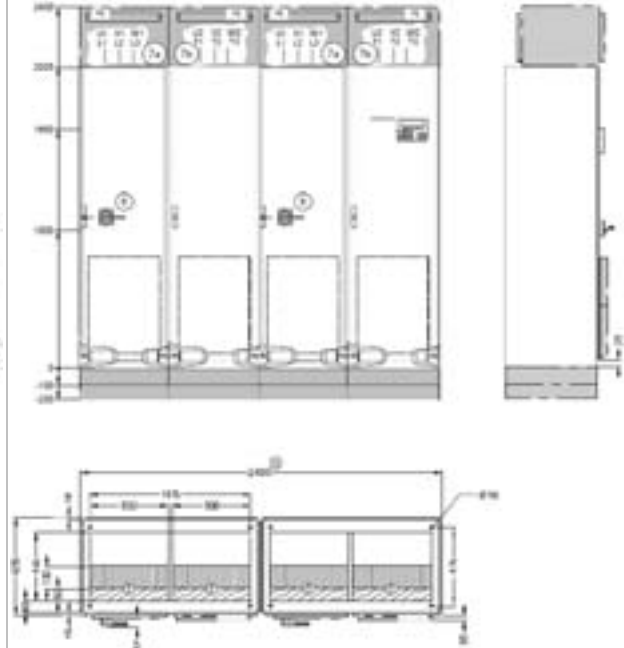


Dimension drawing 26:

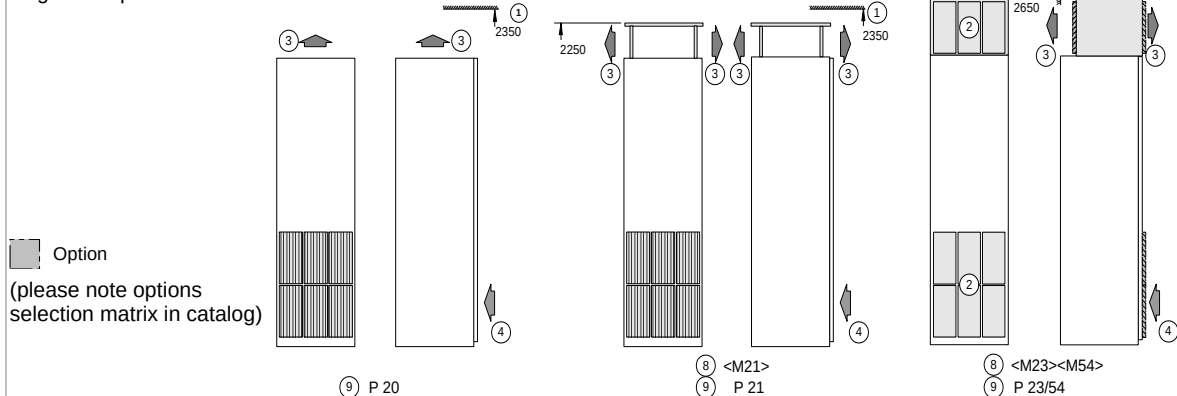
380 V to 480 V

710 - 900 kW

Power supply connection from above, motor connection from above



Degrees of protection:



Legend:

- Minimum ceiling height for wall mounting
- Ventilation grid
- Air outlet area
- Air inlet area
- Cables can enter from below within hatched area
- Main circuit breaker, can be secured by padlock (option)
- Power connection (7a: power supply, 7b: motor)
- Degree of protection option
- Degree of protection IP20
IP21
IP23
IP43
IP54
- 2 transport units, each 1200 mm

Dimension Drawings

Engineering Information

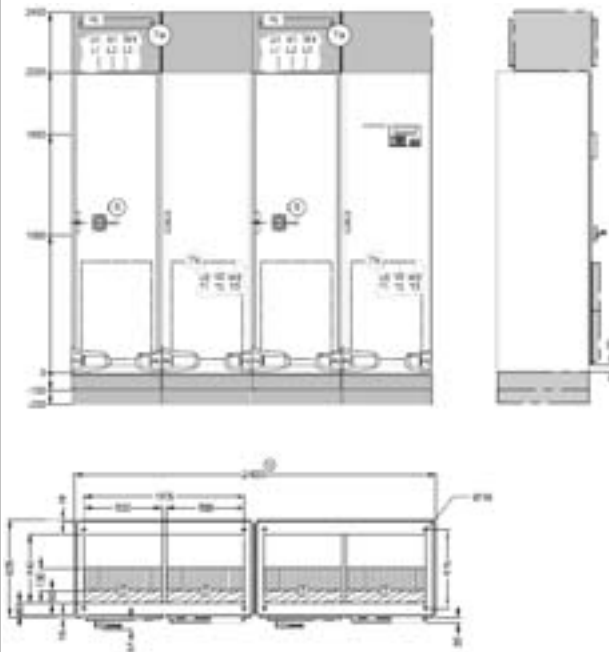
SINAMICS G150 (type A), continued

Dimension drawing 27:

380 V to 480 V

710 - 900 kW

Power supply connection from above, motor connection from below

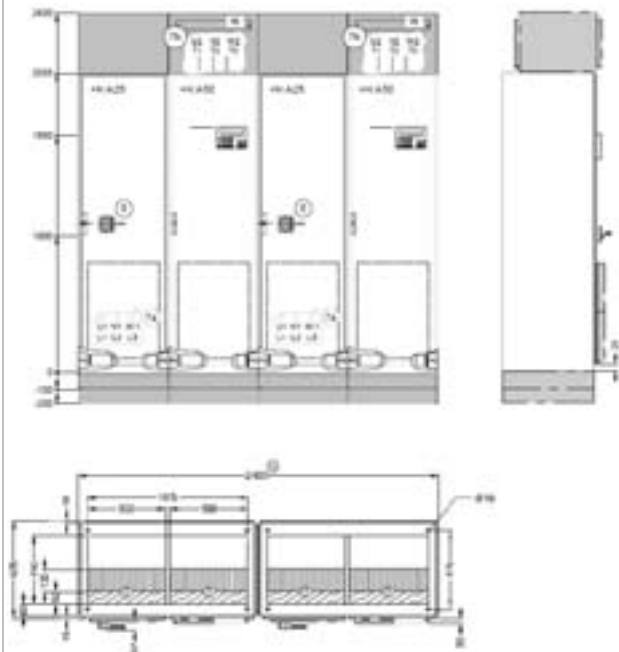


Dimension drawing 28:

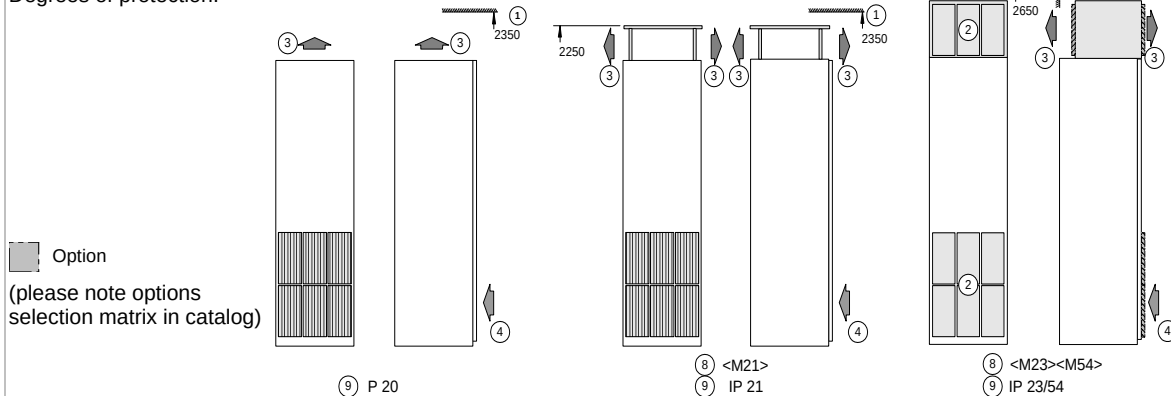
380 V to 480 V

710 - 900 kW

Power supply connection from below, motor connection from above



Degrees of protection:



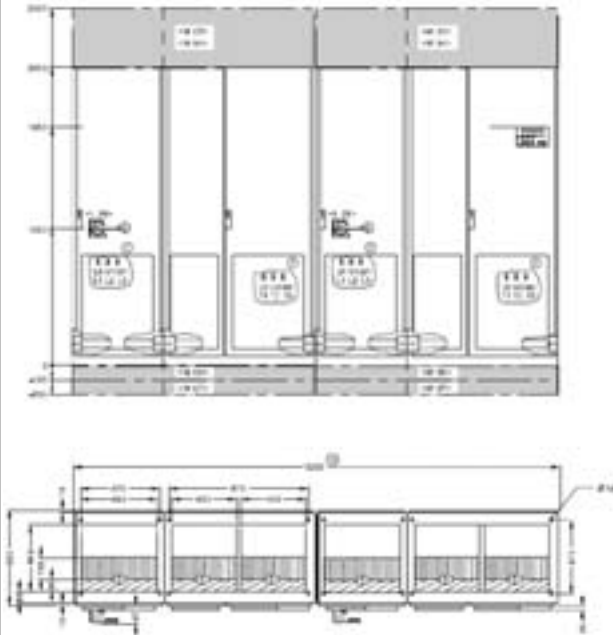
Legend:

1. Minimum ceiling height for wall mounting	7. Power connection (7a: power supply, 7b: motor)
2. Ventilation grid	8. Degree of protection option
3. Air outlet area	9. Degree of protection
4. Air inlet area	IP20
5. Cables can enter from below within hatched area	Option <M21>
6. Main circuit breaker, can be secured by padlock (option)	IP23
	Option <M23>
	IP43
	Option <M43>
	IP54
	Option <M54>
	10. 2 transport units, each 1200 mm

SINAMICS G150 (type A), continued

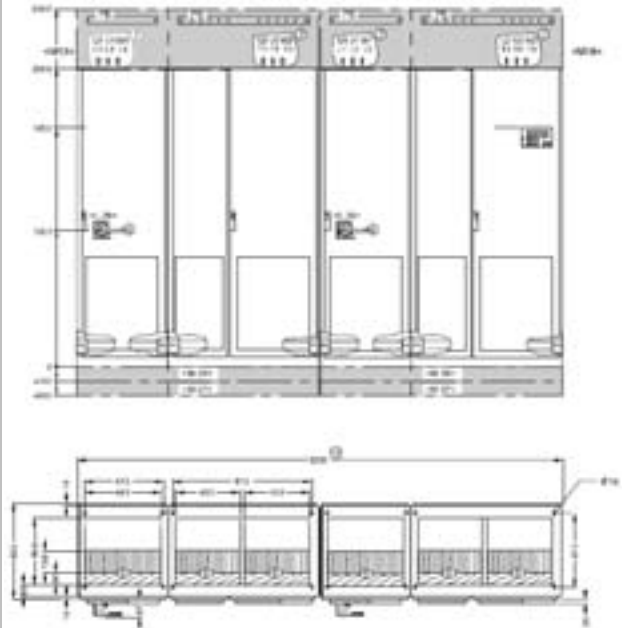
Dimension drawing 29:

500 V to 600 V 1000 kW
 660 V to 690 V 1350 - 1500 kW
 Power supply connection from below, motor connection from below

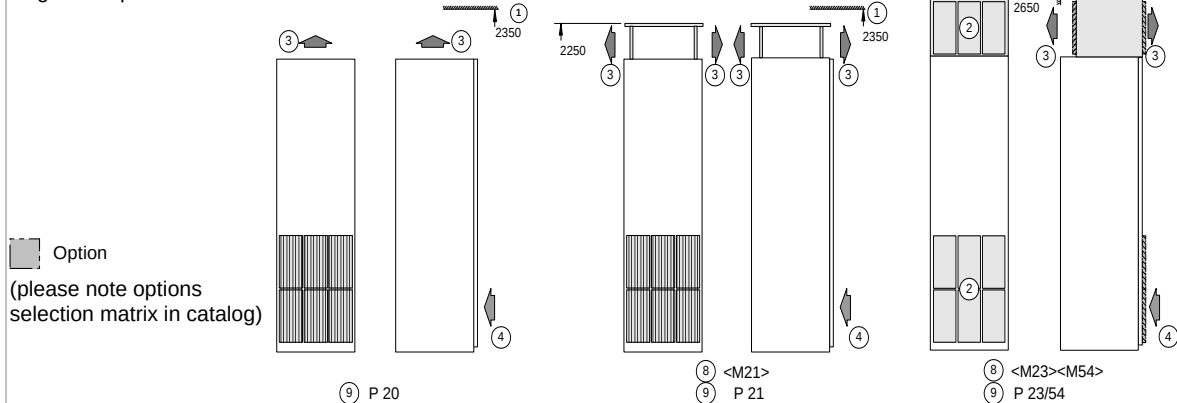


Dimension drawing 30:

500 V to 600 V 1000 kW
 660 V to 690 V 1350 - 1500 kW
 Power supply connection from above, motor connection from above



Degrees of protection:



Legend:

1. Minimum ceiling height for wall mounting	7. Power connection (7a: power supply, 7b: motor)
2. Ventilation grid	8. Degree of protection option
3. Air outlet area	9. Degree of protection
4. Air inlet area	IP21 Option <M21>
5. Cables can enter from below within hatched area	IP23 Option <M23>
6. Main circuit breaker, can be secured by padlock (option)	IP43 Option <M43>
	IP54 Option <M54>
	10. 2 transport units, each 1600 mm

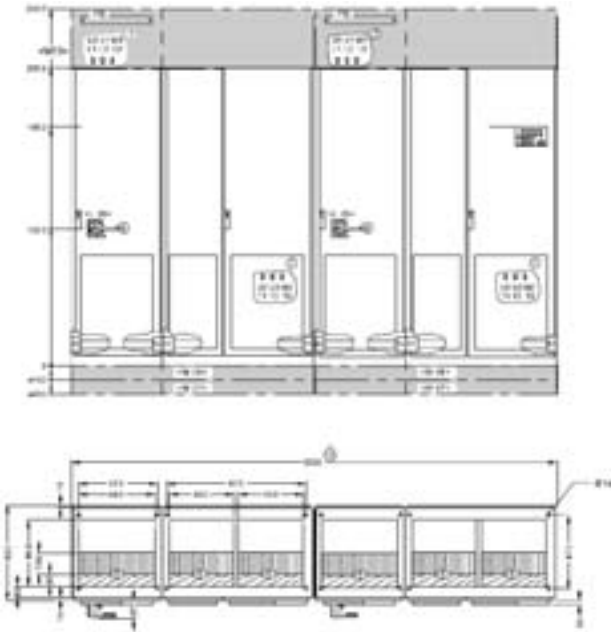
Dimension Drawings

Engineering Information

SINAMICS G150 (type A), continued

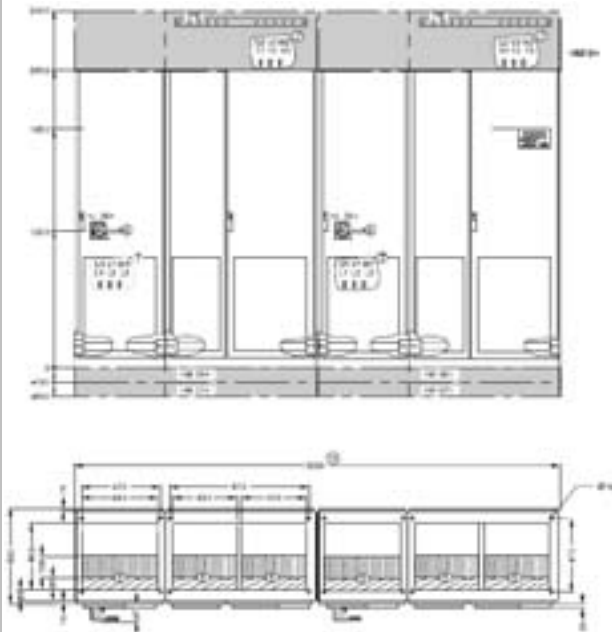
Dimension drawing 31:

500 V to 600 V 1000 kW
 660 V to 690 V 1350 - 1500 kW
 Power supply connection from above, motor connection from below

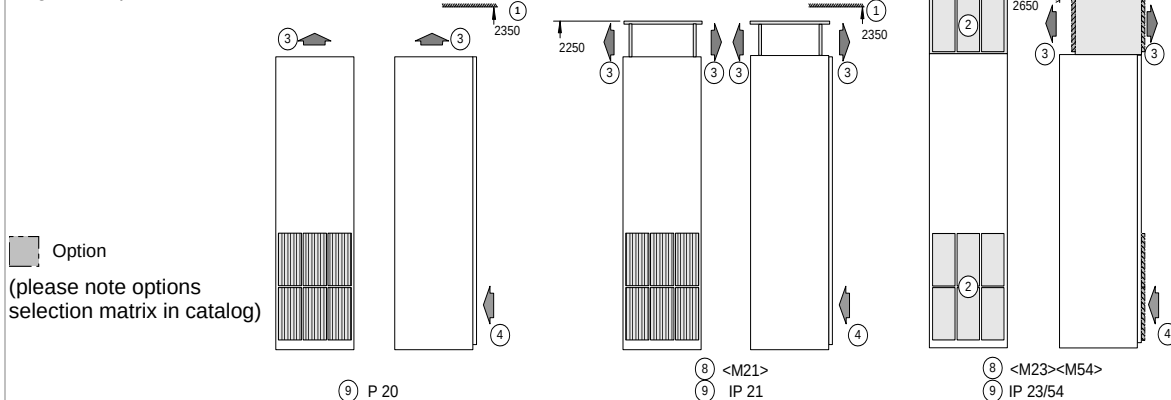


Dimension drawing 32:

500 V to 600 V 1000 kW
 660 V to 690 V 1350 - 1500 kW
 Power supply connection from below, motor connection from above



Degrees of protection:



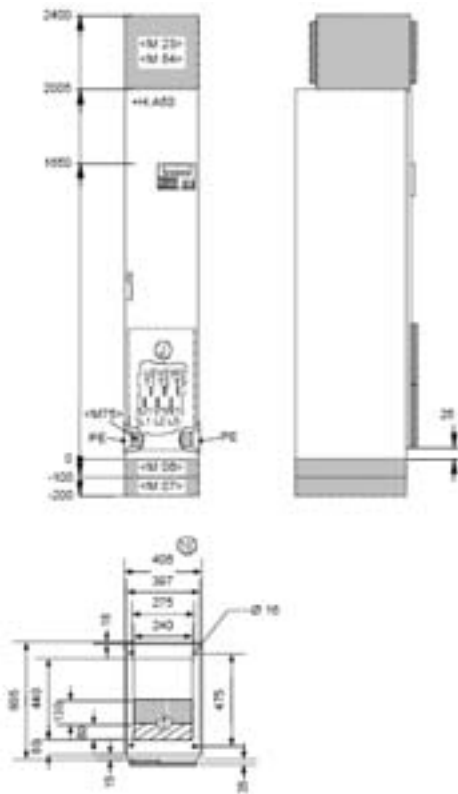
Legend:

1. Minimum ceiling height for wall mounting
2. Ventilation grid
3. Air outlet area
4. Air inlet area
5. Cables can enter from below within hatched area
6. Main circuit breaker, can be secured by padlock (option)
7. Power connection (7a: power supply, 7b: motor)
8. Degree of protection option
9. Degree of protection IP20
 - IP21 Option <M21>
 - IP23 Option <M23>
 - IP43 Option <M43>
 - IP54 Option <M54>
10. 2 transport units, each 1600 mm

SINAMICS G150 (type C)

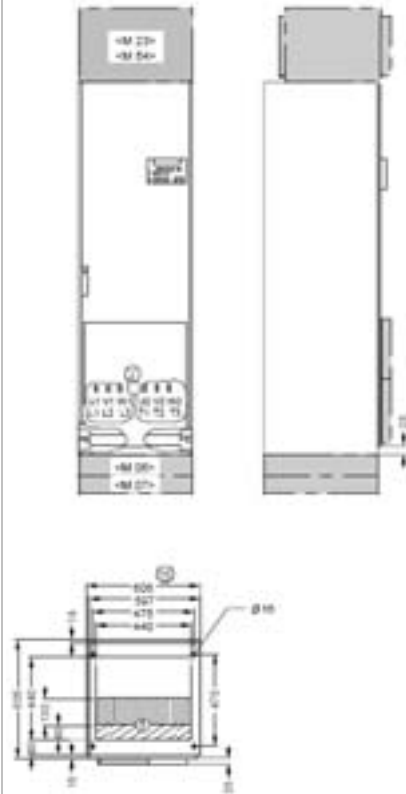
Dimension drawing 1:

380 V to 480 V 110 - 250 kW
 500 V to 600 V 110 - 200 kW
 660 V to 690 V 75 - 315 kW

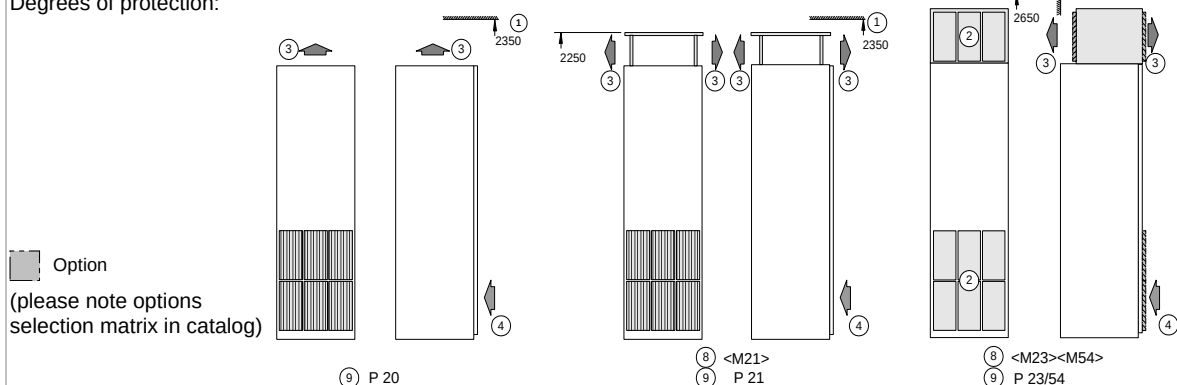


Dimension drawing 2:

380 V to 480 V 315 - 450 kW
 500 V to 600 V 250 - 400 kW
 660 V to 690 V 400 - 560 kW



Degrees of protection:



Legend:

1. Minimum ceiling height for wall mounting
2. Ventilation grid
3. Air outlet area
4. Air inlet area
5. Cables can enter from below within hatched area
- 6.
7. Power connection (7a: power supply, 7b: motor)
8. Degree of protection option
9. Degree of protection IP20

IP21	Option <M21>
IP23	Option <M23>
IP43	Option <M43>
IP54	Option <M54>
10. Transport unit

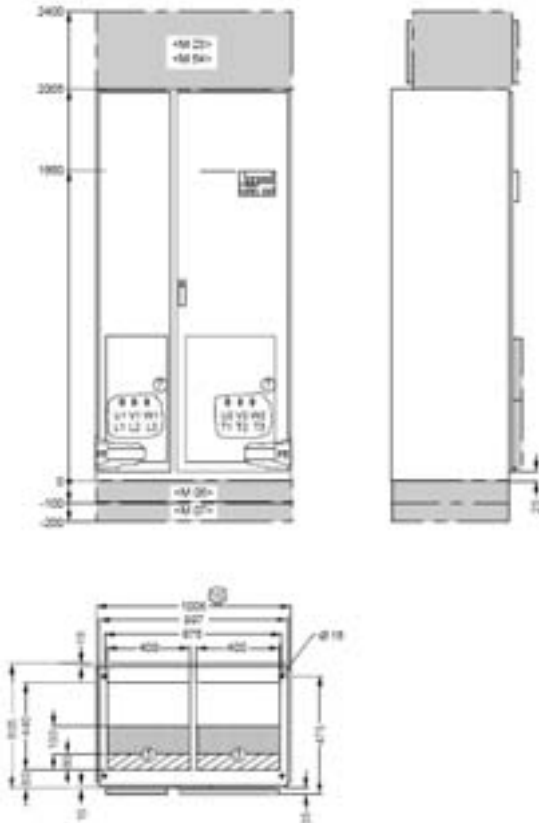
Dimension Drawings

Engineering Information

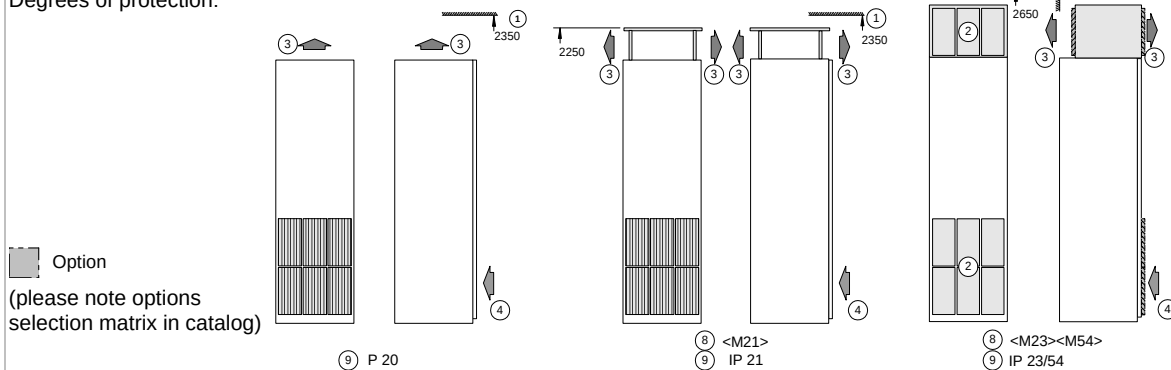
SINAMICS G150 (type C), continued

Dimension drawing 3:

380 V to 480 V 560 kW
 500 V to 600 V 500 - 560 kW
 660 V to 690 V 710 - 800 kW



Degrees of protection:



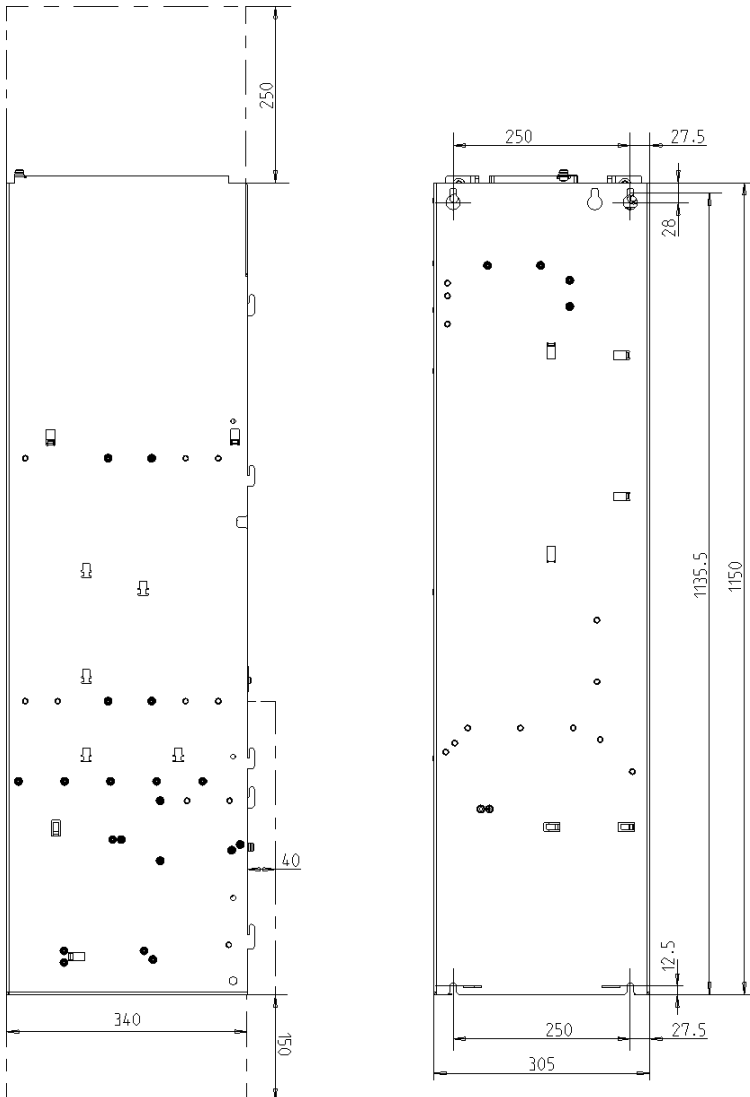
Legend:

1. Minimum ceiling height for wall mounting	7. Power connection (7a: power supply, 7b: motor)
2. Ventilation grid	8. Degree of protection option
3. Air outlet area	9. Degree of protection IP20
4. Air inlet area	IP21 Option <M21>
5. Cables can enter from below within hatched area	IP23 Option <M23>
6.	IP43 Option <M43>
	IP54 Option <M54>
	10. Transport unit

SINAMICS S120 Chassis (Basic Line Modules)

Dimension drawing 1, frame size FB:

380 V to 480 V 200 - 400 kW
500 V to 690 V 250 - 560 kW



Side view			Rear view						
Required clearance for ventilation - - - - -									
Line supply connection			DC link connection			Grounding			
Max. connection cross-section		M10 screw	Max. connection cross-section		M10 screw		Max. connection cross-section		M10 screw
DIN VDE mm²	NEC, CEC AWG/MCM	(No. of holes)	DIN VDE mm²	NEC, CEC AWG/MCM	(No. of holes)		DIN VDE mm²	NEC, CEC AWG/MCM	(No. of holes)
2 x 185	2 x 350 MCM	(1)	2 x 185	2 x 350 MCM	(1)	PE	2 x 185	2 x 350 MCM	(2)

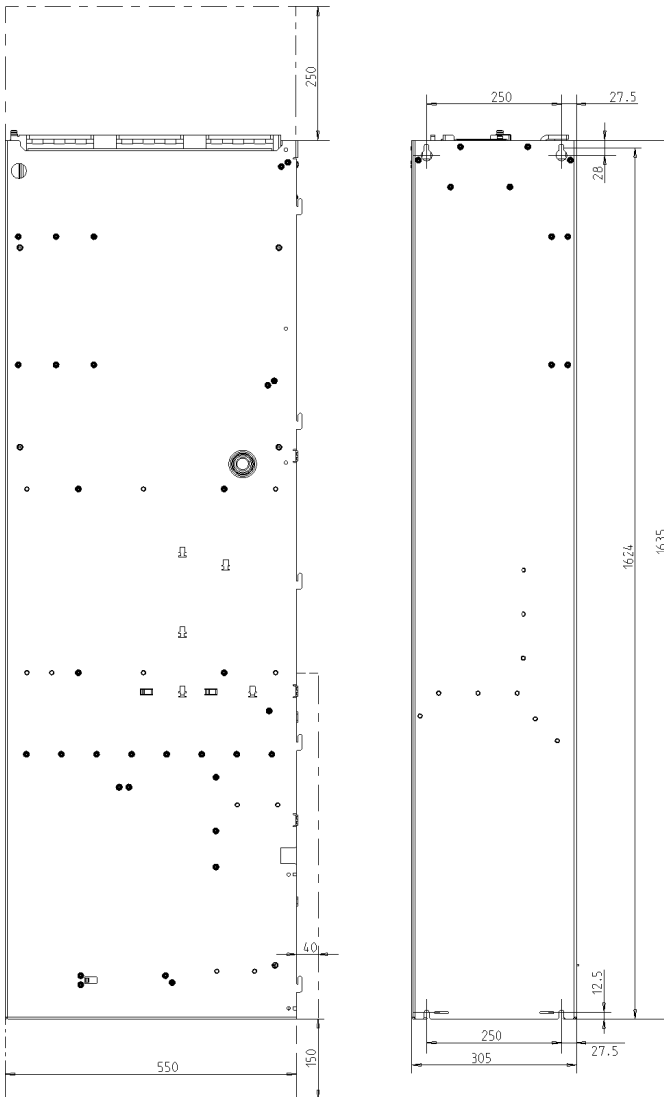
Dimension Drawings

Engineering Information

SINAMICS S120 Chassis (Basic Line Modules), continued

Dimension drawing 2, frame size GB:

380 V to 480 V 560 - 710 kW
500 V to 690 V 900 - 1100 kW

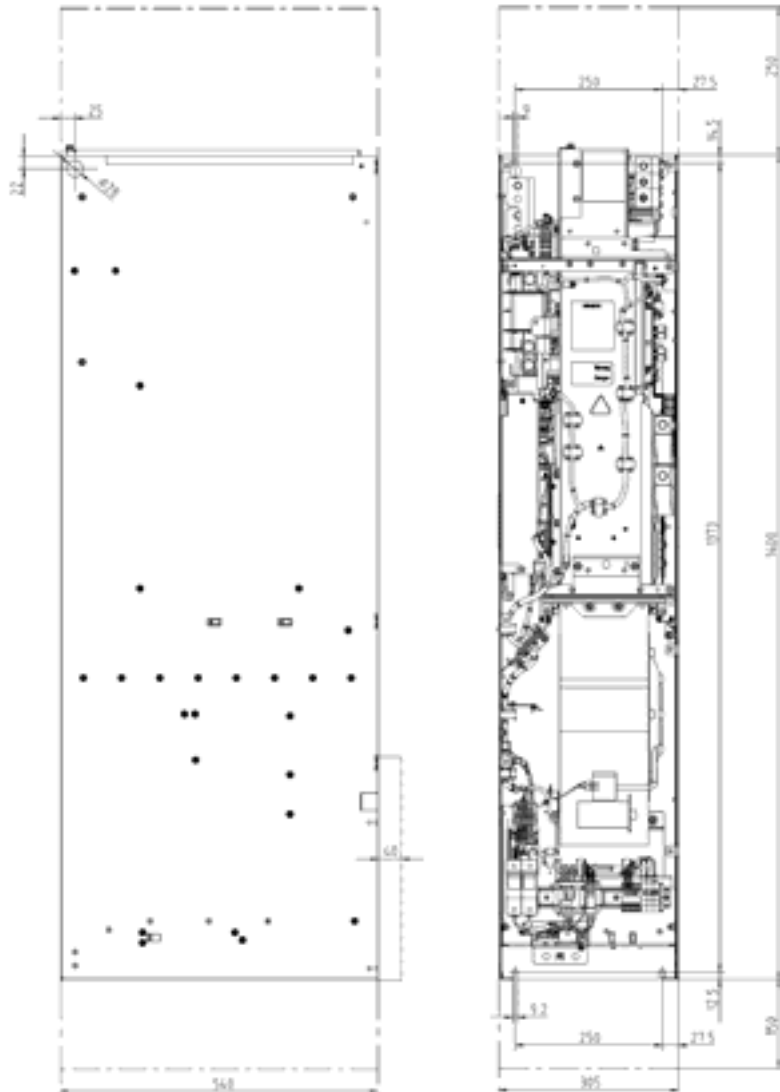


Side view			Rear view						
Required clearance for ventilation - - - - -									
Line supply connection			DC link connection			Grounding			
Max.connection cross-section		M12 screw	Max. connection cross-section		M12 screw		Max. connection cross-section		M10 screw
DIN VDE mm²	NEC, CEC AWG/MCM	(No. of holes)	DIN VDE mm²	NEC, CEC AWG/MCM	(No. of holes)		DIN VDE mm²	NEC, CEC AWG/MCM	(No. of holes)
6 x 240	6 x 500 MCM	(3)	6 x 240	6 x 500 MCM	(3)	PE	4 x 240	2 x 500 MCM	(2)

SINAMICS S120 Chassis (Smart Line Modules)

Dimension drawing 3, frame size GX:

380 V to 480 V	250 - 355 kW
500 V to 690 V	450 kW



Side view			Front view						
Required clearance for ventilation - - - - -									
Line supply connection			DC link connection			Grounding			
Max. connection cross-section		M10 screw	Max. connection cross-section		M10 screw		Max. connection cross-section		M10 screw
DIN VDE mm²	NEC, CEC AWG/MCM	(No. of holes)	DIN VDE mm²	NEC, CEC AWG/MCM	(No. of holes)		DIN VDE mm²	NEC, CEC AWG/MCM	(No. of holes)
2 x 185	2 x 350 MCM	(1)	2 x 185	2 x 350 MCM	(1)	PE1 PE2	1 x 185 2 x 185	1 x 350 MCM 2 x 350 MCM	(1) (2)

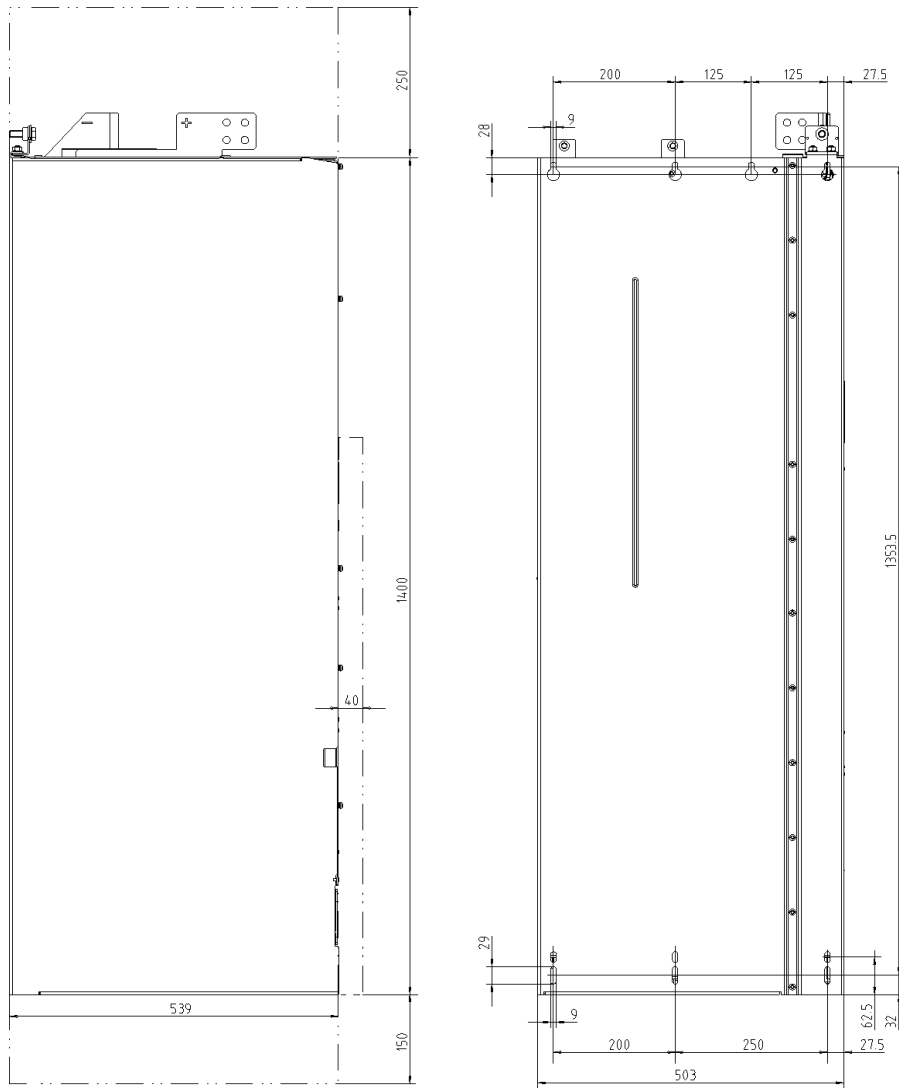
Dimension Drawings

Engineering Information

SINAMICS S120 Chassis (Smart Line Modules), continued

Dimension drawing 4, Frame size HX:

380 V to 480 V 500 kW
500 V to 690 V 710 kW

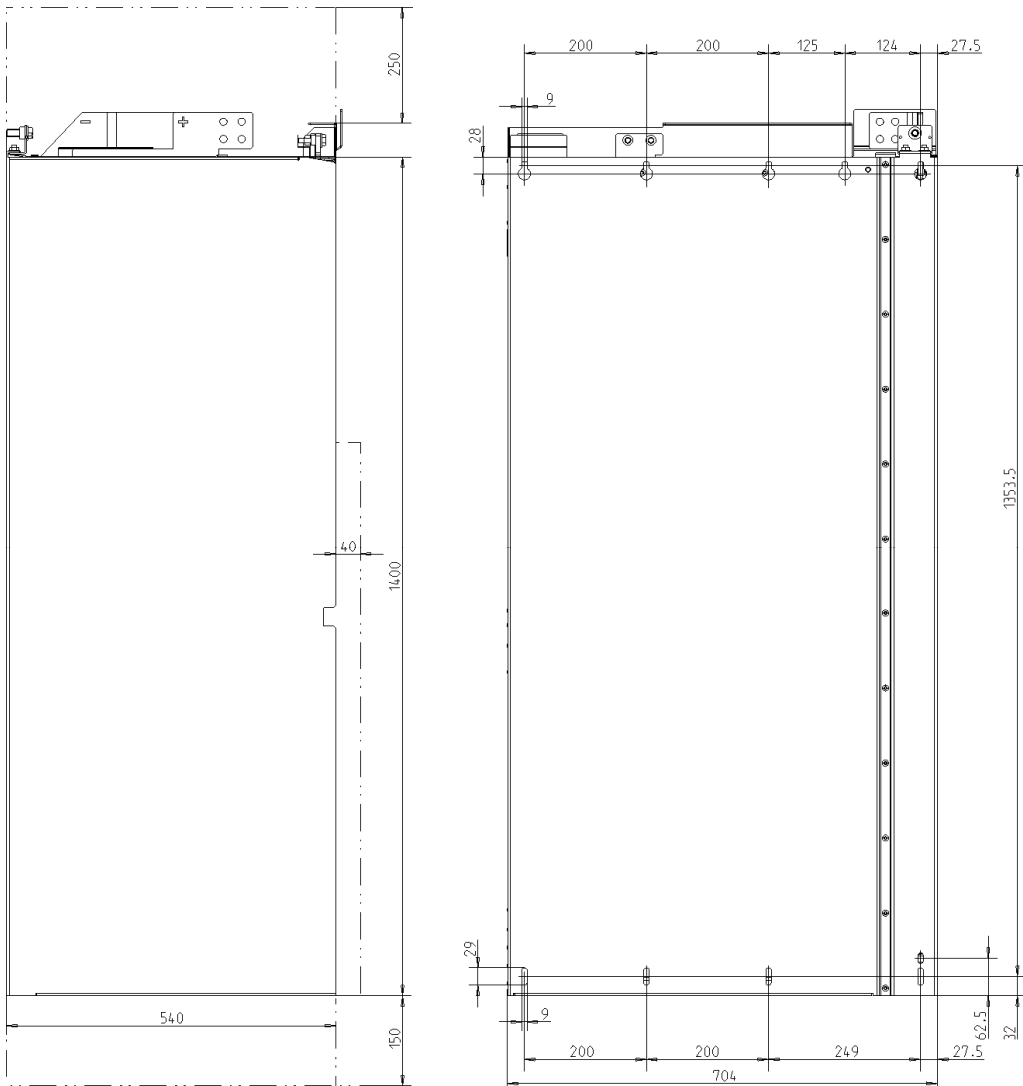


Side view			Rear view						
Required clearance for ventilation - - - - -									
Line supply connection			DC link connection			Grounding			
Max. connection cross-section		M12 screw	Max. connection cross-section		Busbar connection		Max. connection cross-section		M12 screw
DIN VDE mm²	NEC, CEC AWG/MCM	(No. of holes)	DIN VDE mm²				DIN VDE mm²	NEC, CEC AWG/MCM	(No. of holes)
4 x 240	4 x 500 MCM	(2)	60 x 60 x 5			PE1 PE2	1 x 240 2 x 240	1 x 500 MCM 2 x 500 MCM	(1) (2)

SINAMICS S120 Chassis (Smart Line Modules), continued

Dimension drawing 5, frame size JX:

380 V to 480 V 630 – 800 kW
500 V to 690 V 1000 – 1400 kW



Side view			Rear view						
Required clearance for ventilation - - - - -									
Line supply connection			DC link connection			Grounding			
Max. connection cross-section		M12 screw	Max. connection cross-section		Busbar connection		Max. connection cross-section		M12 screw
DIN VDE mm²	NEC, CEC AWG/MCM	(No. of holes)	DIN VDE mm²				DIN VDE mm²	NEC, CEC AWG/MCM	(No. of holes)
6 x 240	6 x 500 MCM	(3)	60 x 60 x 8			PE1 PE2	1 x 240 2 x 240	1 x 500 MCM 2 x 500 MCM	(1) (2)

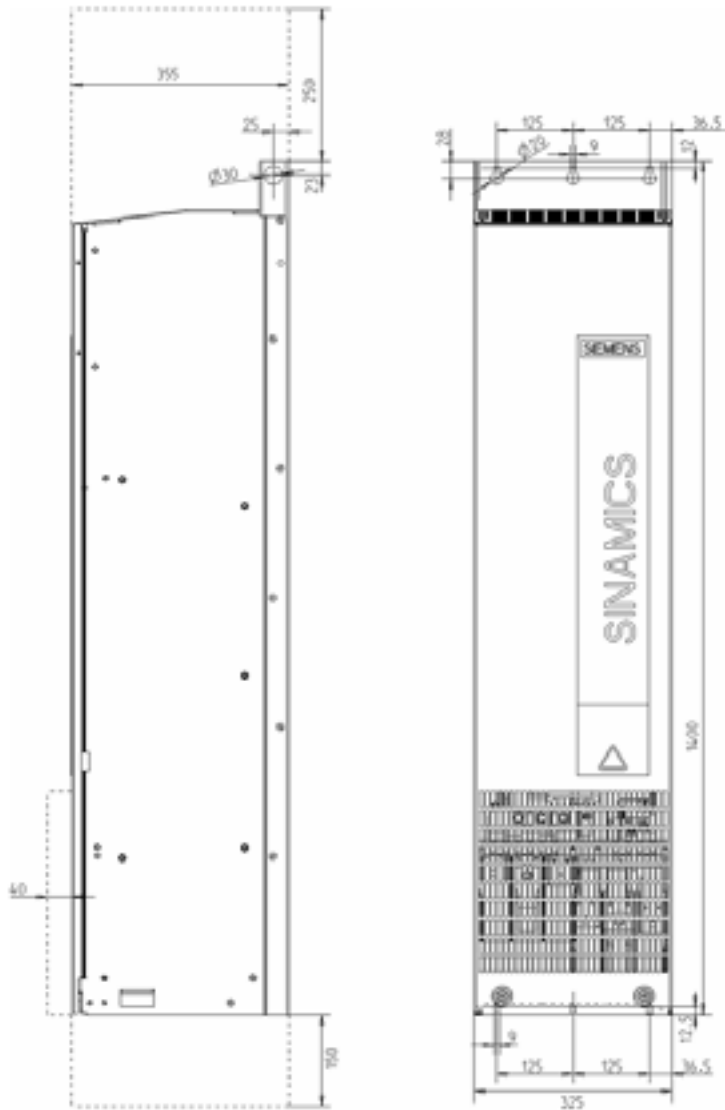
Dimension Drawings

Engineering Information

SINAMICS S120 Chassis (Active Interface Modules)

Dimension drawing 6, frame size FI:

380 V to 480 V 132 - 160 kW



Side view

Front view

Required clearance for ventilation - - - - -

Power supply connection / load

Max. connection cross-section	M10 screw
DIN VDE mm ²	NEC, CEC AWG/MCM
(No. of holes)	
2 x 185	2 x 350 MCM
(1)	

Grounding

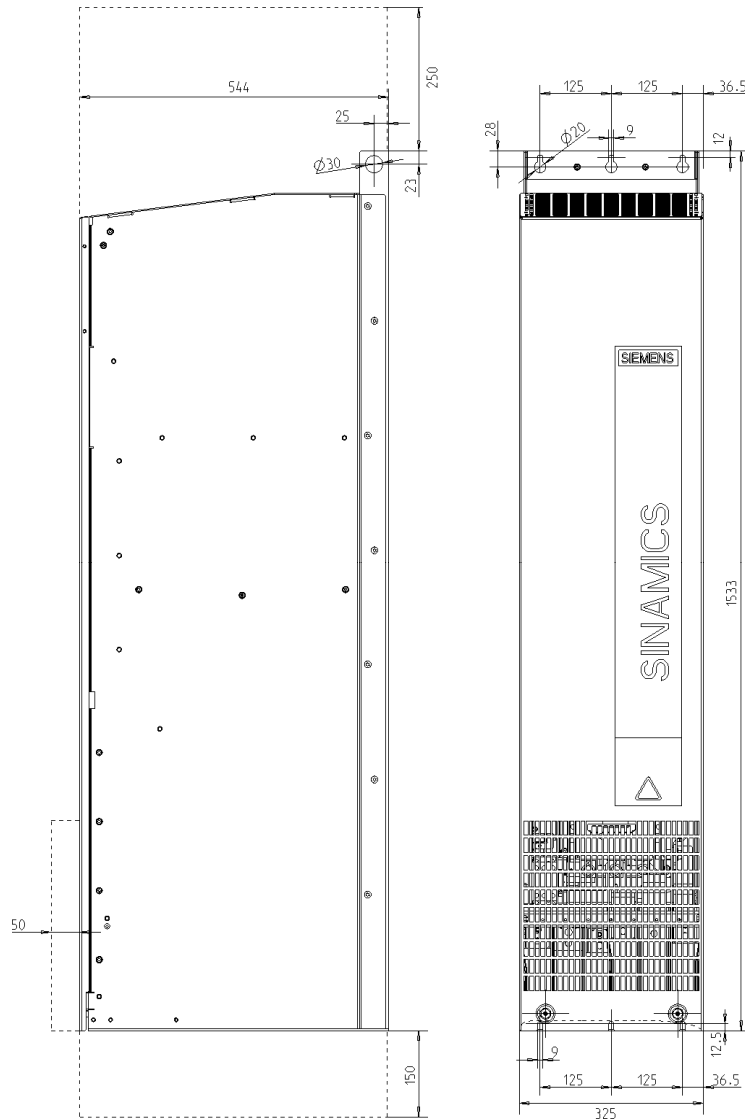
Max. connection cross-section	M10 screw
DIN VDE mm ²	NEC, CEC AWG/MCM
(No. of holes)	
PE1	2 x 185
2 x 350 MCM	(2)

SINAMICS S120 Chassis (Active Interface Modules), continued

Dimension drawing 7, frame size G1:

380 V to 480 V

235 - 300 kW



Side view			Front view					
Required clearance for ventilation - - - - -								
Power supply connection / load					Grounding			
Max. connection cross-section		M10 screw				Max. connection cross-section	M10 screw	
DIN VDE mm²	NEC, CEC AWG/MCM	(No. of holes)				DIN VDE mm²	NEC, CEC AWG/MCM	(No. of holes)
2 x 185	2 x 350 MCM	(1)			PE	2 x 185	2 x 350 MCM	(2)

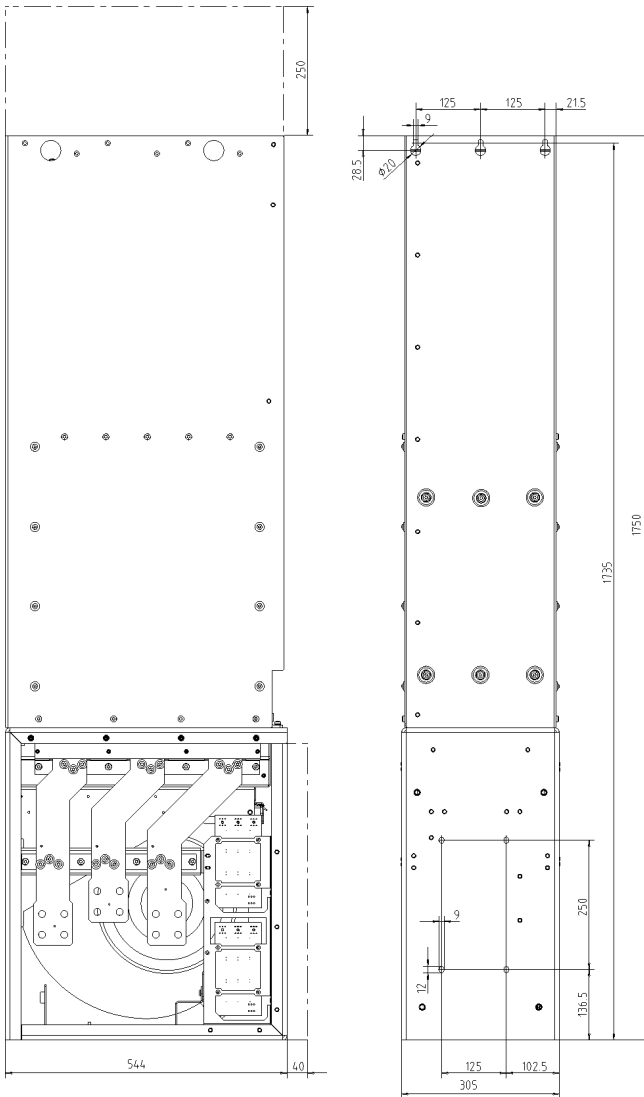
Dimension Drawings

Engineering Information

SINAMICS S120 Chassis (Active Interface Modules), continued

Dimension drawing 8, frame size HI:

380 V to 480 V 380 - 500 kW
500 V to 690 V 560 kW

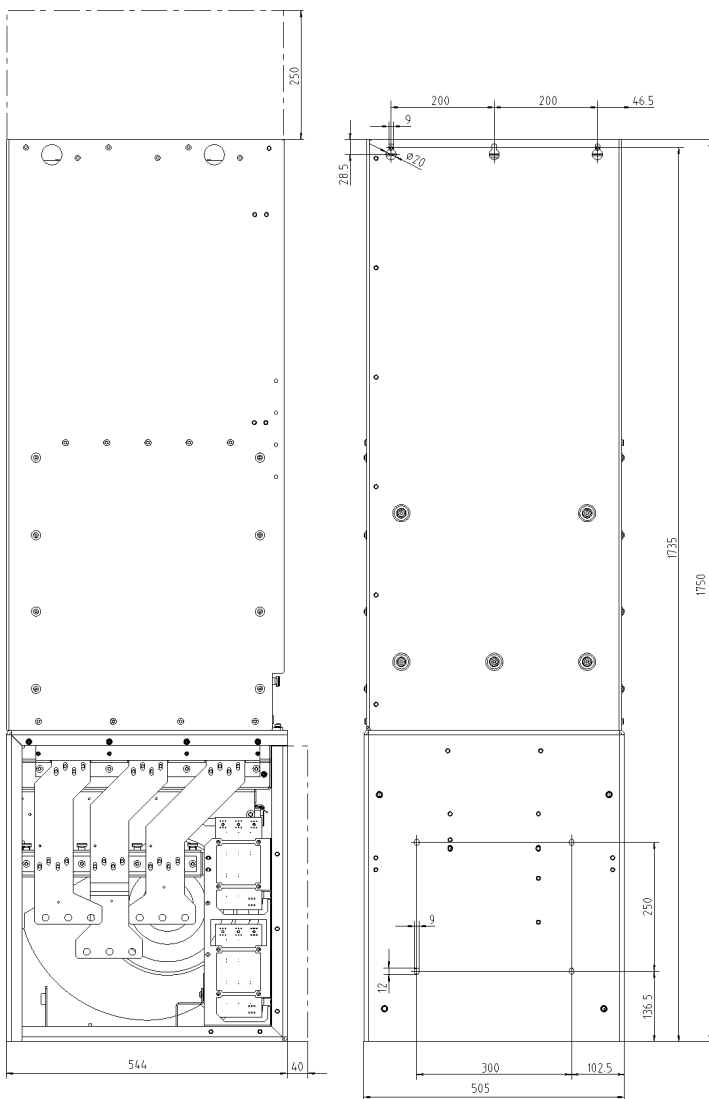


Side view			Rear view						
Required clearance for ventilation - - - - -									
Power supply connection / load			Pre-charging connection			Grounding			
Max. connection cross-section		M12 screw	Max. connection cross-section		Directly at pre-charging contactor		Max. connection cross-section		M12 screw
DIN VDE mm²	NEC, CEC AWG/MCM	(No. of holes)	DIN VDE mm²	NEC, CEC AWG/MCM			DIN VDE mm²	NEC, CEC AWG/MCM	(No. of holes)
4 x 240	4 x 500 MCM	(2)	2 x 16			PE	2 x 240	2 x 500 MCM	(2)

SINAMICS S120 Chassis (Active Interface Modules), continued

Dimension drawing 9, frame size JI:

380 V to 480 V 630 - 900 kW
500 V to 690 V 800 - 1400 kW



Side view			Rear view						
Required clearance for ventilation - - - - -									
Line supply connection / load			Pre-charging connection			Grounding			
Max. connection cross-section		M12 screw	Max. connection cross-section		Directly at pre-charging contactor		Max. connection cross-section		M12 screw
DIN VDE mm²	NEC, CEC AWG/MCM	(No. of holes)	DIN VDE mm²	NEC, CEC AWG/MCM			DIN VDE mm²	NEC, CEC AWG/MCM	(No. of holes)
6 x 240	6 x 500 MCM	(3)	2 x 35			PE	4 x 240	4 x 500 MCM	(2)

Dimension Drawings

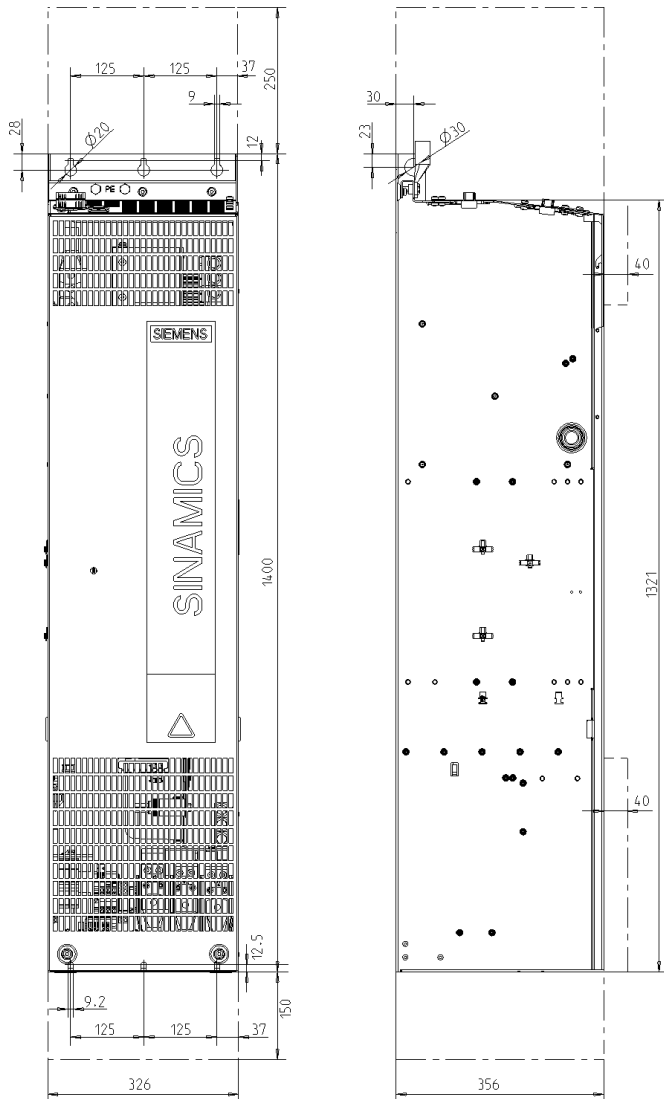
Engineering Information

SINAMICS S120 Chassis (Active Line Modules)

Dimension drawing 10, frame size FX:

380 V to 480 V

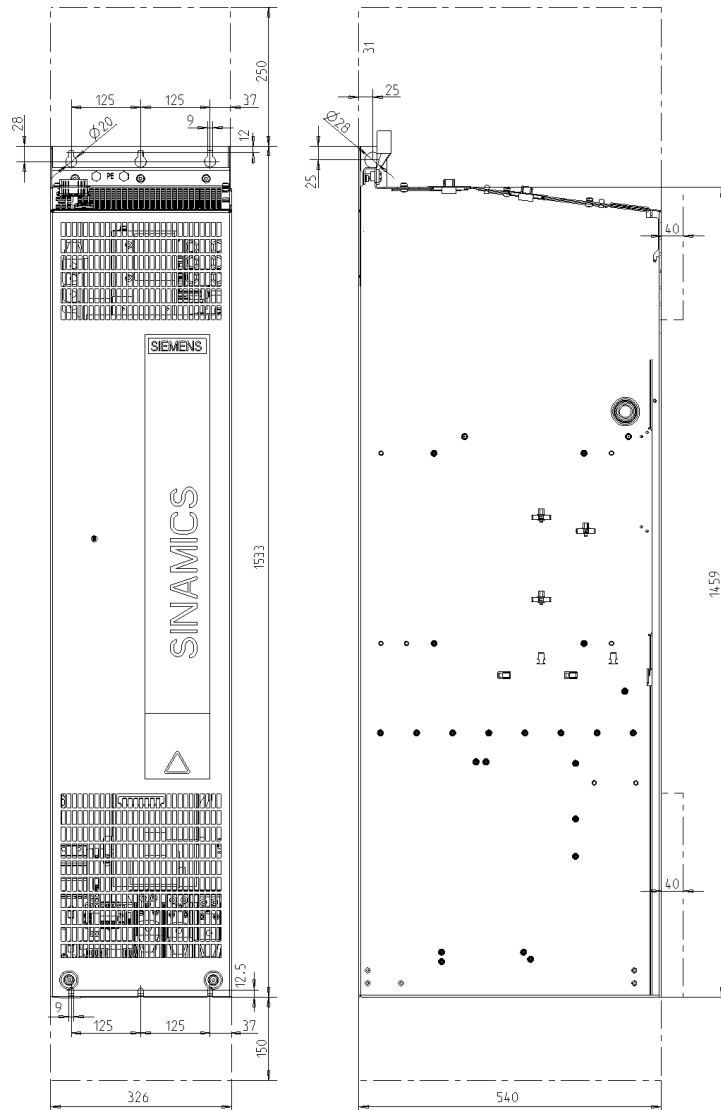
132 - 160 kW



Front view			Side view						
Required clearance for ventilation - - - - -									
Line supply connection			DC link connection			Grounding			
Max. connection cross-section		M10 screw	Max. connection cross-section		M10 screw		Max. connection cross-section		M10 screw
DIN VDE mm²	NEC, CEC AWG/MCM	(No. of holes)	DIN VDE mm²	NEC, CEC AWG/MCM	(No. of holes)		DIN VDE mm²	NEC, CEC AWG/MCM	(No. of holes)
2 x 185	2 x 350 MCM	(1)	2 x 185	2 x 350 MCM	(1)	PE	2 x 185	2 x 350 MCM	(2)

SINAMICS S120 Chassis (Active Line Modules), continued

Dimension drawing 11, frame size GX:
380 V to 480 V 235 - 300 kW



Front view			Side view						
Required clearance for ventilation - - - - -									
Line supply connection			DC link connection			Grounding			
Max. connection cross-section		M12 screw	Max. connection cross-section		M12 screw		Max. connection cross-section		M10 screw
DIN VDE mm²	NEC, CEC AWG/MCM	(No. of holes)	DIN VDE mm²	NEC, CEC AWG/MCM	(No. of holes)		DIN VDE mm²	NEC, CEC AWG/MCM	(No. of holes)
2 x 185	2 x 350 MCM	(1)	2 x 185	2 x 350 MCM	(1)	PE	2 x 185	2 x 350 MCM	(2)

Dimension Drawings

Engineering Information

SINAMICS S120 Chassis (Active Line Modules), continued

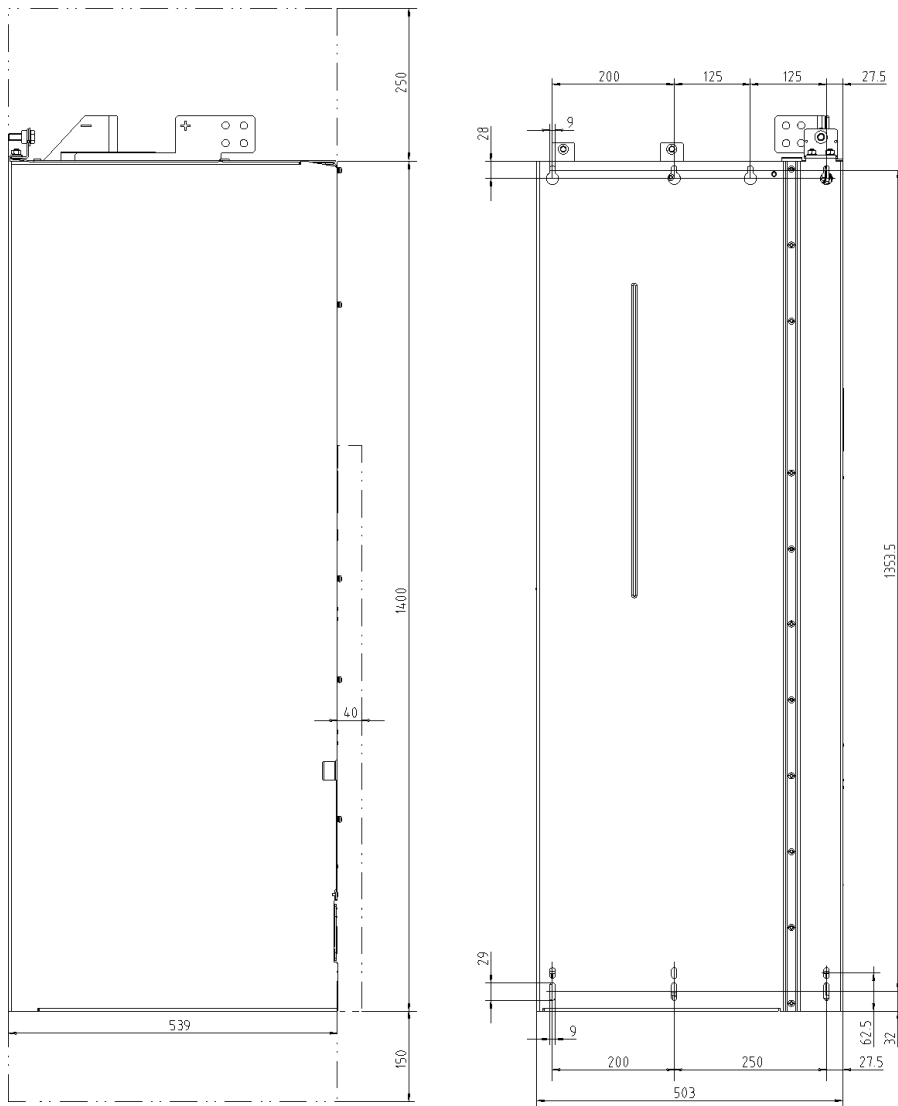
Dimension drawing 12, frame size HX:

380 V to 480 V

380 - 500 kW

500 V to 690 V

560 kW



Side view

Rear view

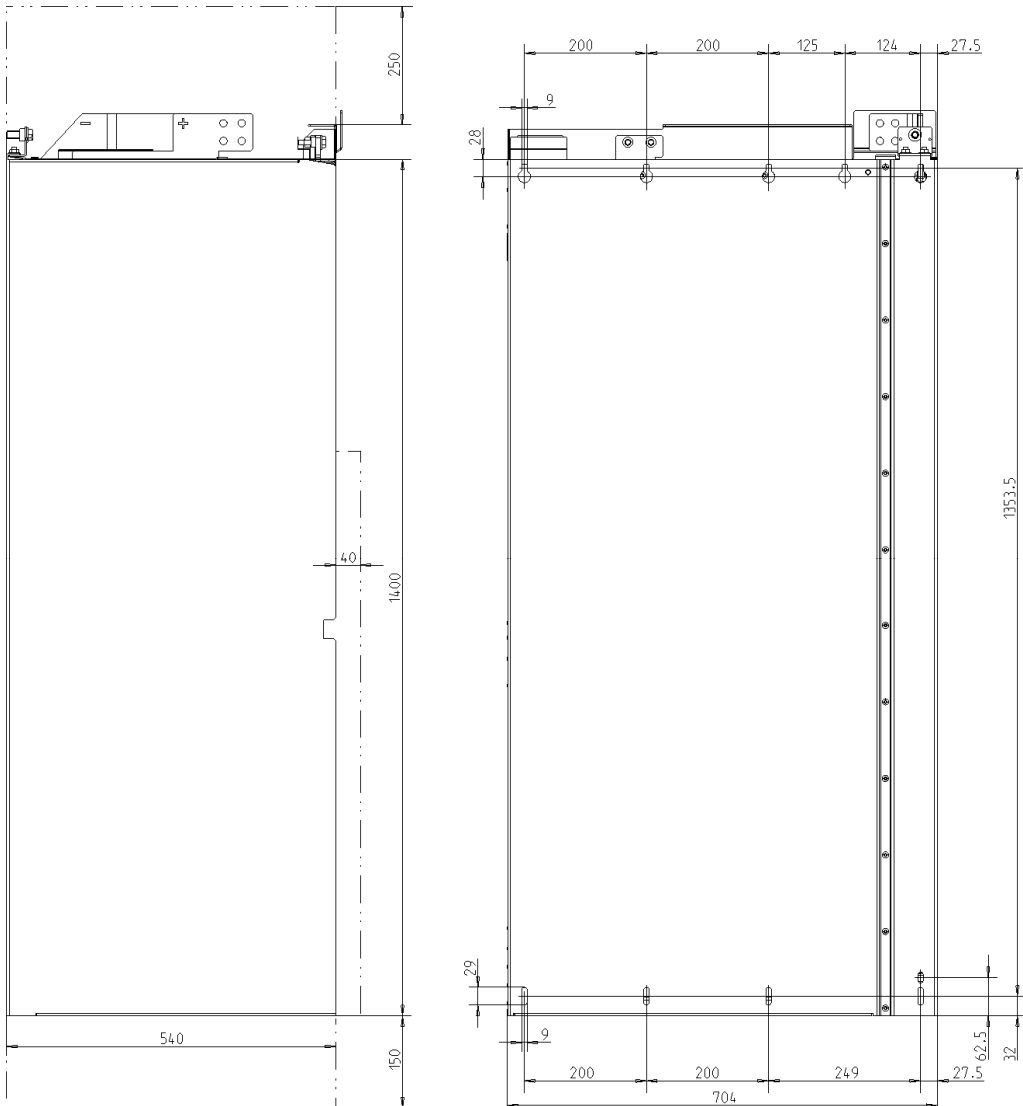
Required clearance for ventilation - - - - -

Line supply connection			DC link connection			Grounding		
Max. connection cross-section		M12 screw	Max. connection cross-section		Busbar connection	Max. connection cross-section		M12 screw
DIN VDE mm ²	NEC, CEC AWG/MCM	(No. of holes)	DIN VDE mm ²			DIN VDE mm ²	NEC, CEC AWG/MCM	(No. of holes)
4 x 240	4 x 500 MCM	(2)	60 x 60 x 5			PE1 PE2	1 x 240 2 x 240	1 x 500 MCM 2 x 500 MCM
								(1) (2)

SINAMICS S120 Chassis (Active Line Modules), continued

Dimension drawing 13, frame size JX:

380 V to 480 V 630 - 900 kW
500 V to 690 V 800 - 1400 kW



Side view				Rear view					
Required clearance for ventilation - - - - -									
Line supply connection				DC link connection			Grounding		
Max. connection cross-section		M12 screw	Max. connection cross-section		Busbar connection		Max. connection cross-section		M12 screw
DIN VDE mm²	NEC, CEC AWG/MCM	(No. of holes)	DIN VDE mm²				DIN VDE mm²	NEC, CEC AWG/MCM	(No. of holes)
6 x 240	6 x 500 MCM	(3)	60 x 60 x 8			PE1 PE2	1 x 240 2 x 240	1 x 500 MCM 2 x 500 MCM	(1) (2)

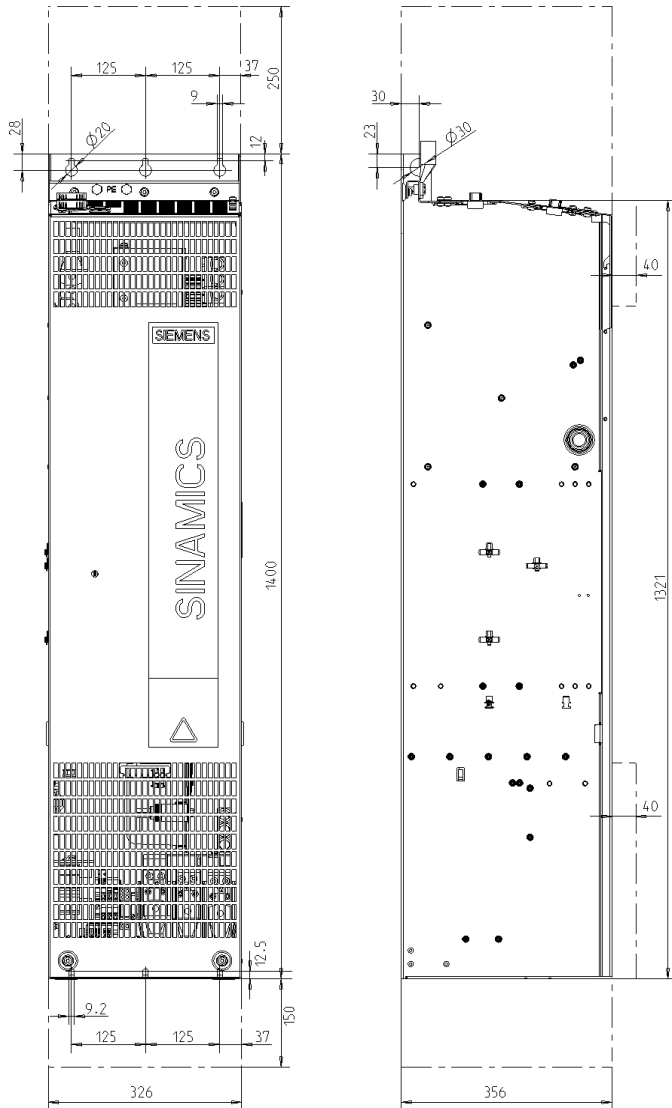
Dimension Drawings

Engineering Information

SINAMICS S120 Chassis (Motor Modules)

Dimension drawing 14, frame size FX:

380 V to 480 V 110 - 132 kW
500 V to 690 V 75 - 132 kW



Front view			Side view						
Required clearance for ventilation - - - - -									
DC link connection			Motor connection			Grounding			
Max. connection cross-section		M10 screw	Max. connection cross-section		M10 screw		Max. connection cross-section		M10 screw
DIN VDE mm²	NEC, CEC AWG/MCM	(No. of holes)	DIN VDE mm²	NEC, CEC AWG/MCM	(No. of holes)		DIN VDE mm²	NEC, CEC AWG/MCM	(No. of holes)
2 x 185	2 x 350 MCM	(1)	2 x 185	2 x 350 MCM	(1)	PE	2 x 185	2 x 350 MCM	(2)

SINAMICS S120 Chassis (Motor Modules), continued

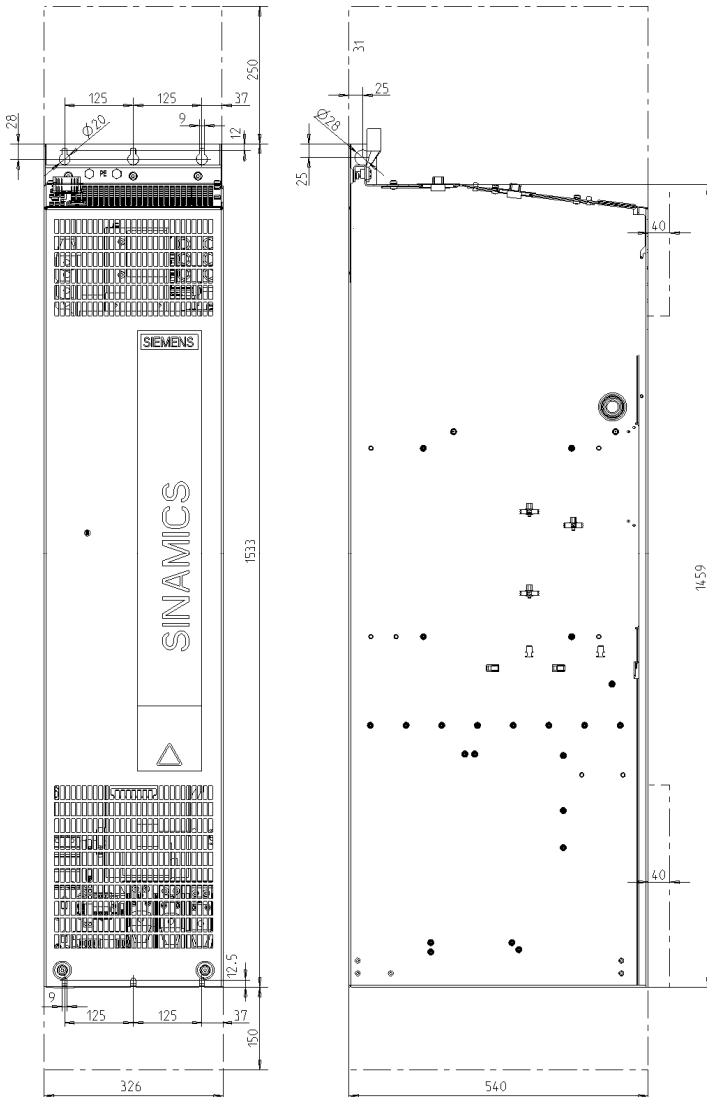
Dimension drawing 15, frame size GX:

380 V to 480 V

160 - 250 kW

500 V to 690 V

160 - 315 kW



Front view			Side view						
Required clearance for ventilation - - - - -									
DC link connection			Motor connection			Grounding			
Max. connection cross-section		M12 screw	Max. connection cross-section		M12 screw		Max. connection cross-section		M10 screw
DIN VDE mm²	NEC, CEC AWG/MCM	(No. of holes)	DIN VDE mm²	NEC, CEC AWG/MCM	(No. of holes)		DIN VDE mm²	NEC, CEC AWG/MCM	(No. of holes)
2 x 185	2 x 350 MCM	(1)	2 x 185	2 x 350 MCM	(1)	PE	2 x 185	2 x 350 MCM	(2)

Dimension Drawings

Engineering Information

SINAMICS S120 Chassis (Motor Modules), continued

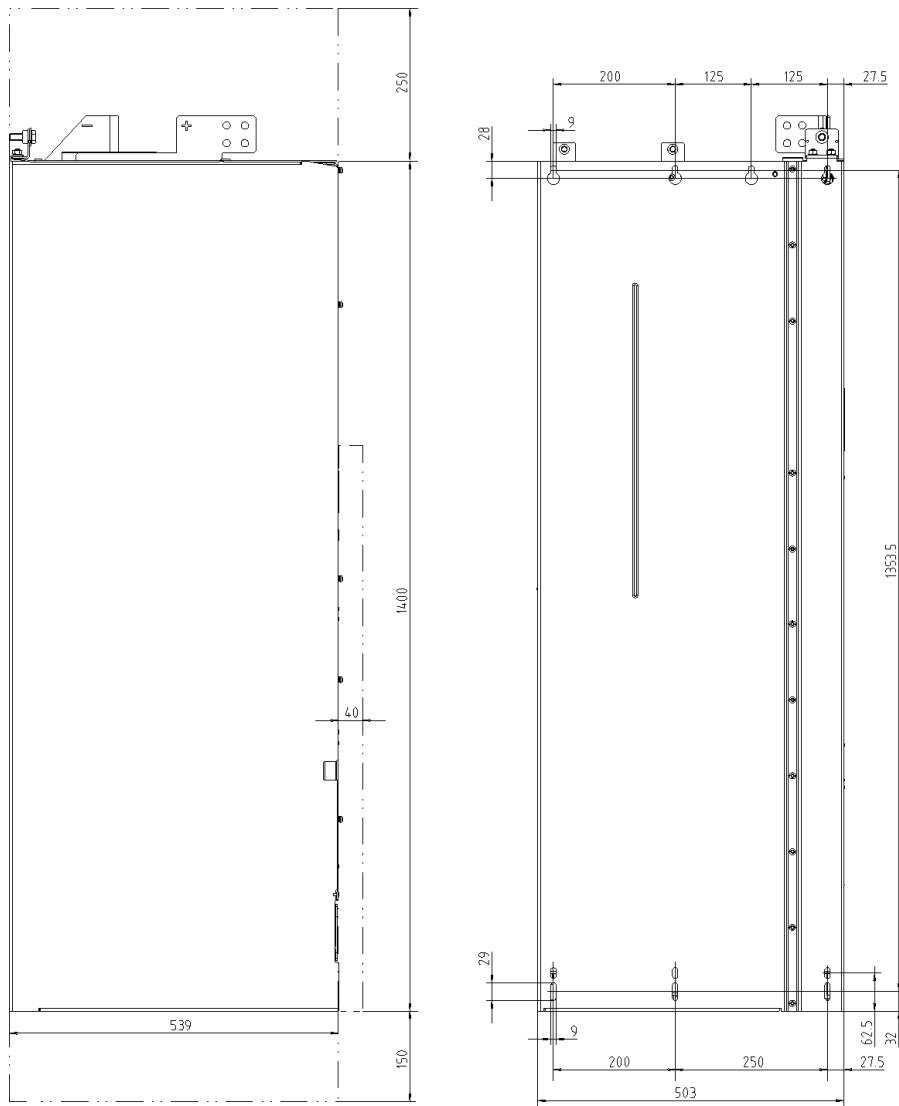
Dimension drawing 16, frame size HX:

380 V to 480 V

315 - 450 kW

500 V to 690 V

400 - 560 kW



Side view

Rear view

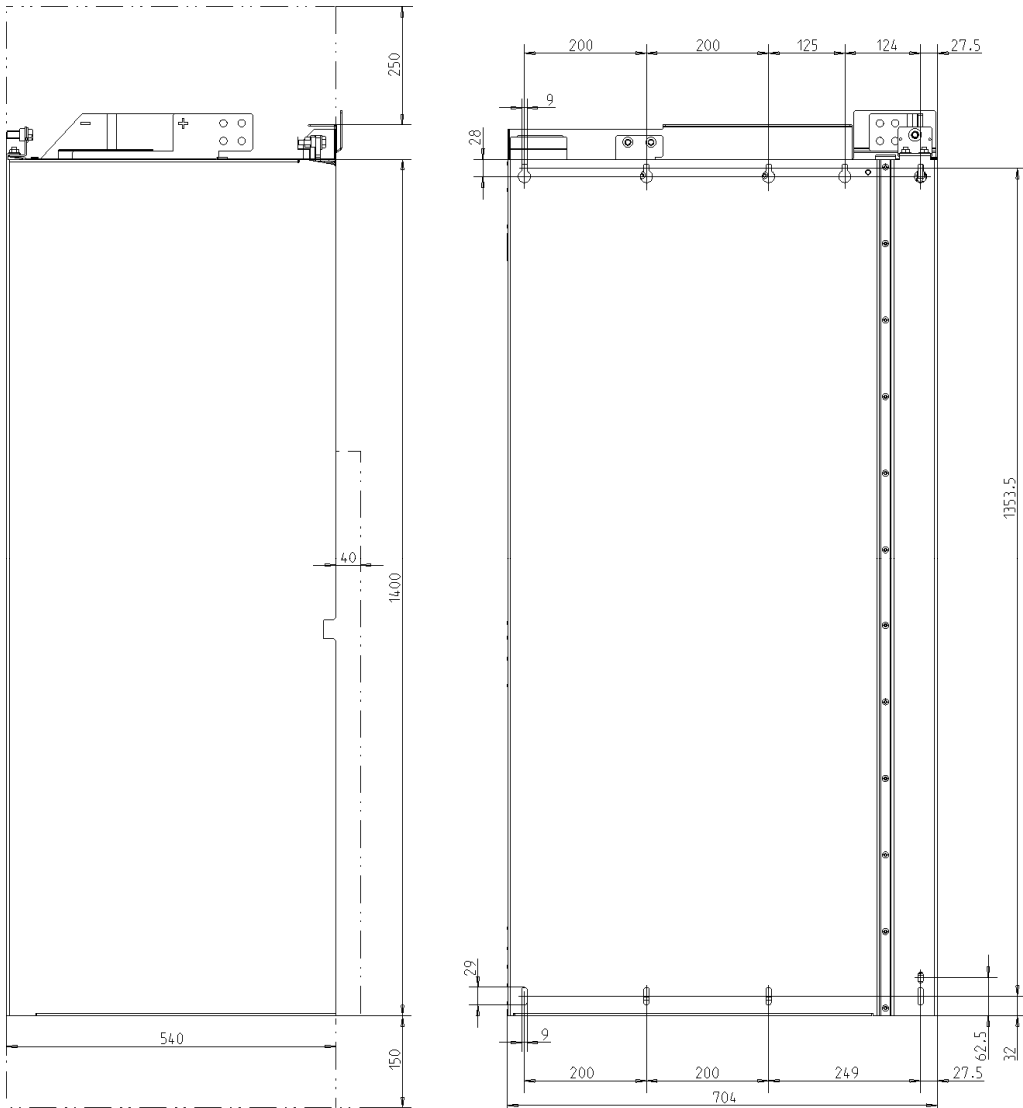
Required clearance for ventilation - - - - -

DC link connection		Motor connection			Grounding			
Max. connection cross-section		Busbar connection		Max. connection cross-section	M12 screw	Max. connection cross-section		M12 screw
DIN VDE mm ²		DIN VDE mm ²	NEC, CEC AWG/MCM	(No. of holes)		DIN VDE mm ²	NEC, CEC AWG/MCM	(No. of holes)
60 x 60 x 5		4 x 240	4 x 500 MCM	(2)	PE1 PE2	1 x 240 2 x 240	1 x 500 MCM 2 x 500 MCM	(1) (2)

SINAMICS S120 Chassis (Motor Modules), continued

Dimension drawing 17, frame size JX:

380 V to 480 V 560 - 800 kW
500 V to 690 V 710 - 1200 kW



Side view				Rear view					
Required clearance for ventilation - - - - -									
DC link connection			Motor connection			Grounding			
Cross-section per connection		Busbar connection	Max. cross-section per connection		M12 screw		Max. connection cross-section		Screw M12
DIN VDE mm²			DIN VDE mm²	NEC, CEC AWG/MCM	(No. of holes)		DIN VDE mm²	NEC, CEC AWG/MCM	(No. of holes)
60 x 60 x 8			6 x 240	6 x 500 MCM	(3)	PE1 PE2	1 x 240 2 x 240	1 x 500 MCM 2 x 500 MCM	(1) (2)

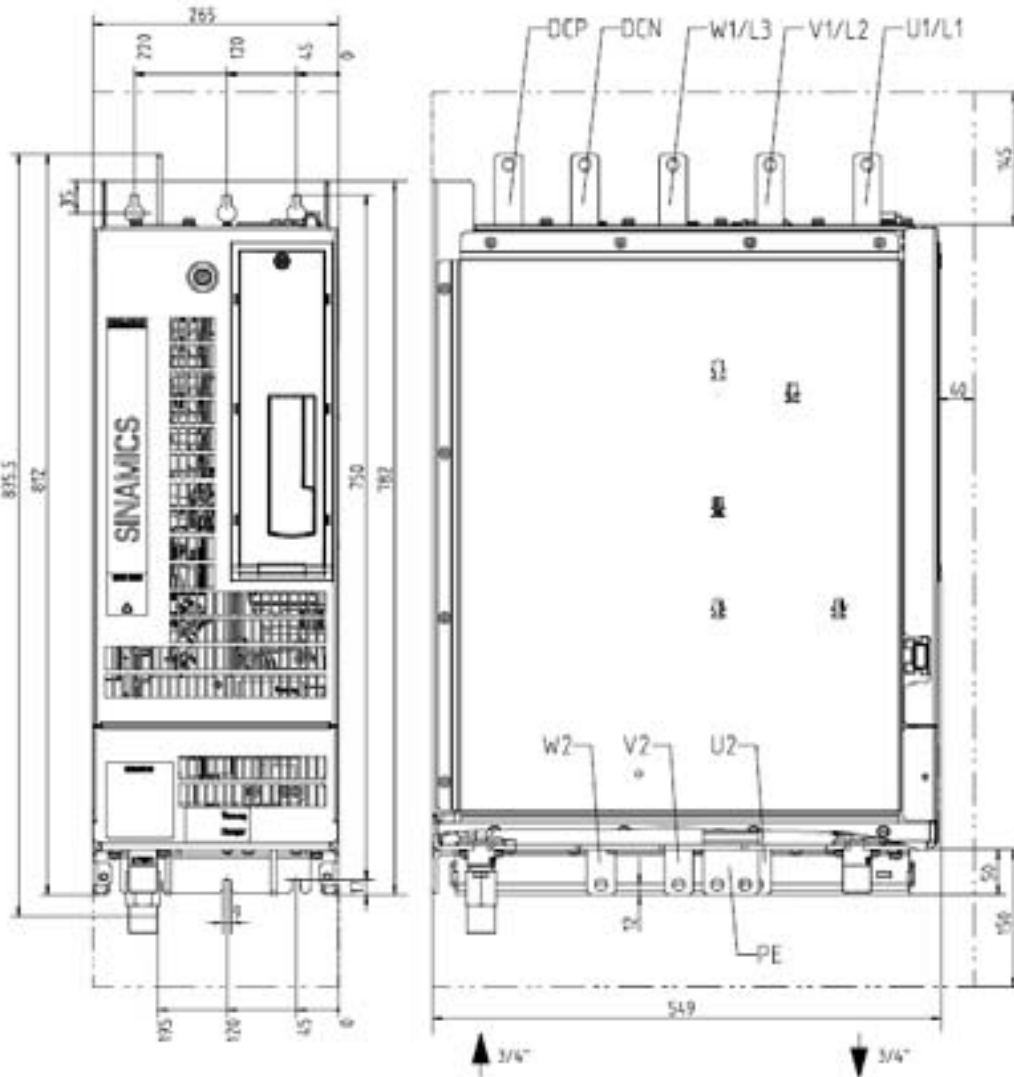
Dimension Drawings

Engineering Information

SINAMICS S120 Chassis Liquid Cooled (Power Modules)

Dimension drawing 1, frame size FL:

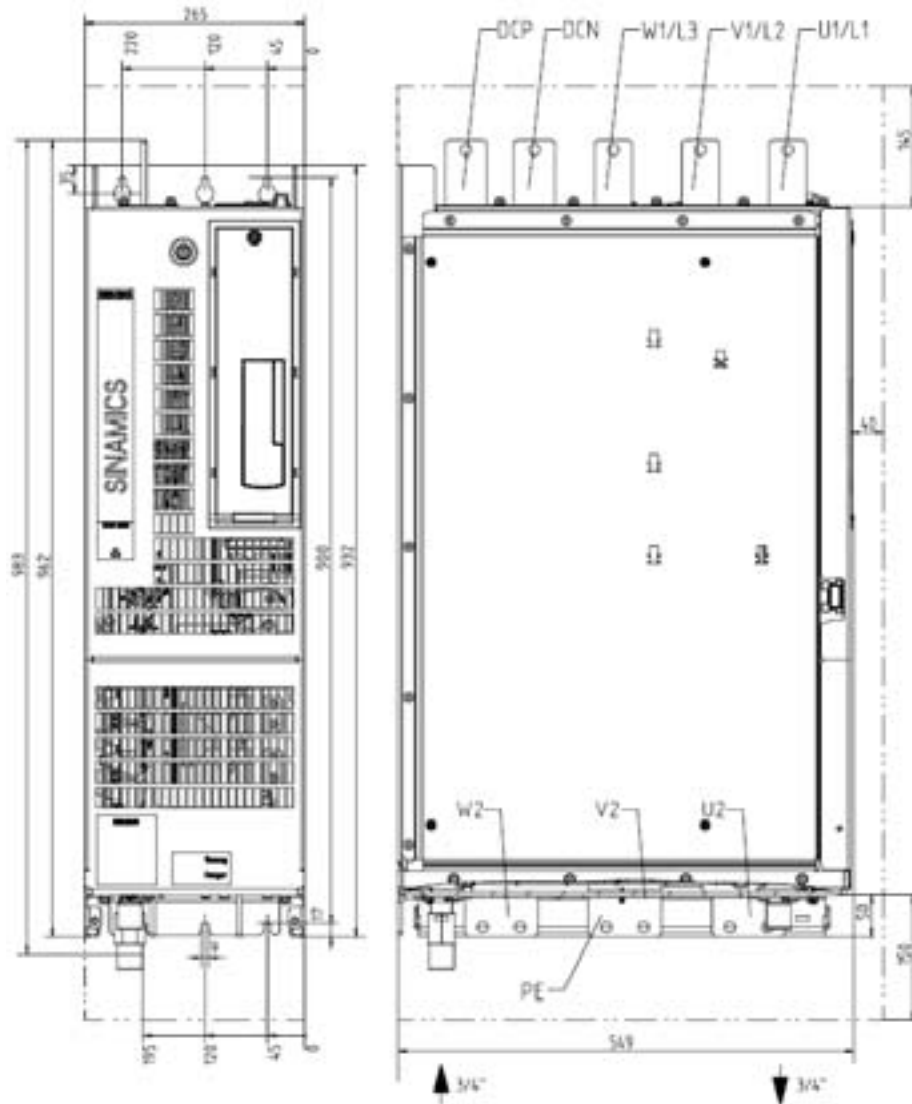
380 V to 480 V 110 – 132 kW



Front view			Side view						
Required clearance for ventilation - - - - -									
Line supply connection			Motor connection				Grounding		
Max. connection cross-section		M12 screw	Max. connection cross-section		M12 screw		Max. connection cross-section		M12 screw
DIN VDE mm²	NEC, CEC AWG/MCM	(No. of holes)	DIN VDE mm²	NEC, CEC AWG/MCM	(No. of holes)		DIN VDE mm²	NEC, CEC AWG/MCM	(No. of holes)
2 x 95		(2)	2 x 95		(2)	PE	2 x 95		(2)

SINAMICS S120 Chassis Liquid Cooled (Power Modules), continued

Dimension drawing 2, frame size GL:
380 V to 480 V 160 – 250 kW



Front view			Side view						
Required clearance for ventilation - - - - -									
Line supply connection			Motor connection				Grounding		
Max. connection cross-section		M12 screw	Max. connection cross-section		M12 screw		Max. connection cross-section		M12 screw
DIN VDE mm²	NEC, CEC AWG/MCM	(No. of holes)	DIN VDE mm²	NEC, CEC AWG/MCM	(No. of holes)		DIN VDE mm²	NEC, CEC AWG/MCM	(No. of holes)
2 x 240	2 x 500 MCM	(2)	2 x 240	2 x 500 MCM	(2)	PE	2 x 240	2 x 500 MCM	(2)

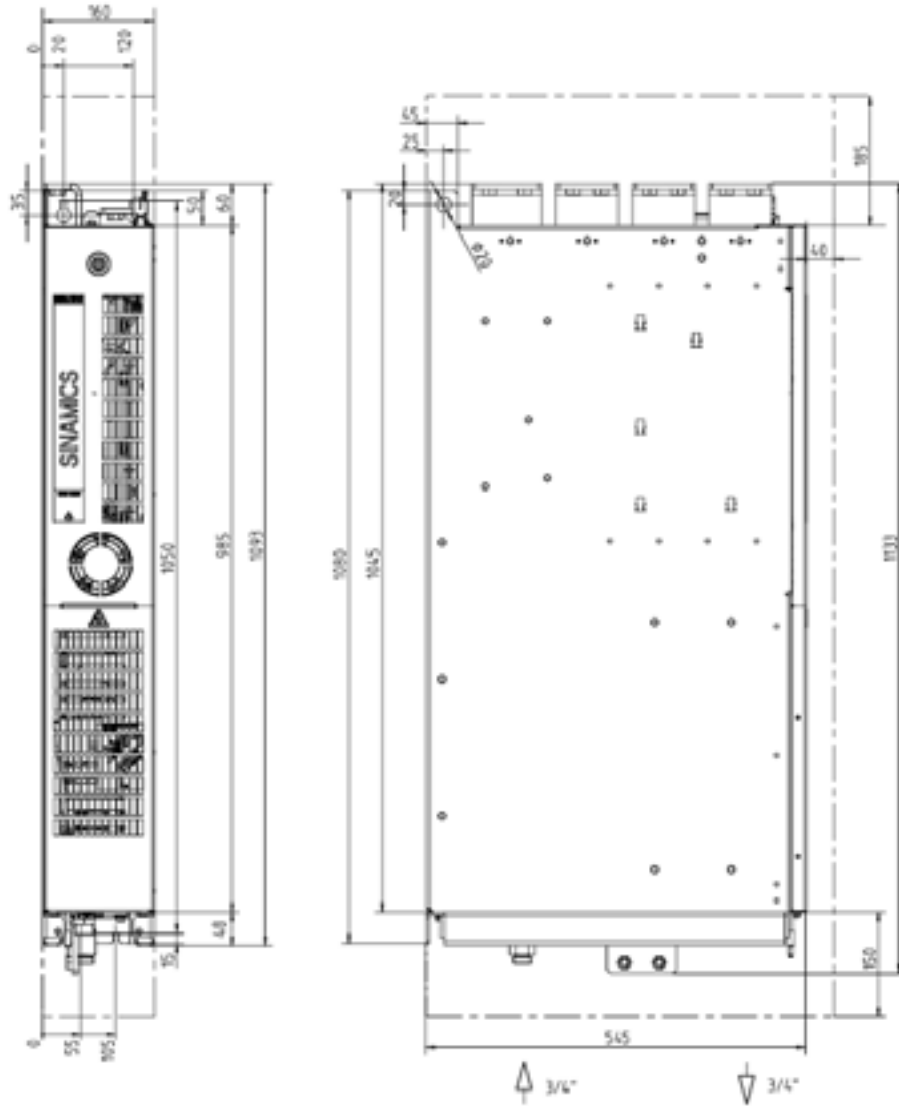
Dimension Drawings

Engineering Information

SINAMICS S120 Chassis Liquid Cooled (Basic Line Modules)

Dimension drawing 3, frame size FBL:

380 V to 480 V 360 - 600 kW
500 V to 690 V 355 - 630 kW



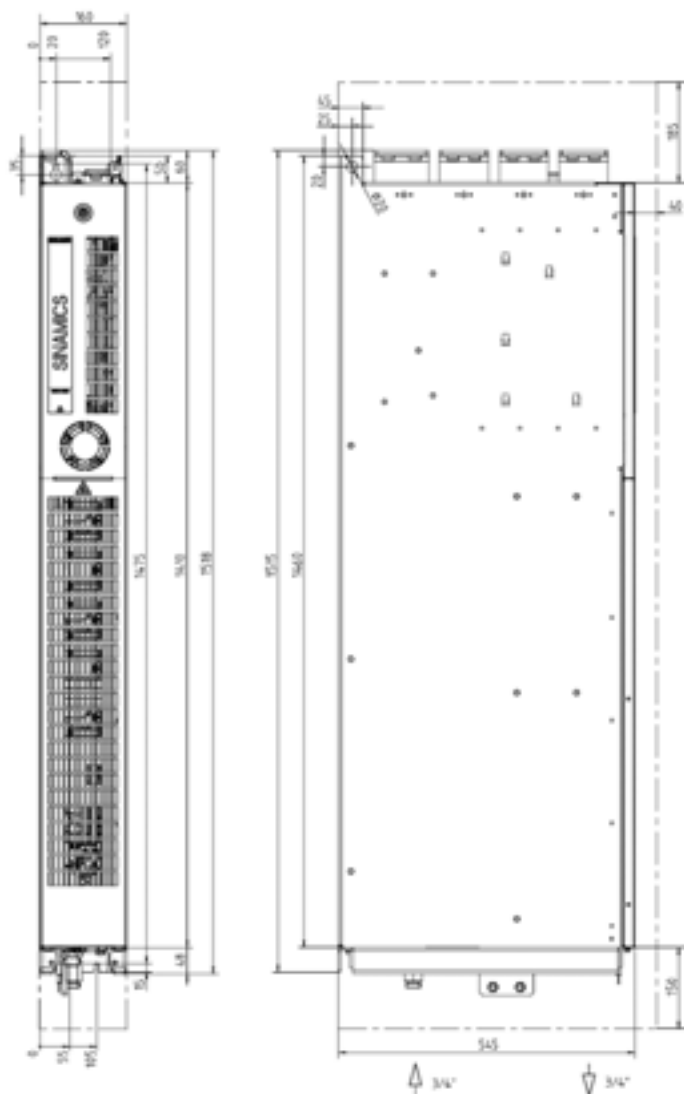
Front view				Side view							
Required clearance for ventilation - - - - -											
Line supply connection				DC link connection			Grounding				
Max. connection cross-section		Busbar connection		Max. connection cross-section		Busbar connection			Max. connection cross-section		M12 screw
DIN VDE mm²			DIN VDE mm²				DIN VDE mm²	NEC, CEC AWG/MCM		(No. of holes)	
90 x 35 x 8			100 x 35 x 8			PE	2 x 240	2 x 500 MCM		(2)	

SINAMICS S120 Chassis Liquid Cooled (Basic Line Modules), continued

Dimension drawing 4, frame size GBL:

500 V to 690 V

1100 - 1370 kW



Front view				Side view					
Required clearance for ventilation - - - - -									
Line supply connection			DC link connection			Grounding			
Max. connection cross-section		Busbar connection	Max. connection cross-section		Busbar connection		Max. connection cross-section		M12 screw
DIN VDE mm²			DIN VDE mm²				DIN VDE mm²	NEC, CEC AWG/MCM	(No. of holes)
90 x 35 x 8			100 x 35 x 8			PE	2 x 240	2 x 500 MCM	(2)

Dimension Drawings

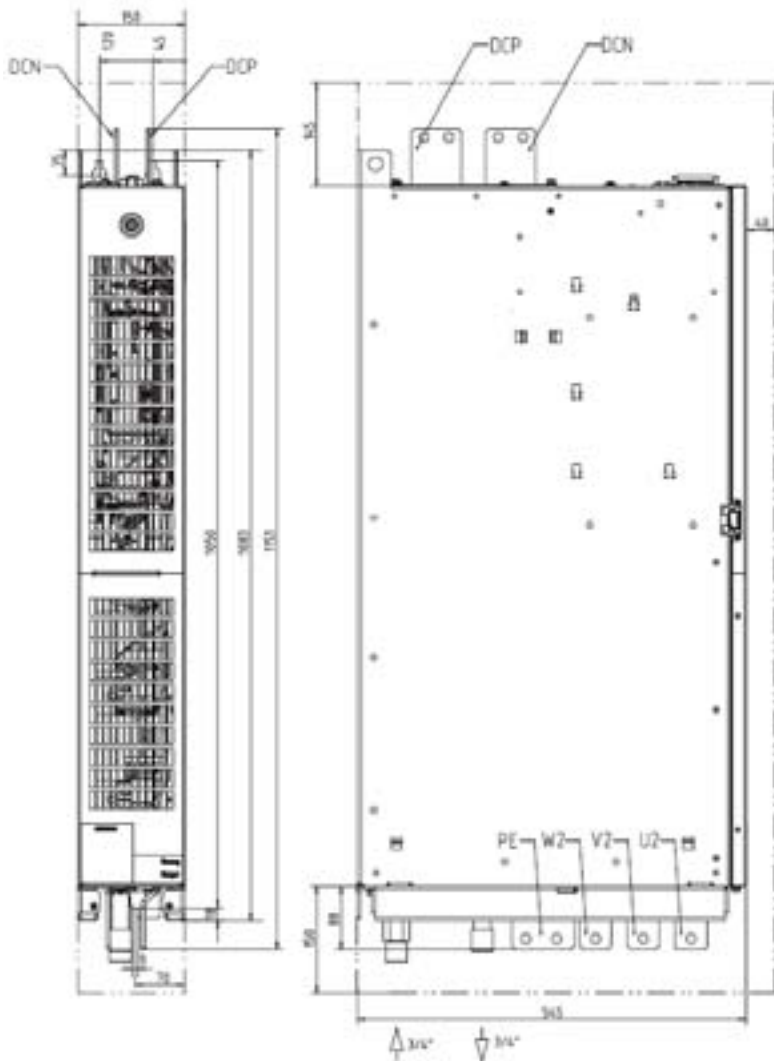
Engineering Information

SINAMICS S120 Chassis Liquid Cooled (Motor Modules)

Dimension drawing 5, frame size GXL:

380 V to 480 V

160 – 250 kW



Front view

Side view

Required clearance for ventilation - - - - -

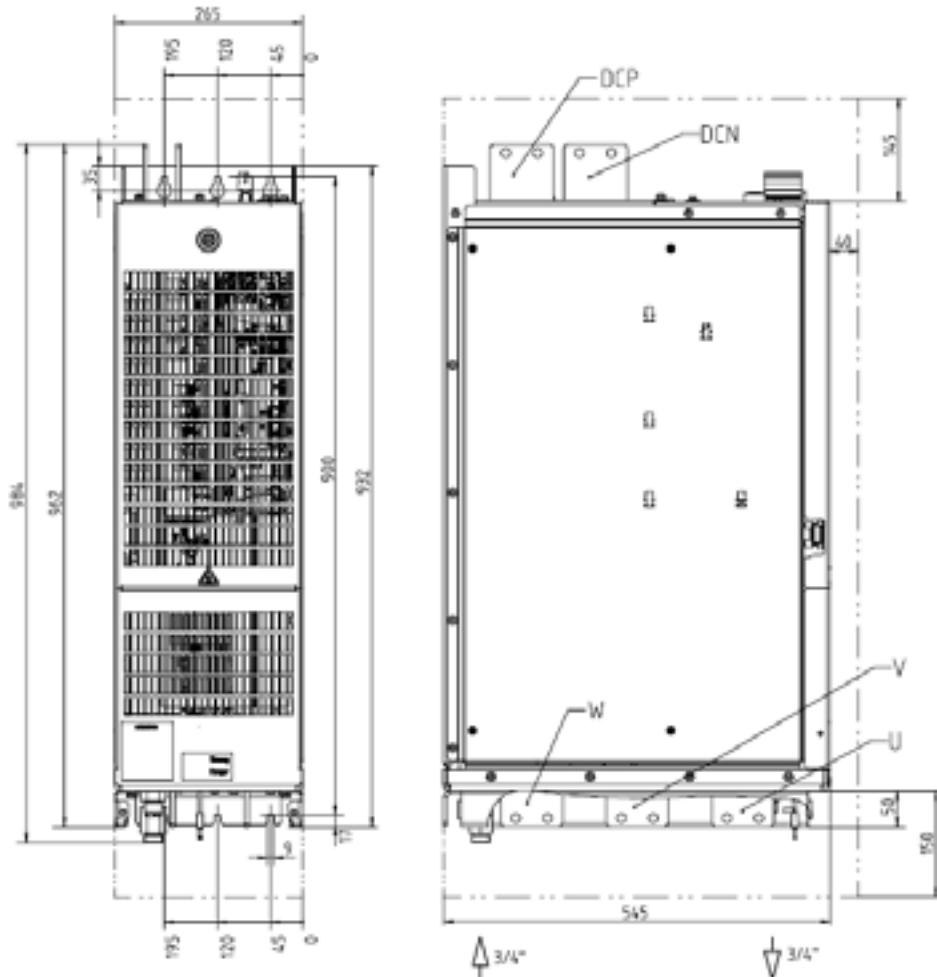
Dc link connection			Motor connection			Grounding			
Max. connection cross-section		M12 screw	Max. connection cross-section		M12 screw		Max. connection cross-section		M12 screw
DIN VDE mm ²	NEC, CEC AWG/MCM	(No. of holes)	DIN VDE mm ²	NEC, CEC AWG/MCM	(No. of holes)		DIN VDE mm ²	NEC, CEC AWG/MCM	(No. of holes)
2 x 240	2 x 500 MCM	(2)	2 x 240	2 x 500 MCM	(2)	PE	2 x 240	2 x 500 MCM	(2)

SINAMICS S120 Chassis Liquid Cooled (Motor Modules), continued

Dimension drawing 6, frame size HXL:

500 V to 690 V

560 kW



Front view				Side view						
Required clearance for ventilation - - - - -										
DC link connection				Motor connection			Grounding			
Max. connection cross-section		Busbar connection		Max. connection cross-section		M12 screw		Max. connection cross-section		M12 screw
DIN VDE mm²			DIN VDE mm²	NEC, CEC AWG/MCM	(No. of holes)		DIN VDE mm²	NEC, CEC AWG/MCM	(No. of holes)	
90 x 35 x 6			4 x 185	4 x 350 MCM	(2)	PE	4 x 185	4 x 350 MCM	(2)	

Dimension Drawings

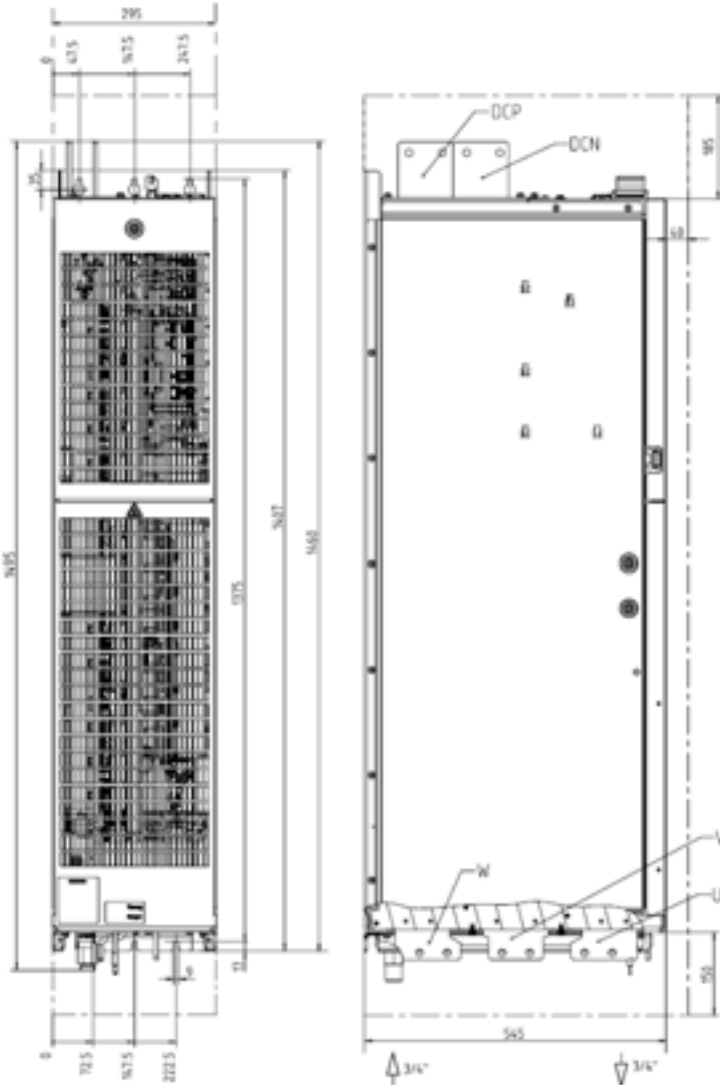
Engineering Information

SINAMICS S120 Chassis Liquid Cooled (Motor Modules), continued

Dimension drawing 7, frame size JXL:

500 V to 690 V

800 - 1200 kW



Front view

Side view

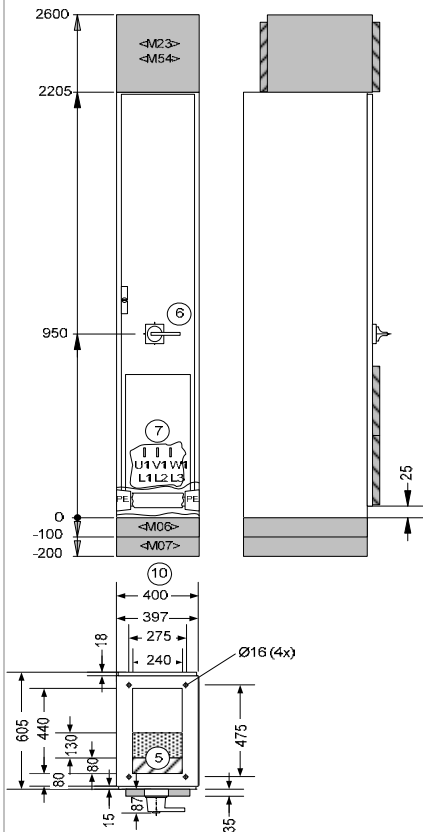
Required clearance for ventilation - - - - -

DC link connection		Motor connection		Grounding			
Max. connection cross-section	Busbar connection	Max. connection cross-section	Busbar connection		Max. connection cross-section	M12 screw	
DIN VDE mm ²		DIN VDE mm ²			DIN VDE mm ²	NEC, CEC AWG/MCM	(No. of holes)
100 x 35 x 8		100 x 35 x 8		PE	4 x 240	4 x 500 MCM	(2)

SINAMICS S120 Cabinet Modules (Line Connection Modules)

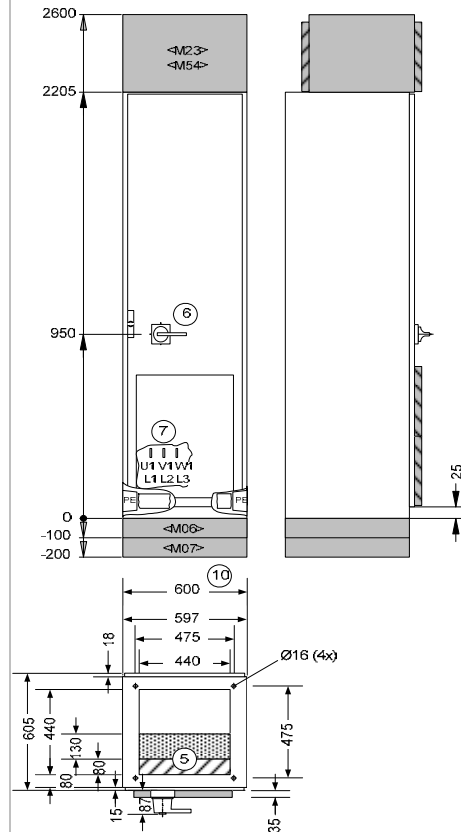
Dimension drawing 1:

380 V to 480 V 250 - 400 A
500 V to 690 V 280 - 400 A

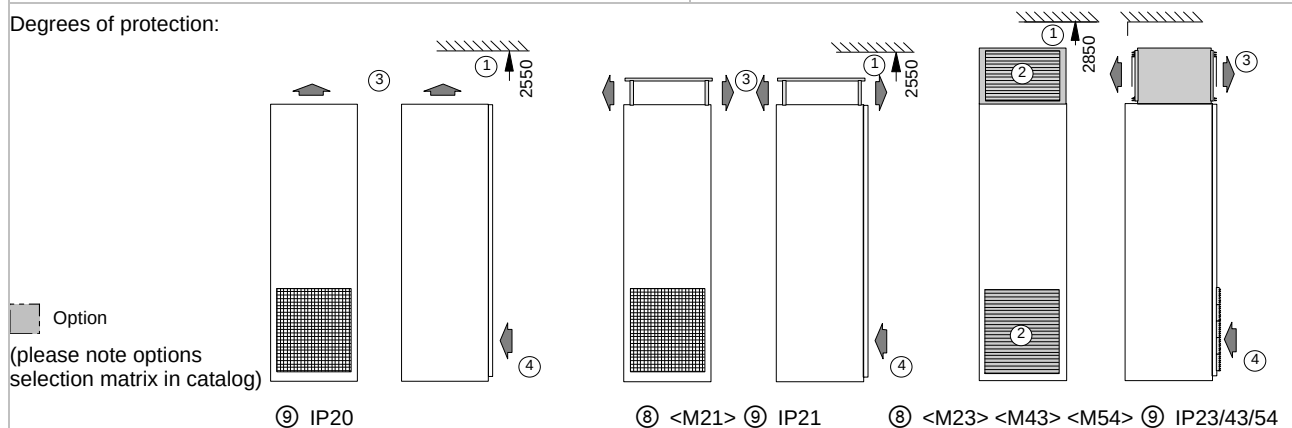


Dimension drawing 2:

380 V to 480 V 630 - 800 A
500 V to 690 V 630 - 800 A



Degrees of protection:



Legend:

1. Minimum ceiling height for wall mounting
2. Ventilation grid
3. Air outlet area
4. Air inlet area
5. Cables can enter from below within hatched area
6. Main circuit breaker, can be secured by padlock

7. Power connection, Infeed from below
8. Degree of protection option
9. Degree of protection IP20

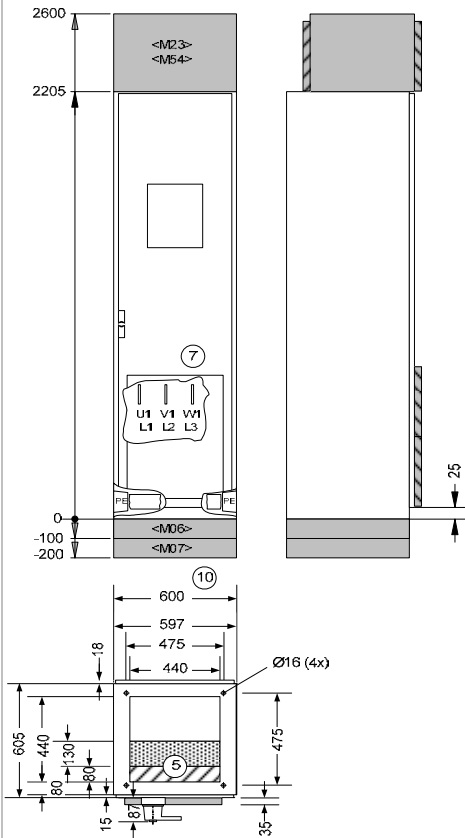
IP21 Option <M21>
IP23 Option <M23>
IP43 Option <M43>
IP54 Option <M54>

10. Transport unit

SINAMICS S120 Cabinet Modules (Line Connection Modules), continued

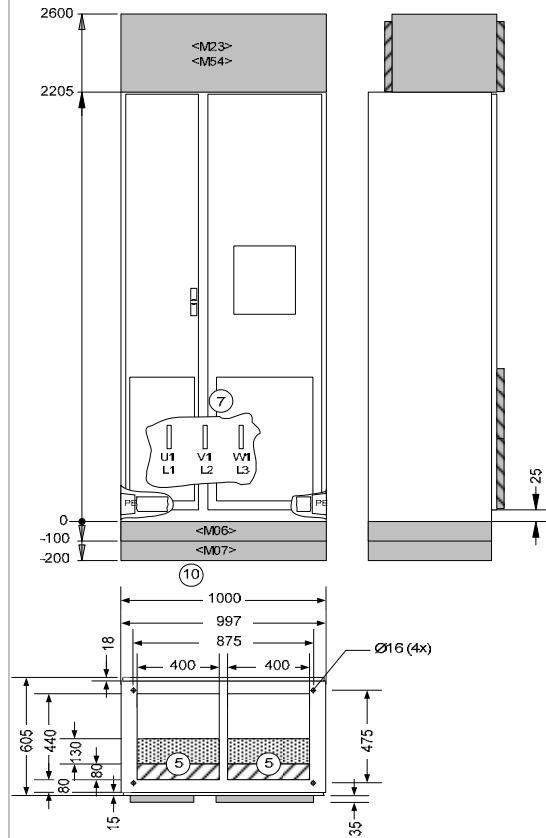
Dimension drawing 3:

380 V to 480 V 1000 - 1600 A
500 V to 690 V 1000 - 1600 A

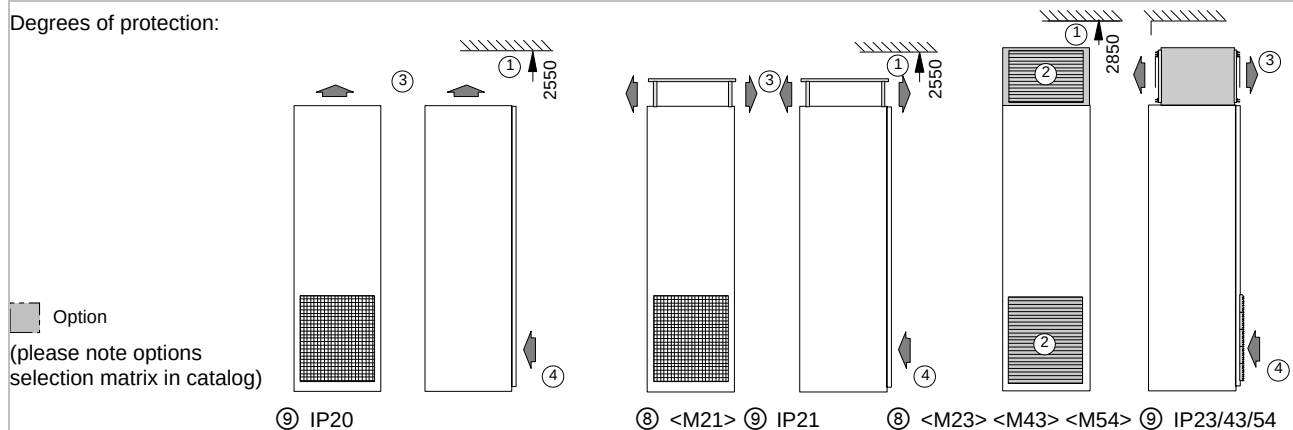


Dimension drawing 4:

380 V to 480 V 2000 - 3200 A
500 V to 690 V 2000 - 3200 A



Degrees of protection:



Legend:

- Minimum ceiling height for wall mounting
- Ventilation grid
- Air outlet area
- Air inlet area
- Cables can enter from below within hatched area
-

- Power connection, Infeed from below

- Degree of protection option

- Degree of protection IP20

IP21 Option <M21>

IP23 Option <M23>

IP43 Option <M43>

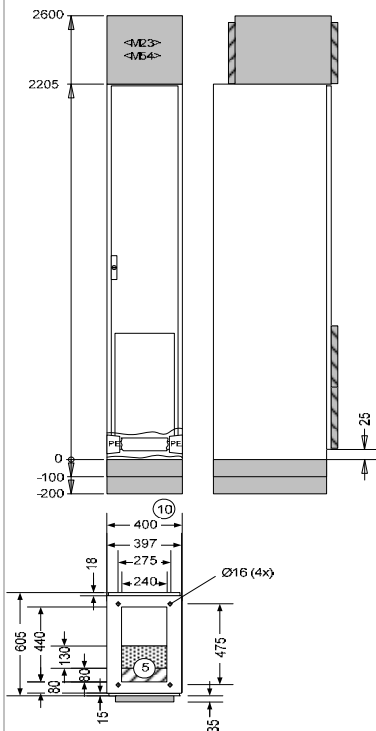
IP54 Option <M54>

- Transport unit

SINAMICS S120 Cabinet Modules (Basic Line Modules)

Dimension drawing 5:

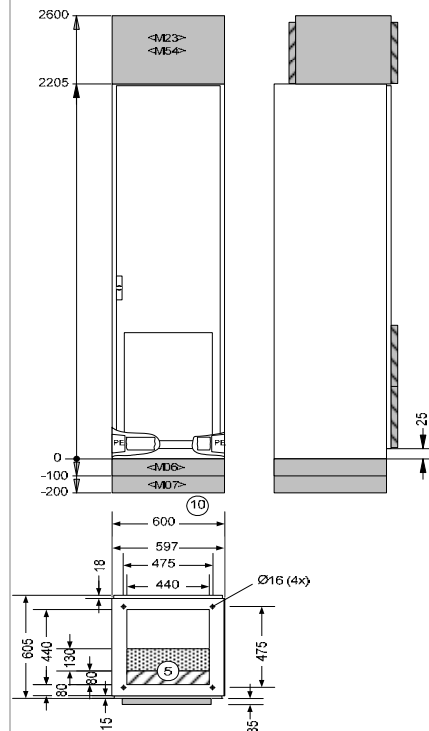
380 V to 480 V 200 - 560 kW
500 V to 690 V 250 - 1500 kW



Dimension drawing 6:

380 V to 480 V 560 - 900 kW
500 V to 690 V 900 - 1500 kW

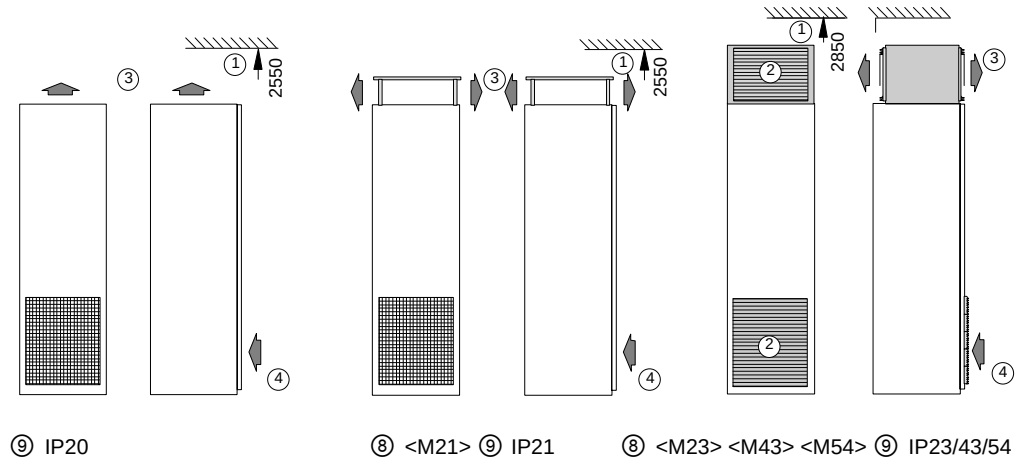
(for creating parallel connections of Basic Line Modules with line-side fuses)



Degrees of protection:

Option

(please note options selection matrix in catalog)



Legend:

- Minimum ceiling height for wall mounting
- Ventilation grid
- Air outlet area
- Air inlet area
- Cables can enter from below within hatched area
-

-
-
-
-
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-
- Degree of protection option
- Degree of protection IP20

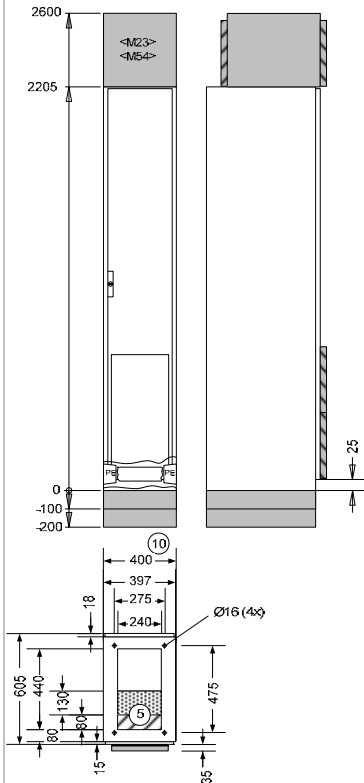
IP21 Option <M21>
IP23 Option <M23>
IP43 Option <M43>
IP54 Option <M54>

-
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-
-
-
-
-
- Transport unit

SINAMICS S120 Cabinet Modules (Smart Line Modules)

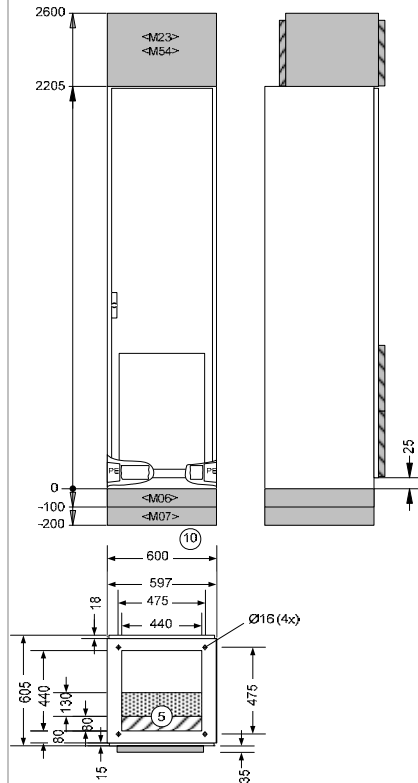
Dimension drawing 7:

380 V to 480 V 250 - 355 kW
500 V to 690 V 450 kW

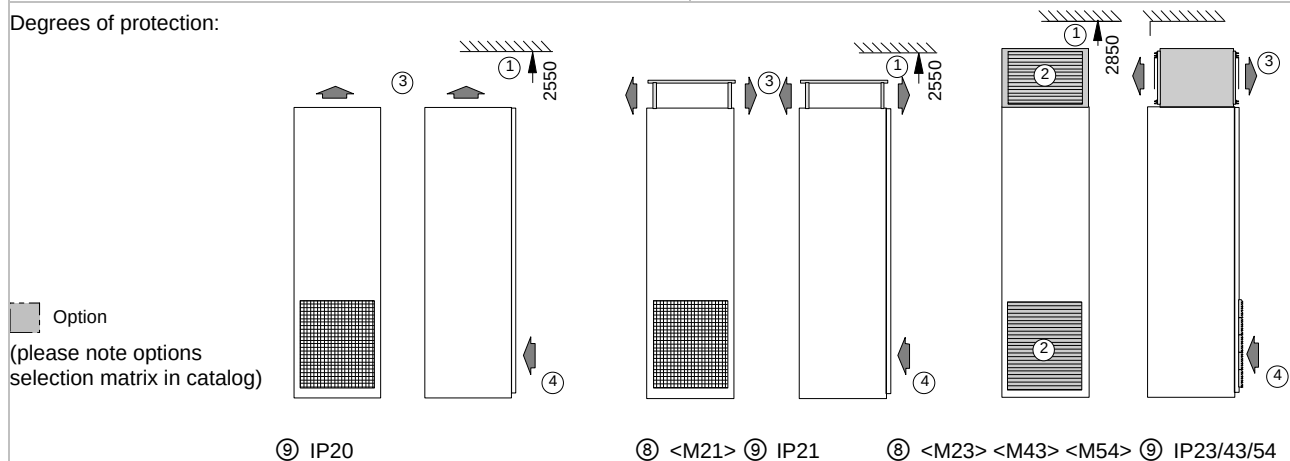


Dimension drawing 8:

380 V to 480 V 500 kW
500 V to 690 V 710 kW



Degrees of protection:



Legend:

- Minimum ceiling height for wall mounting
- Ventilation grid
- Air outlet area
- Air inlet area
- Cables can enter from below within hatched area
-

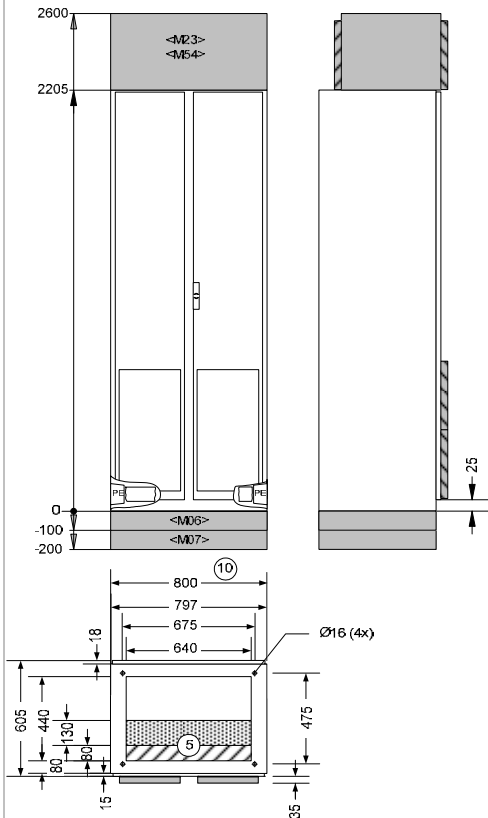
-
-
-
-
-
-
-
- Degree of protection option
- Degree of protection IP20
IP21 Option <M21>
IP23 Option <M23>
IP43 Option <M43>
IP54 Option <M54>

10. Transport unit

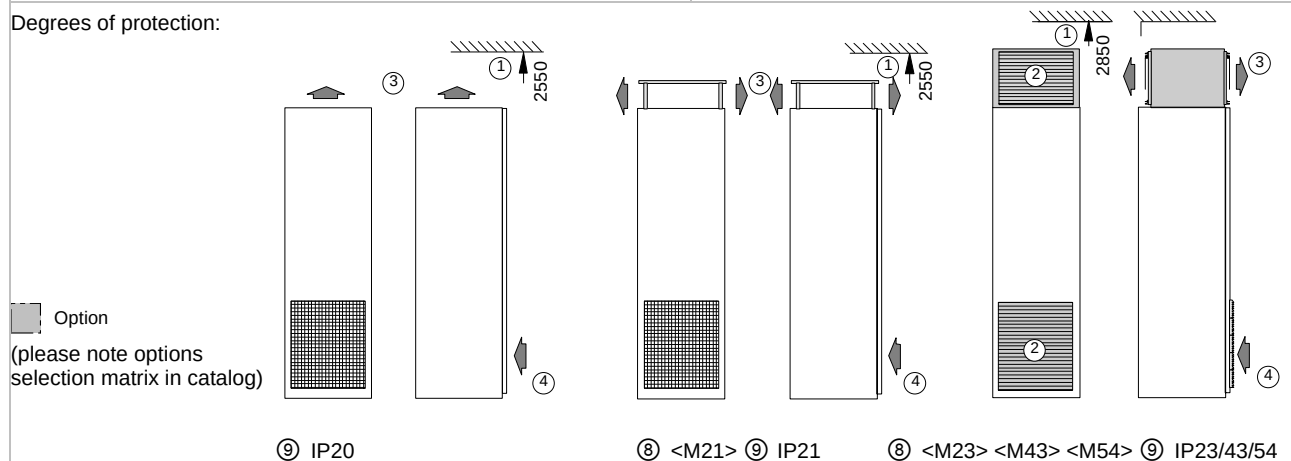
SINAMICS S120 Cabinet Modules (Smart Line Modules), continued

Dimension drawing 9:

380 V to 480 V 630 - 800 kW
500 V to 690 V 1000 - 1400 kW



Degrees of protection:



Legend:

1. Minimum ceiling height for wall mounting
2. Ventilation grid
3. Air outlet area
4. Air inlet area
5. Cables can enter from below within hatched area
- 6.

- 7.
8. Degree of protection option
9. Degree of protection IP20

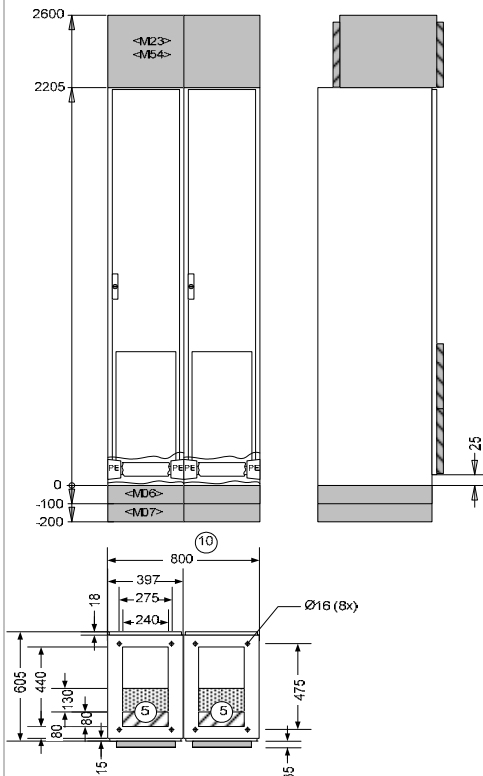
IP21 Option <M21>
IP23 Option <M23>
IP43 Option <M43>
IP54 Option <M54>

10. Transport unit

SINAMICS S120 Cabinet Modules (Active Interface Modules + Active Line Modules)

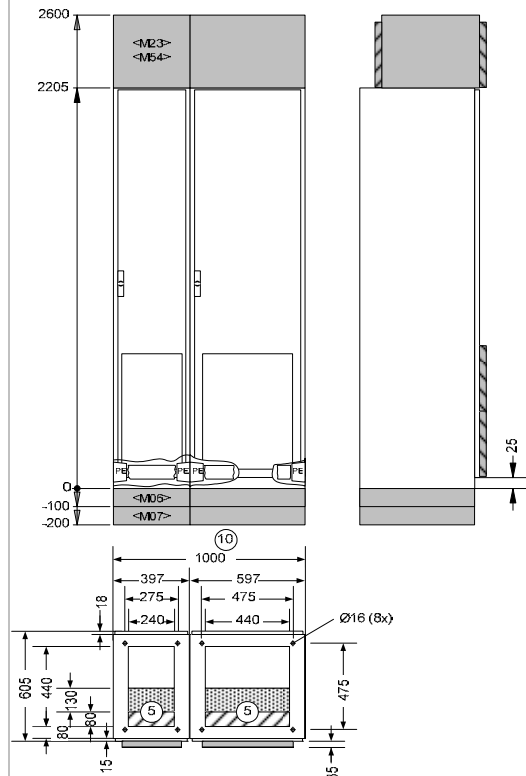
Dimension drawing 10:

380 V to 480 V 132 - 300 kW
500 V to 690 V 160 - 315 kW

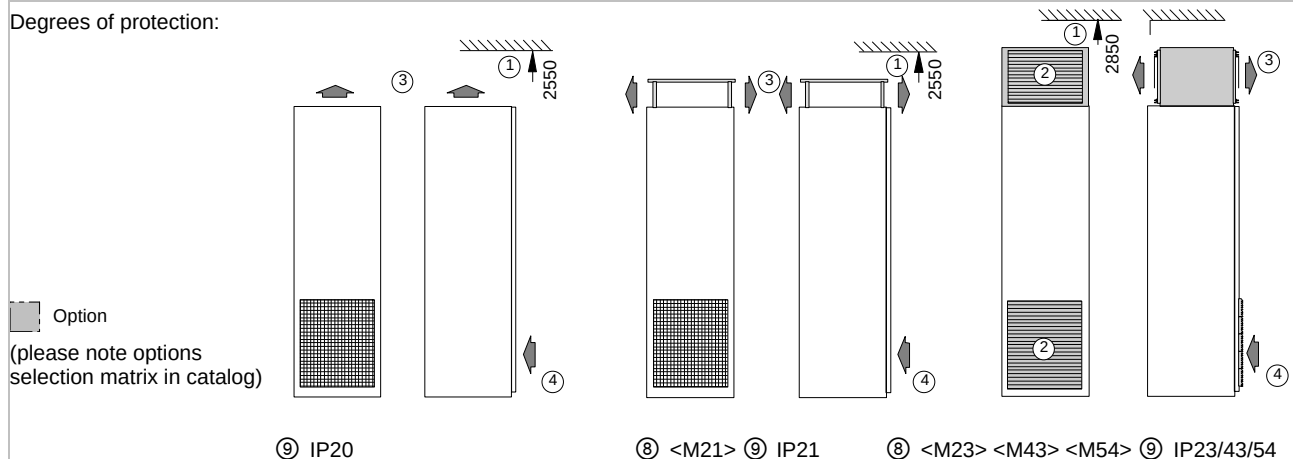


Dimension drawing 11:

380 V to 480 V 380 - 500 kW
500 V to 690 V 560 kW



Degrees of protection:



Legend:

1. Minimum ceiling height for wall mounting
2. Ventilation grid
3. Air outlet area
4. Air inlet area
5. Cables can enter from below within hatched area
- 6.

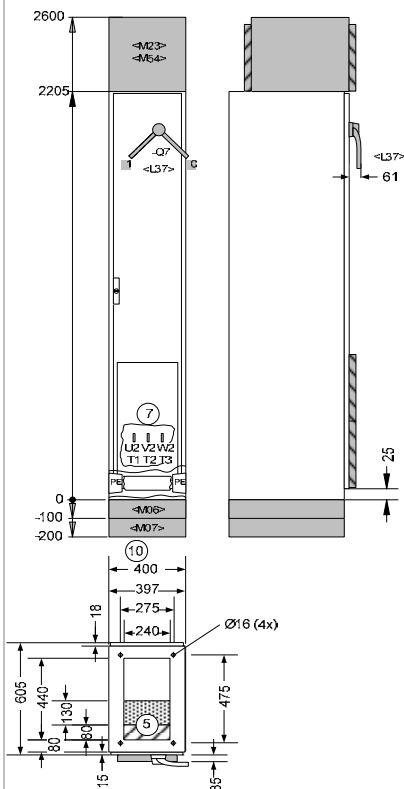
- 7.
8. Degree of protection option
9. Degree of protection IP20
IP21 Option <M21>
IP23 Option <M23>
IP43 Option <M43>
IP54 Option <M54>

10. Transport unit

SINAMICS S120 Cabinet Modules (Motor Modules)

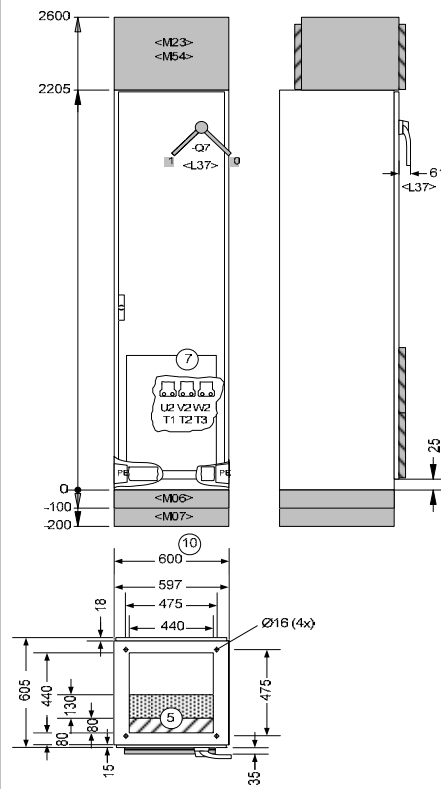
Dimension drawing 13:

380 V to 480 V 110 - 250 kW
500 V to 690 V 75 - 315 kW

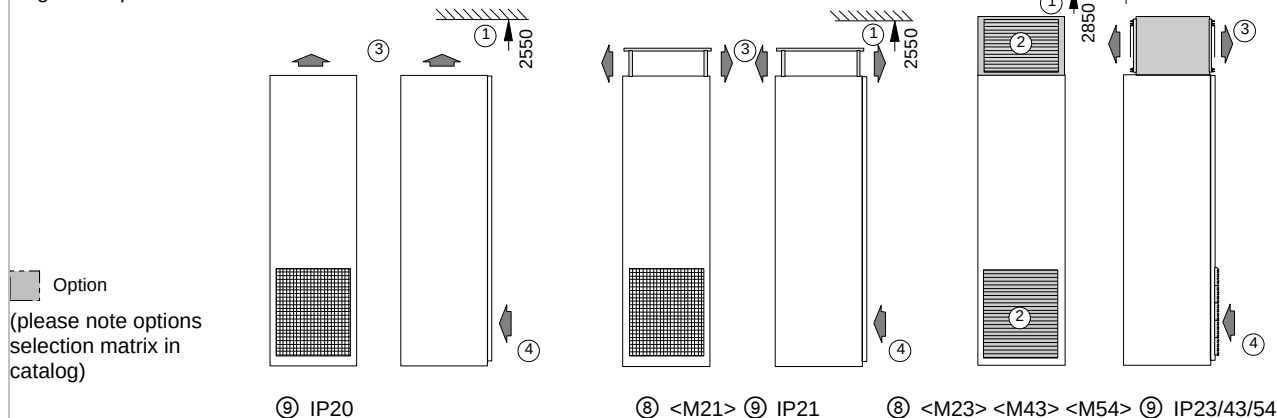


Dimension drawing 14:

380 V to 480 V 315 - 450 kW
500 V to 690 V 400 - 560 kW



Degrees of protection:



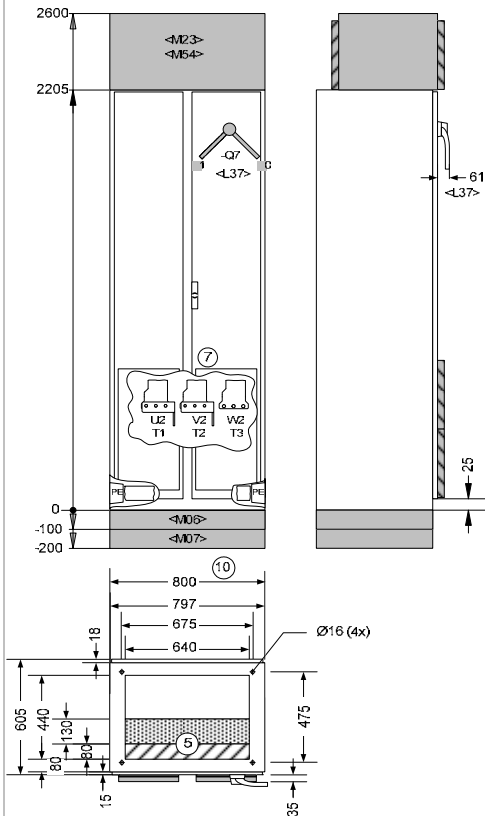
Legend:

- Minimum ceiling height for wall mounting
- Ventilation grid
- Air outlet area
- Air inlet area
- Cables can enter from below within hatched area
-
- Power connection, motor outgoing feeder below
- Degree of protection option
- Degree of protection IP20
IP21 Option <M21>
IP23 Option <M23>
IP43 Option <M43>
IP54 Option <M54>
- Transport unit

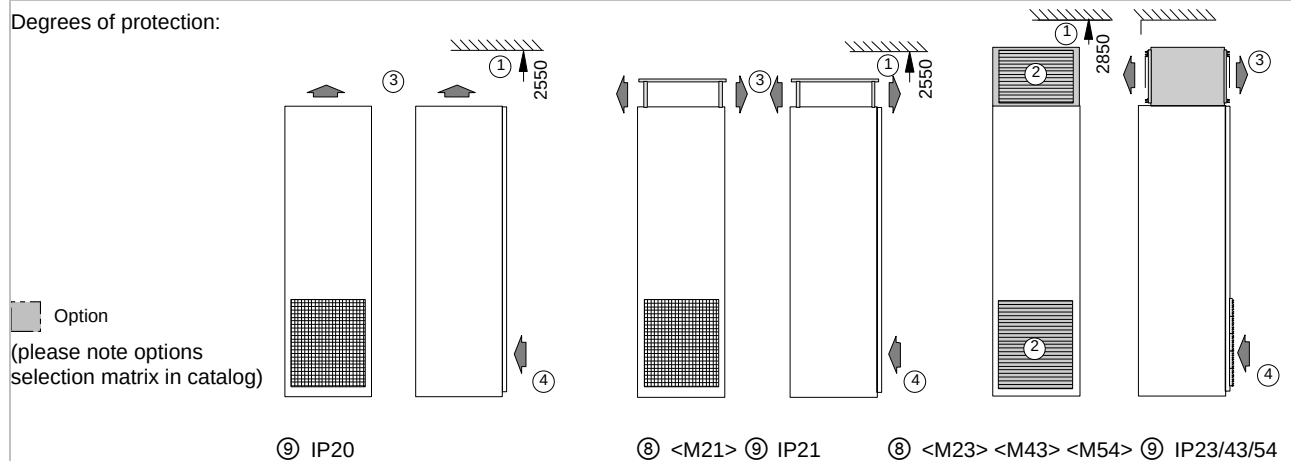
SINAMICS S120 Cabinet Modules (Motor Modules), continued

Dimension drawing 15:

380 V to 480 V 560 - 800 kW
500 V to 690 V 710 - 1200 kW



Degrees of protection:



Legend:

1. Minimum ceiling height for wall mounting
2. Ventilation grid
3. Air outlet area
4. Air inlet area
5. Cables can enter from below within hatched area
- 6.

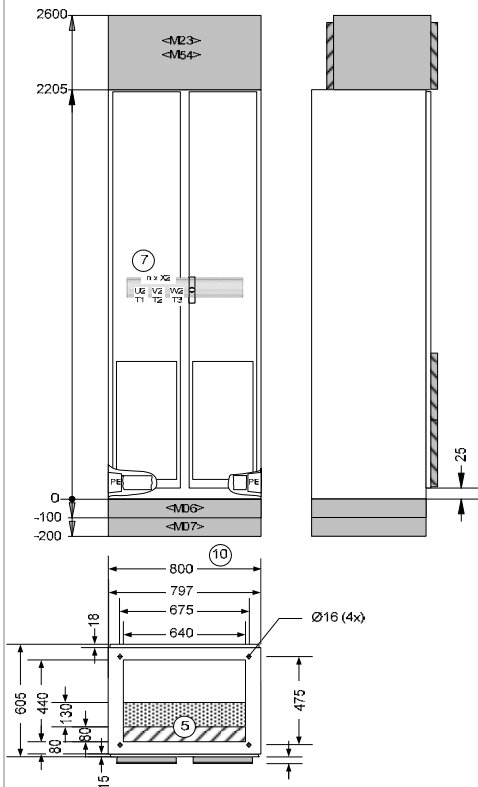
7. Power connection, motor outgoing feeder below
8. Degree of protection option
9. Degree of protection IP20
 - IP21 Option <M21>
 - IP23 Option <M23>
 - IP43 Option <M43>
 - IP54 Option <M54>

10. Transport unit

SINAMICS S120 Cabinet Modules (Booksize Base Cabinet / Booksize Cabinet Kits)

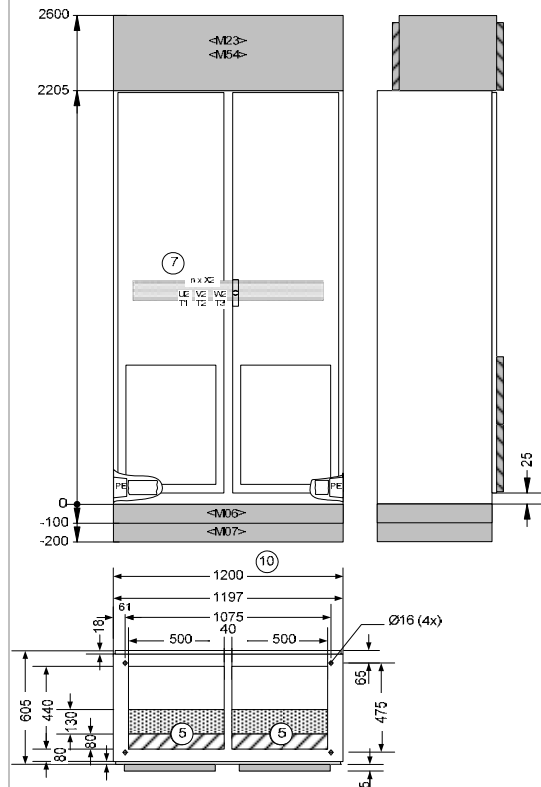
Dimension drawing 16:

Cabinet width 800mm

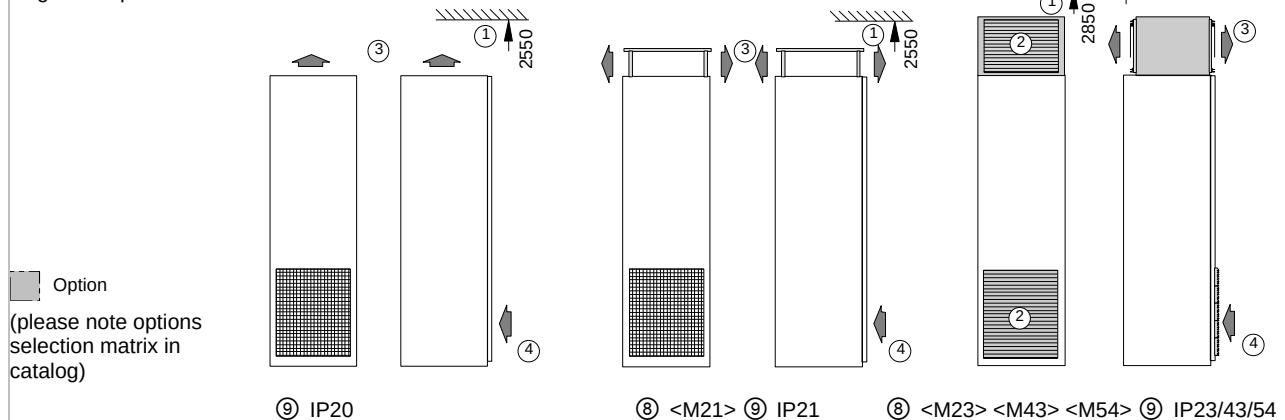


Dimension drawing 17:

Cabinet width 1200mm



Degrees of protection:

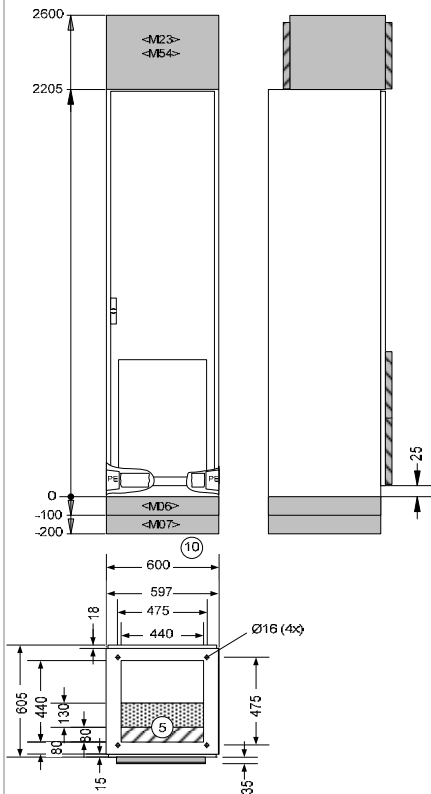


Legend:

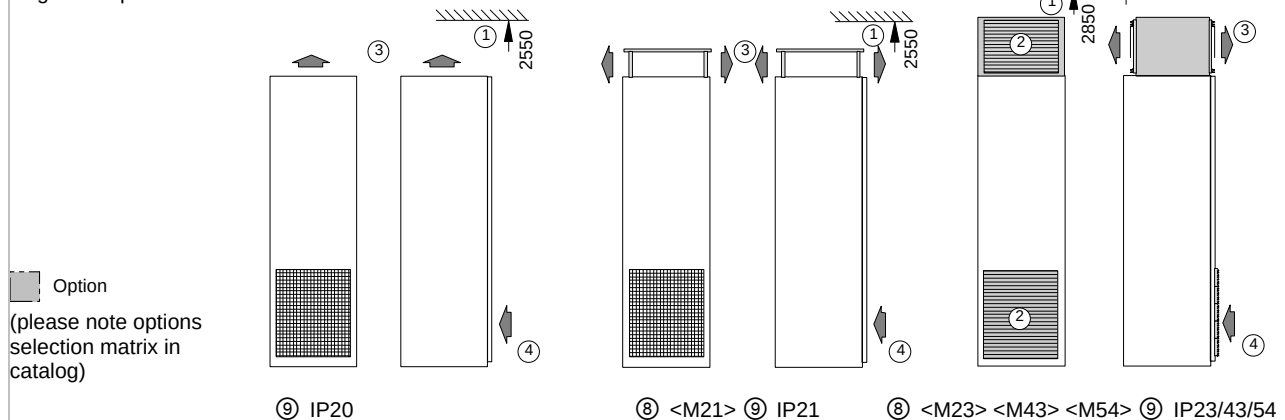
1. Minimum ceiling height for wall mounting	7. Power connection, motor outgoing feeder (note options)
2. Ventilation grid	8. Degree of protection option
3. Air outlet area	9. Degree of protection
4. Air inlet area	IP20
5. Cables can enter from below within hatched area	IP21 Option <M21>
6.	IP23 Option <M23>
	IP43 Option <M43>
	IP54 Option <M54>
	10. Transport unit

SINAMICS S120 Cabinet Modules (Auxiliary Power Supply Modules)

Dimension drawing 19:



Degrees of protection:



Legend:

1. Minimum ceiling height for wall mounting	7.		
2. Ventilation grid	8. Degree of protection option		
3. Air outlet area	9. Degree of protection	IP20	
4. Air inlet area		IP21	Option <M21>
5. Cables can enter from below within hatched area		IP23	Option <M23>
6.		IP43	Option <M43>
		IP54	Option <M54>

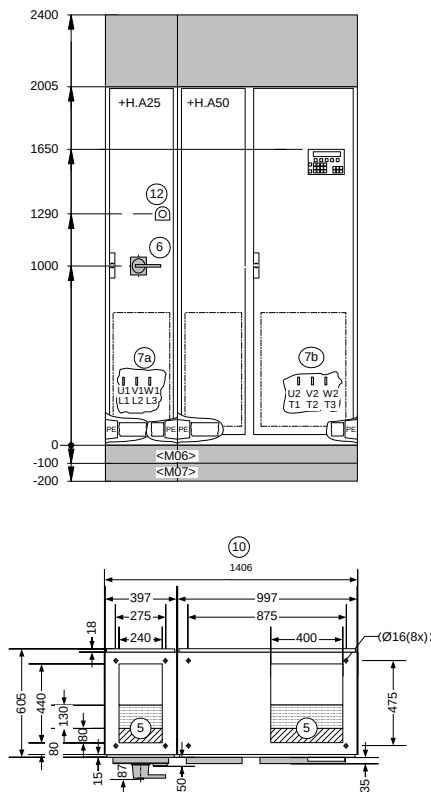
10. Transport unit

SINAMICS S150

Dimension drawing 1:

380 V to 480 V 110 kW - 132 kW
500 V to 690 V 75 kW - 132 kW

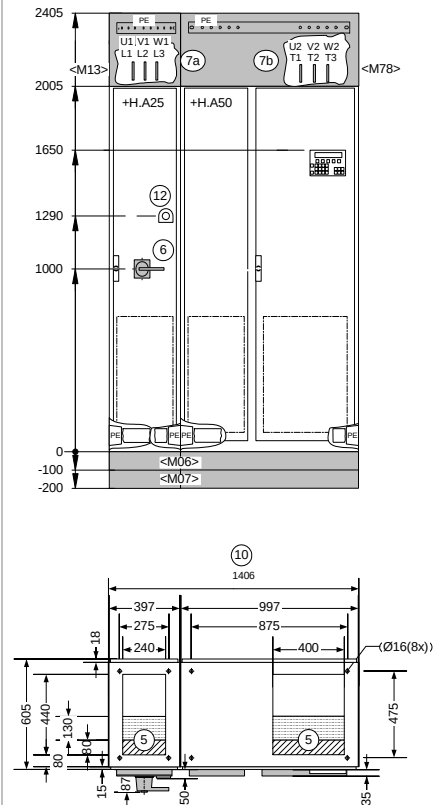
Power supply connection from below, motor connection from below



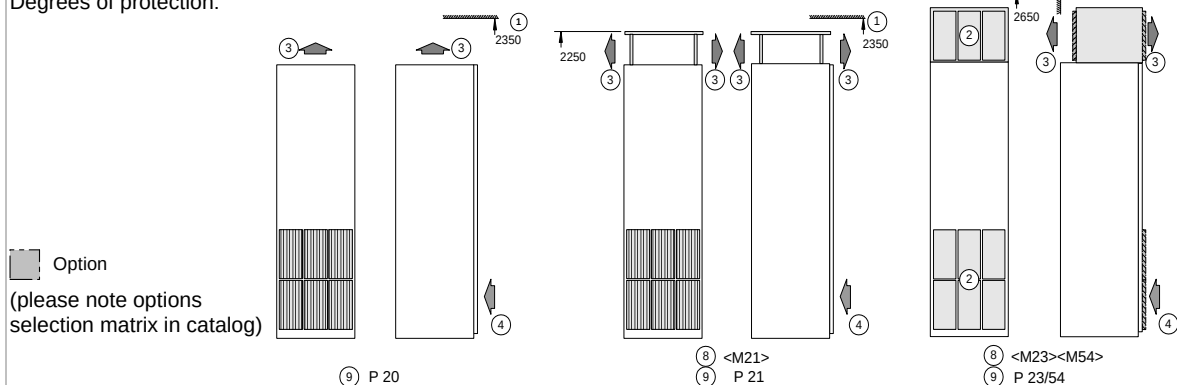
Dimension drawing 2:

380 V to 480 V 110 kW - 132 kW
500 V to 690 V 75 kW - 132 kW

Power supply connection from above, motor connection from above



Degrees of protection:



Legend:

- Minimum ceiling height for wall mounting
- Ventilation grid
- Air outlet area
- Air inlet area
- Cables can enter from below within hatched area
- Main circuit breaker, can be secured by padlock

- Power connection (7a: power supply, 7b: motor)
- Degree of protection option
- Degree of protection IP20
- Degree of protection IP21
- Degree of protection IP23
- Degree of protection IP43
- Degree of protection IP54

- Transport unit
- EMERGENCY OFF button (option)

- Option <M21>
Option <M23>
Option <M43>
Option <M54>

Dimension Drawings

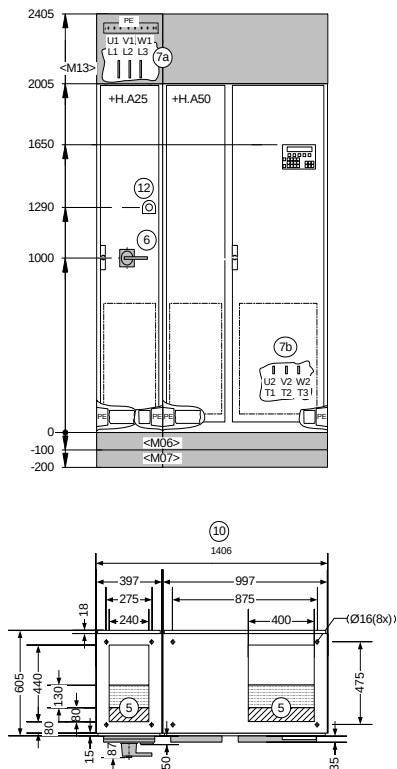
Engineering Information

SINAMICS S150, continued

Dimension drawing 3:

380 V to 480 V 110 kW - 132 kW
500 V to 690 V 75 kW - 132 kW

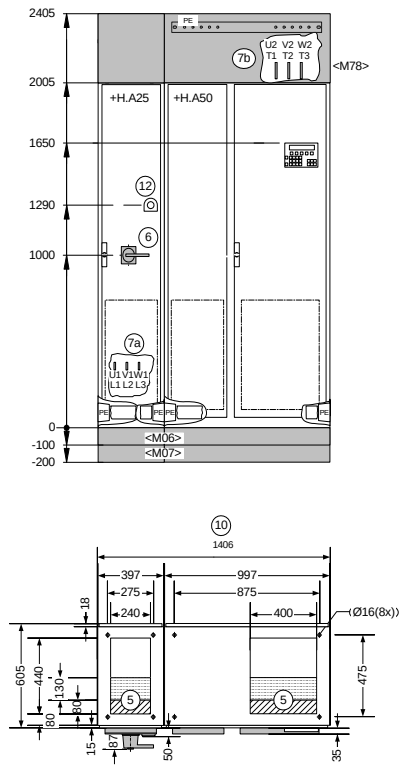
Power supply connection from above, motor connection from below



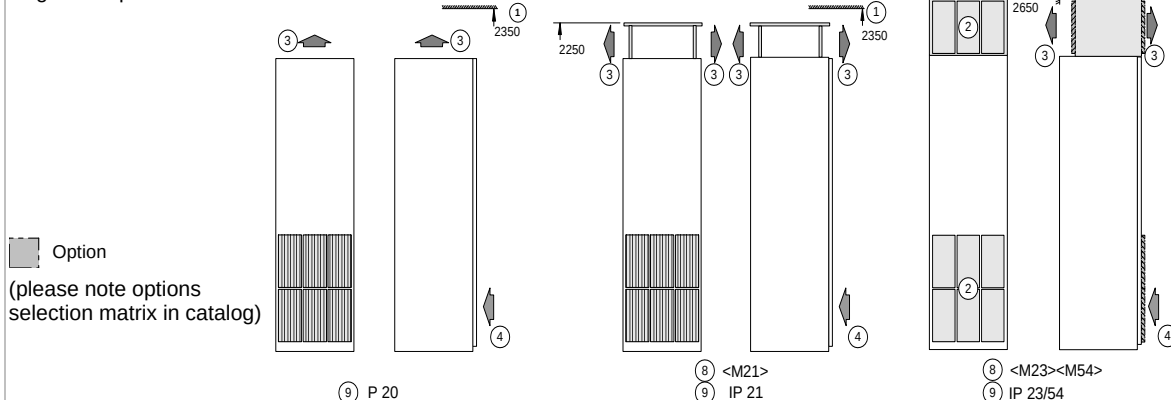
Dimension drawing 4:

380 V to 480 V 110 kW - 132 kW
500 V to 690 V 75 kW - 132 kW

Power supply connection from below, motor connection from above



Degrees of protection:



Legend:

1. Minimum ceiling height for wall mounting
2. Ventilation grid
3. Air outlet area
4. Air inlet area
5. Cables can enter from below within hatched area
6. Main circuit breaker, can be secured by padlock

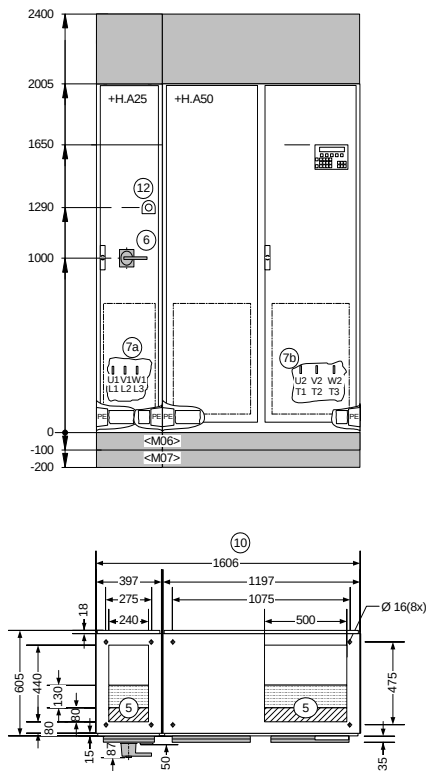
7. Power connection (7a: power supply, 7b: motor)
8. Degree of protection option
9. Degree of protection IP20
 - IP21 Option <M21>
 - IP23 Option <M23>
 - IP43 Option <M43>
 - IP54 Option <M54>
10. Transport unit
- 11
- 12 EMERGENCY OFF button (option)

SINAMICS S150, continued

Dimension drawing 5:

380 V to 480 V 160 kW
500 V to 690 V 160 kW - 315 kW

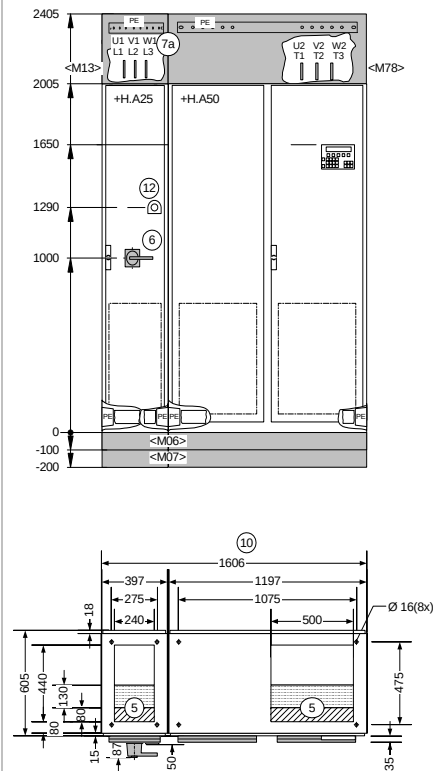
Power supply connection from below, motor connection from below



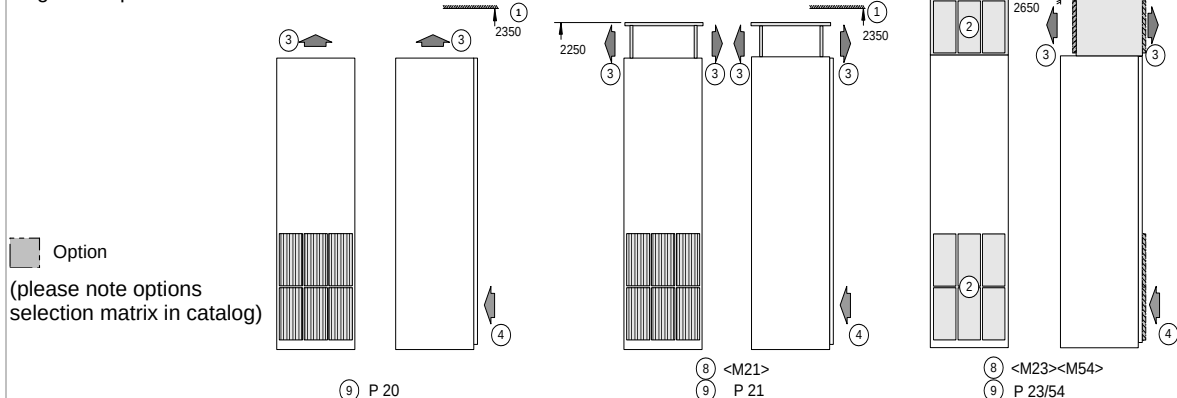
Dimension drawing 6:

380 V to 480 V 160 kW
500 V to 690 V 160 kW - 315 kW

Power supply connection from above, motor connection from above



Degrees of protection:



Legend:

1. Minimum ceiling height for wall mounting
2. Ventilation grid
3. Air outlet area
4. Air inlet area
5. Cables can enter from below within hatched area
6. Main circuit breaker, can be secured by padlock

7. Power connection (7a: power supply, 7b: motor)
8. Degree of protection option
9. Degree of protection

IP20	
IP21	Option <M21>
IP23	Option <M23>
IP43	Option <M43>
IP54	Option <M54>
10. Transport unit
- 11.
12. EMERGENCY OFF button (option)

Dimension Drawings

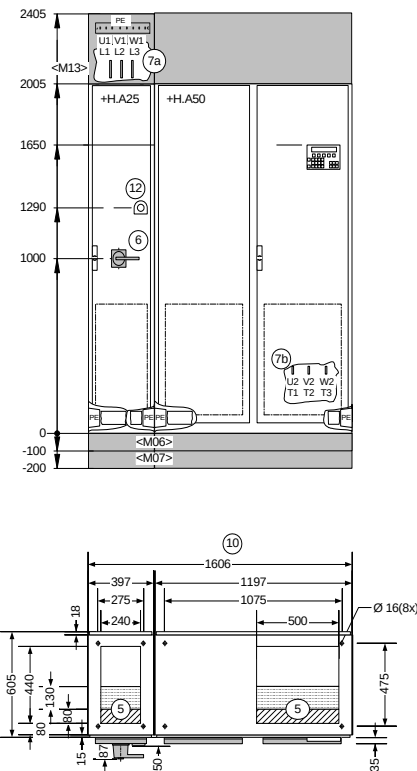
Engineering Information

SINAMICS S150, continued

Dimension drawing 7:

380 V to 480 V 160 kW
500 V to 690 V 160 kW - 315 kW

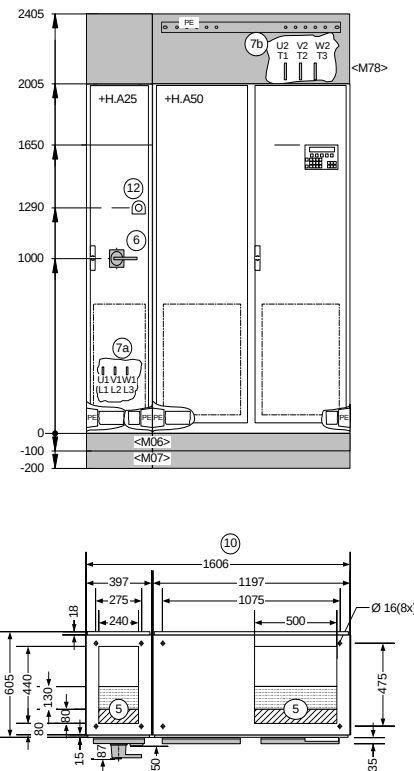
Power supply connection from above, motor connection from below



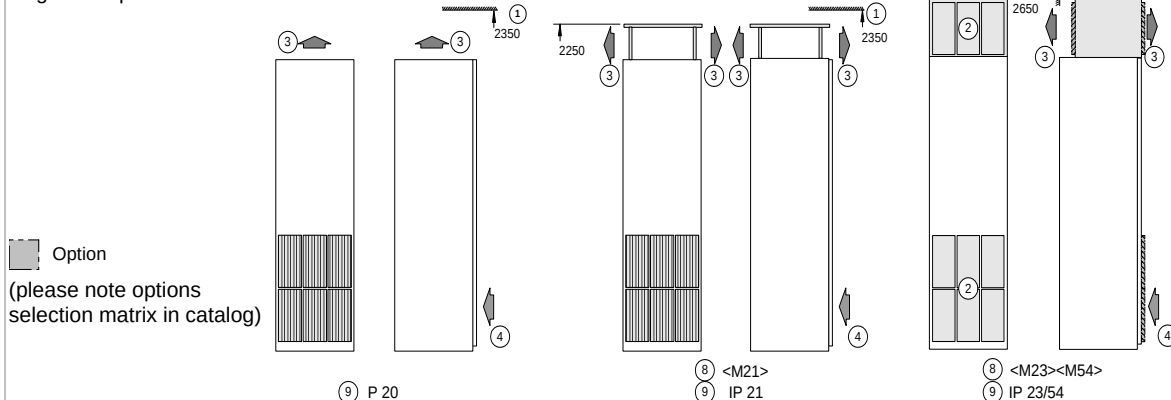
Dimension drawing 8:

380 V to 480 V 160 kW
500 V to 690 V 160 kW - 315 kW

Power supply connection from below, motor connection from above



Degrees of protection:



Legend:

- Minimum ceiling height for wall mounting
- Ventilation grid
- Air outlet area
- Air inlet area
- Cables can enter from below within hatched area
- Main circuit breaker, can be secured by padlock

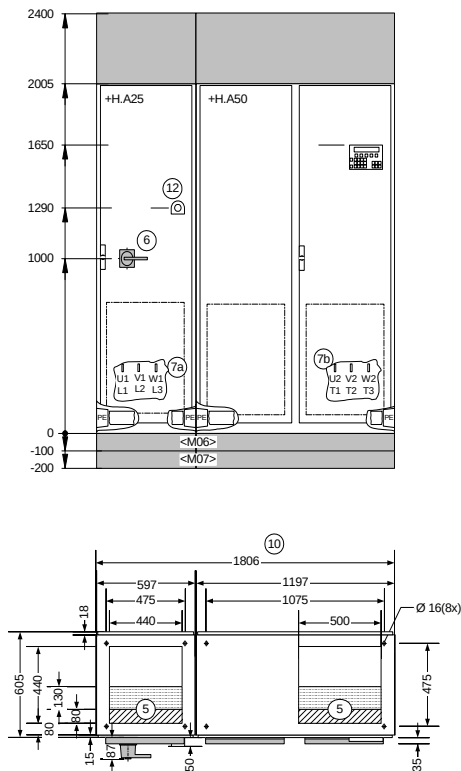
- Power connection (7a: power supply, 7b: motor)
- Degree of protection option
- Degree of protection IP20
- Option <M21>
- Option <M23>
- Option <M43>
- Option <M54>
- Transport unit
- EMERGENCY OFF button (option)

SINAMICS S150, continued

Dimension drawing 9:

380 V to 480 V 200 kW - 250 kW

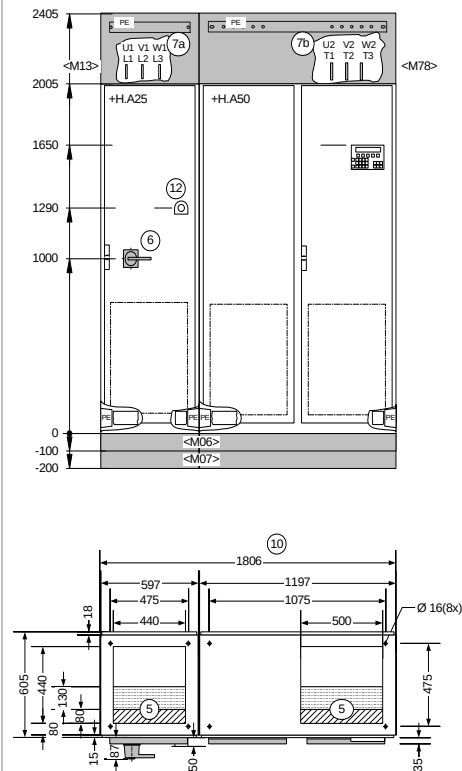
Power supply connection from below, motor connection from below



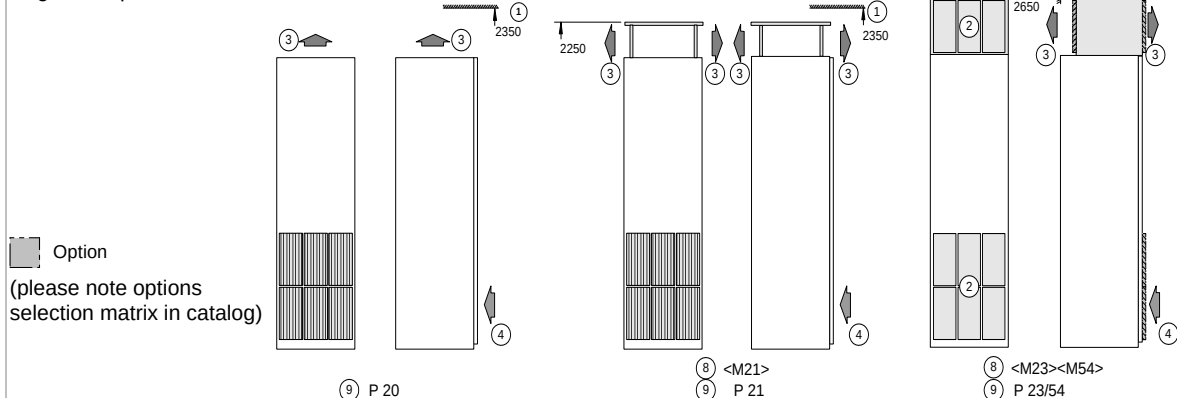
Dimension drawing 10:

380 V to 480 V 200 kW - 250 kW

Power supply connection from above, motor connection from above



Degrees of protection:



Legend:

1. Minimum ceiling height for wall mounting
2. Ventilation grid
3. Air outlet area
4. Air inlet area
5. Cables can enter from below within hatched area
6. Main circuit breaker, can be secured by padlock

7. Power connection (7a: power supply, 7b: motor)
8. Degree of protection option
9. Degree of protection IP20
 - IP21 Option <M21>
 - IP23 Option <M23>
 - IP43 Option <M43>
 - IP54 Option <M54>
10. Transport unit
- 11.
12. EMERGENCY OFF button (option)

Dimension Drawings

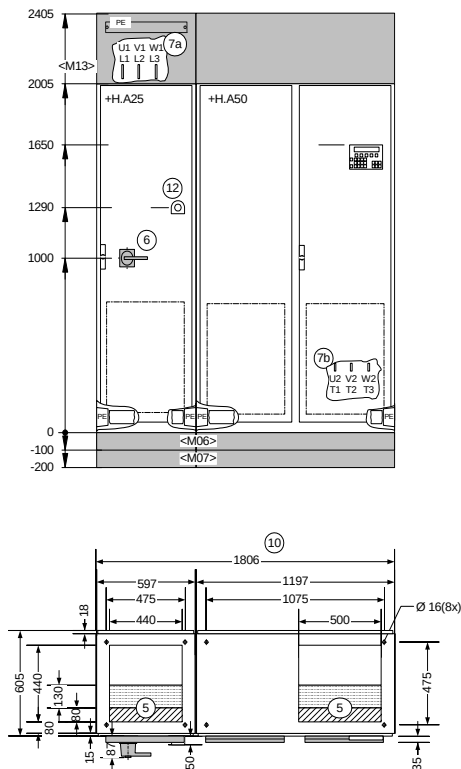
Engineering Information

SINAMICS S150, continued

Dimension drawing 11:

380 V to 480 V 200 kW - 250 kW

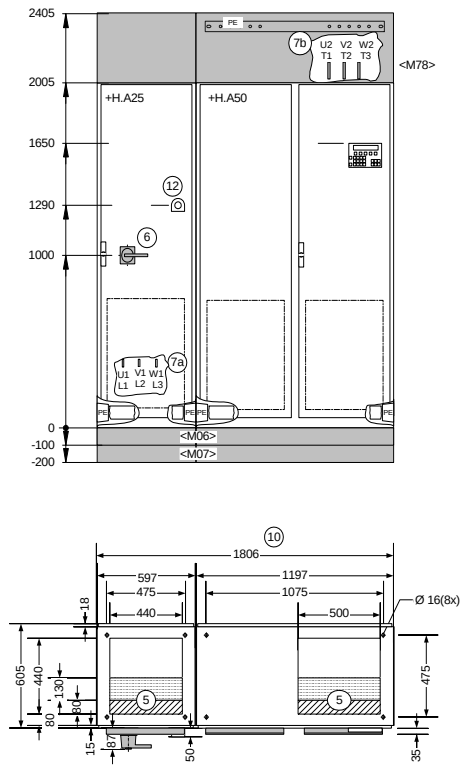
Power supply connection from above, motor connection from below



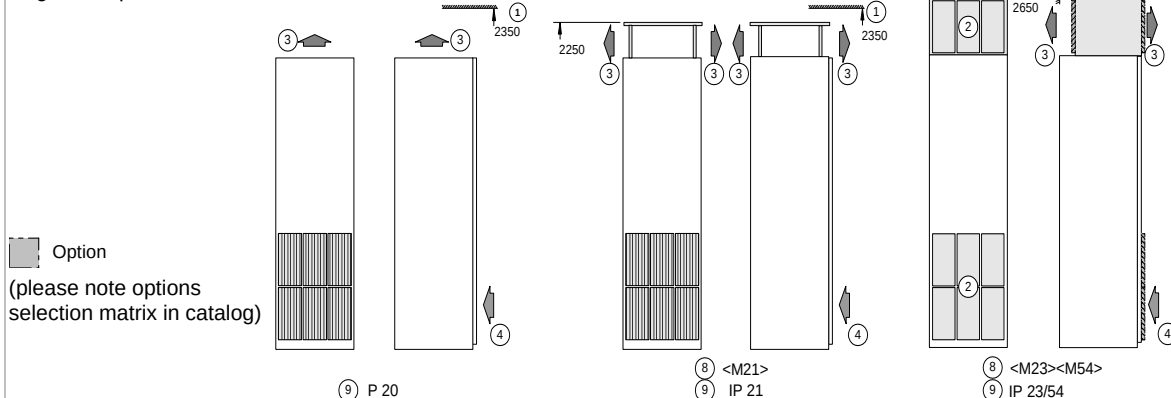
Dimension drawing 12:

380 V to 480 V 200 kW - 250 kW

Power supply connection from below, motor connection from above



Degrees of protection:



Legend:

1. Minimum ceiling height for wall mounting
2. Ventilation grid
3. Air outlet area
4. Air inlet area
5. Cables can enter from below within hatched area
6. Main circuit breaker, can be secured by padlock

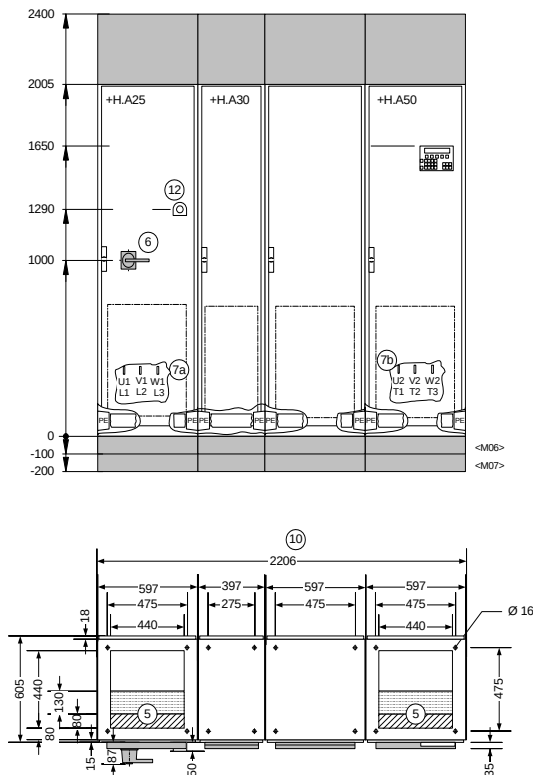
7. Power connection (7a: power supply, 7b: motor)
8. Degree of protection option
9. Degree of protection IP20
IP21 Option <M21>
IP23 Option <M23>
IP43 Option <M43>
IP54 Option <M54>
10. Transport unit
- 11.
12. EMERGENCY OFF button (option)

SINAMICS S150, continued

Dimension drawing 13:

380 V to 480 V 315 kW - 450 kW
500 V to 690 V 400 kW - 560 kW

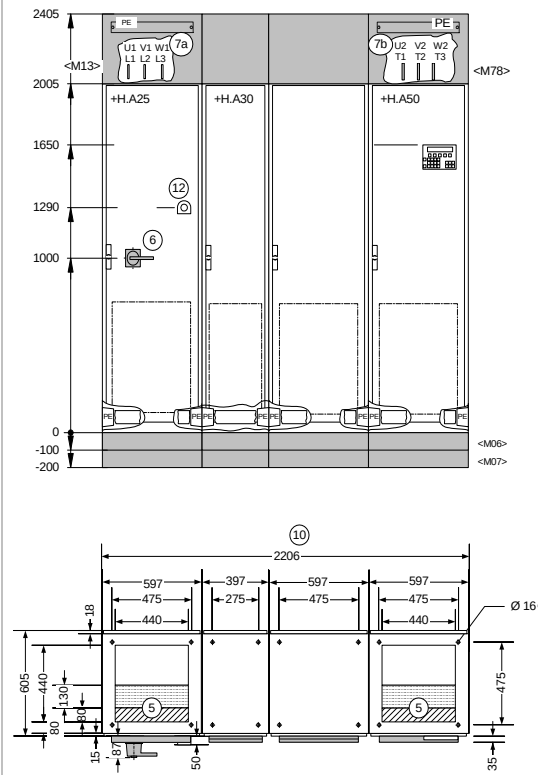
Power supply connection from below, motor connection from below



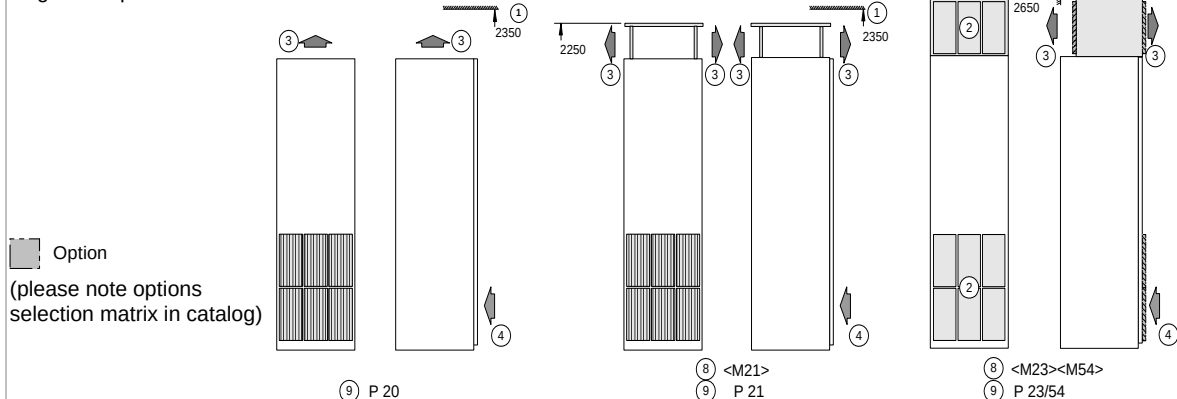
Dimension drawing 14:

380 V to 480 V 315 kW - 450 kW
500 V to 690 V 400 kW - 560 kW

Power supply connection from above, motor connection from above



Degrees of protection:



Legend:

1. Minimum ceiling height for wall mounting
2. Ventilation grid
3. Air outlet area
4. Air inlet area
5. Cables can enter from below within hatched area
6. Main circuit breaker, can be secured by padlock

7. Power connection (7a: power supply, 7b: motor)
8. Degree of protection option
9. Degree of protection IP20
IP21 Option <M21>
IP23 Option <M23>
IP43 Option <M43>
IP54 Option <M54>
10. Transport unit
- 11.
12. EMERGENCY OFF button (option)

Dimension Drawings

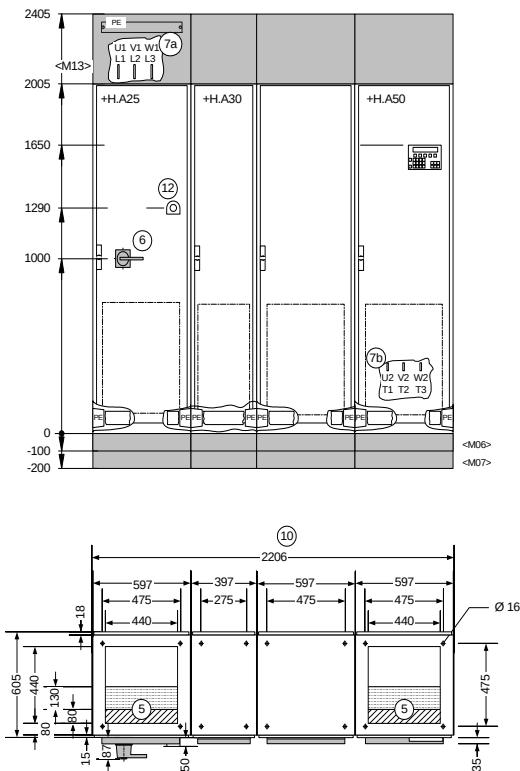
Engineering Information

SINAMICS S150, continued

Dimension drawing 15:

380 V to 480 V 315 kW - 450 kW
500 V to 690 V 400 kW - 560 kW

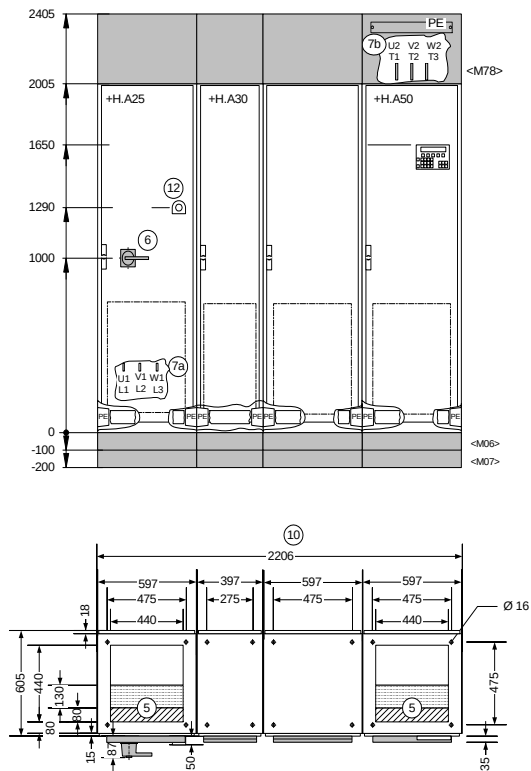
Power supply connection from above, motor connection from below



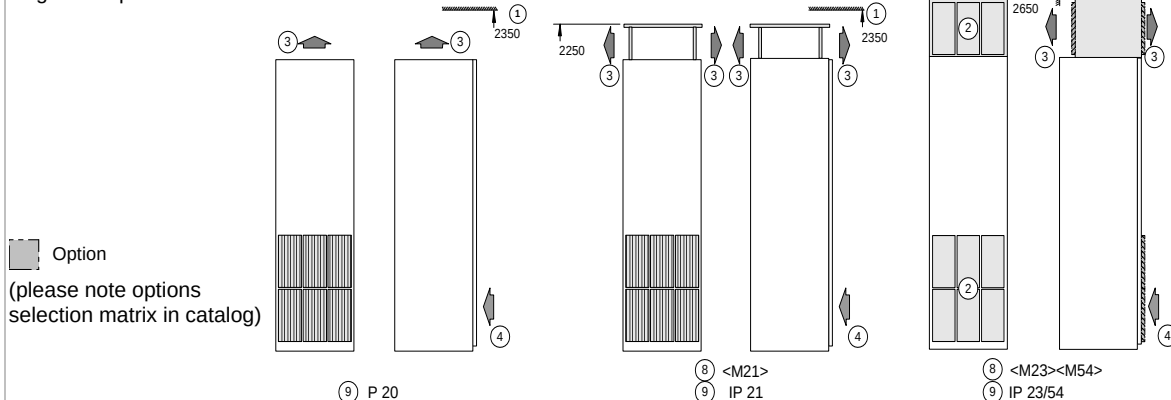
Dimension drawing 16:

380 V to 480 V 315 kW - 450 kW
500 V to 690 V 400 kW - 560 kW

Power supply connection from below, motor connection from above



Degrees of protection:



Legend:

1. Minimum ceiling height for wall mounting
2. Ventilation grid
3. Air outlet area
4. Air inlet area
5. Cables can enter from below within hatched area
6. Main circuit breaker, can be secured by padlock

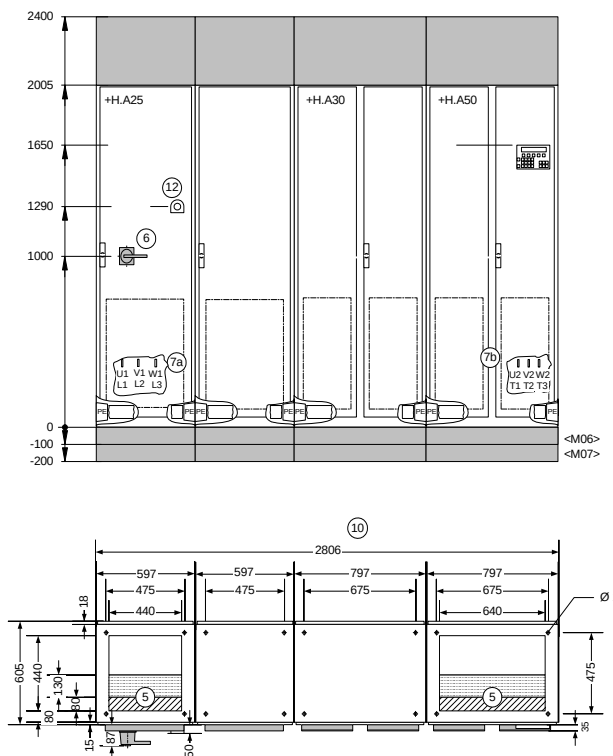
7. Power connection (7a: power supply, 7b: motor)
8. Degree of protection option
9. Degree of protection IP20
 - IP21 Option <M21>
 - IP23 Option <M23>
 - IP43 Option <M43>
 - IP54 Option <M54>
10. Transport unit
- 11.
12. EMERGENCY OFF button (option)

SINAMICS S150, continued

Dimension drawing 17:

380 V to 480 V 560 kW - 800 kW
500 V to 690 V 710 kW - 1200 kW

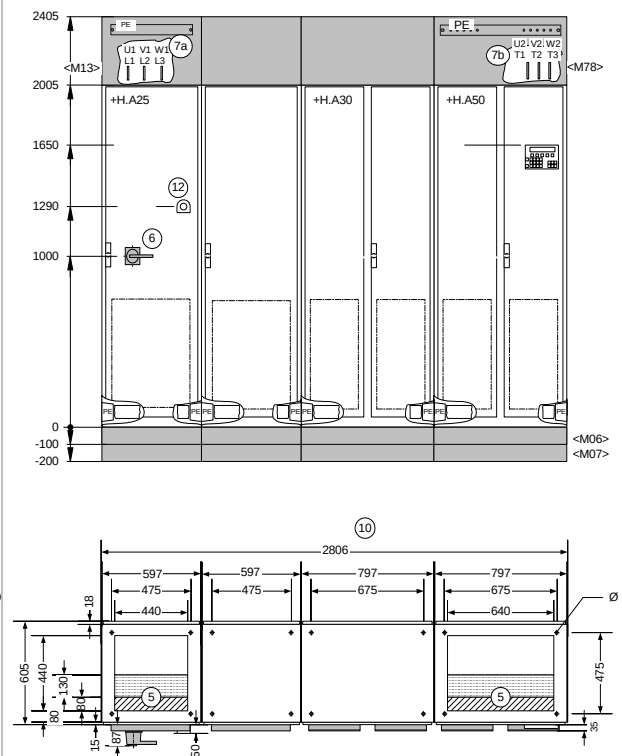
Power supply connection from below, motor connection from below



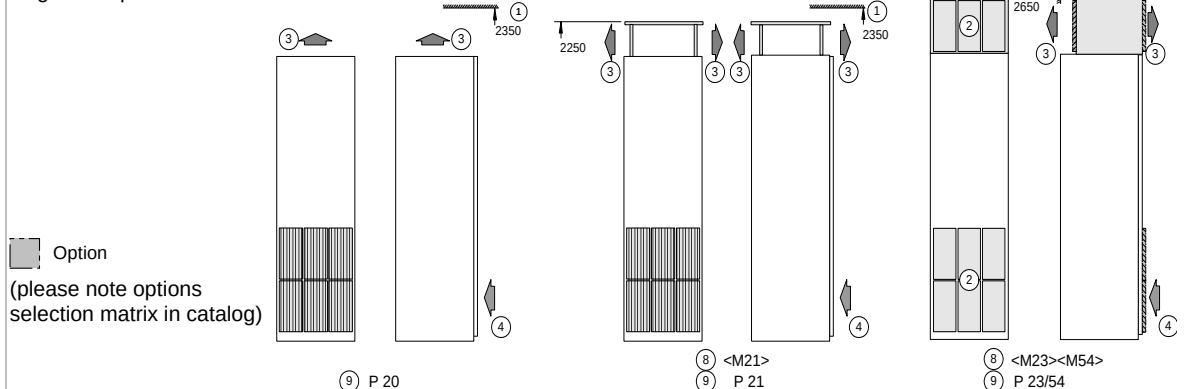
Dimension drawing 18:

380 V to 480 V 560 kW - 800 kW
500 V to 690 V 710 kW - 1200 kW

Power supply connection from above, motor connection from above



Degrees of protection:



Legend:

1. Minimum ceiling height for wall mounting
2. Ventilation grid
3. Air outlet area
4. Air inlet area
5. Cables can enter from below within hatched area
6. Main circuit breaker, can be secured by padlock

7. Power connection (7a: power supply, 7b: motor)
8. Degree of protection option
9. Degree of protection IP20
 - IP21 Option <M21>
 - IP23 Option <M23>
 - IP43 Option <M43>
 - IP54 Option <M54>
10. Transport unit
- 11.
12. EMERGENCY OFF button (option)

Dimension Drawings

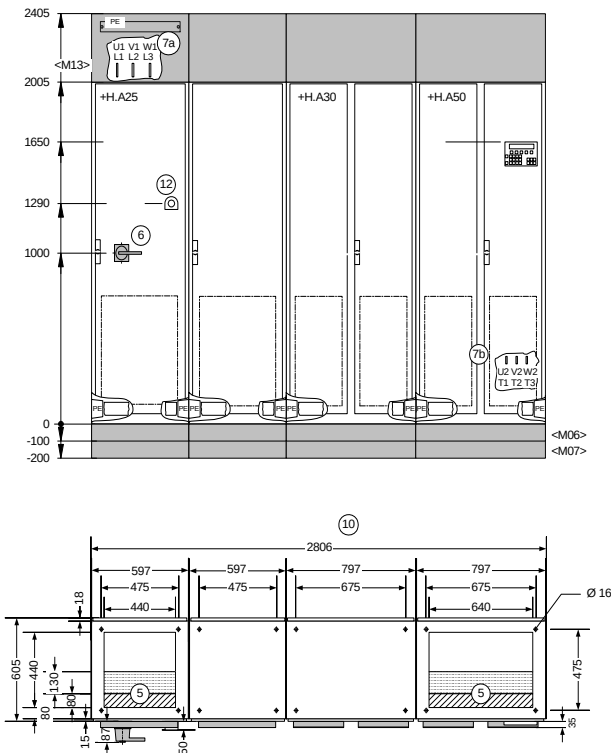
Engineering Information

SINAMICS S150, continued

Dimension drawing 19:

380 V to 480 V 560 kW - 800 kW
500 V to 690 V 710 kW - 1200 kW

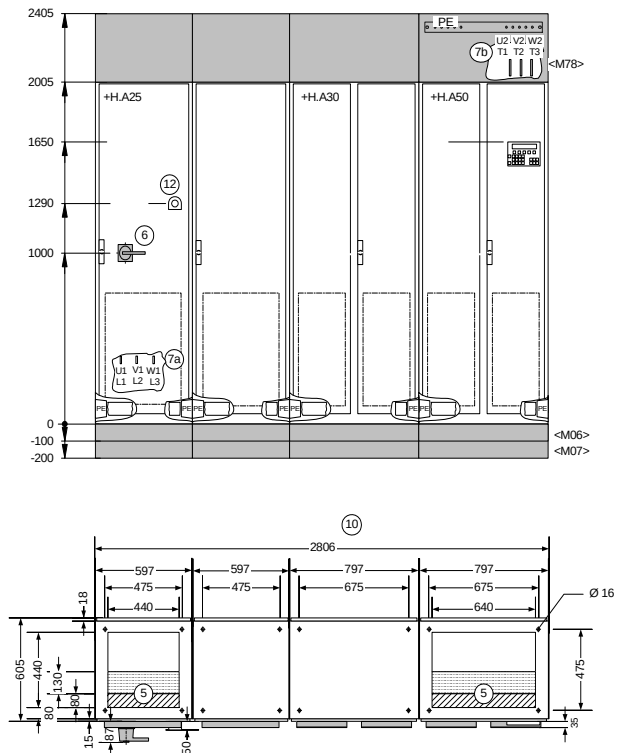
Power supply connection from above, motor connection from below



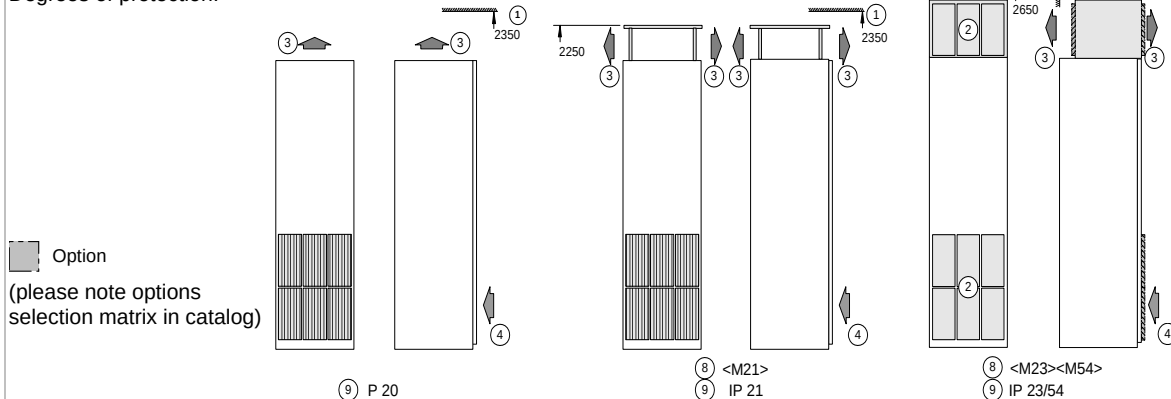
Dimension drawing 20:

380 V to 480 V 560 kW - 800 kW
500 V to 690 V 710 kW - 1200 kW

Power supply connection from below, motor connection from above



Degrees of protection:



Legend:

- Minimum ceiling height for wall mounting
- Ventilation grid
- Air outlet area
- Air inlet area
- Cables can enter from below within hatched area
- Main circuit breaker, can be secured by padlock

- Power connection (7a: power supply, 7b: motor)
- Degree of protection option
- Degree of protection

IP21	Option <M21>
IP23	Option <M23>
IP43	Option <M43>
IP54	Option <M54>
- Transport unit
- EMERGENCY OFF button (option)

Notes

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