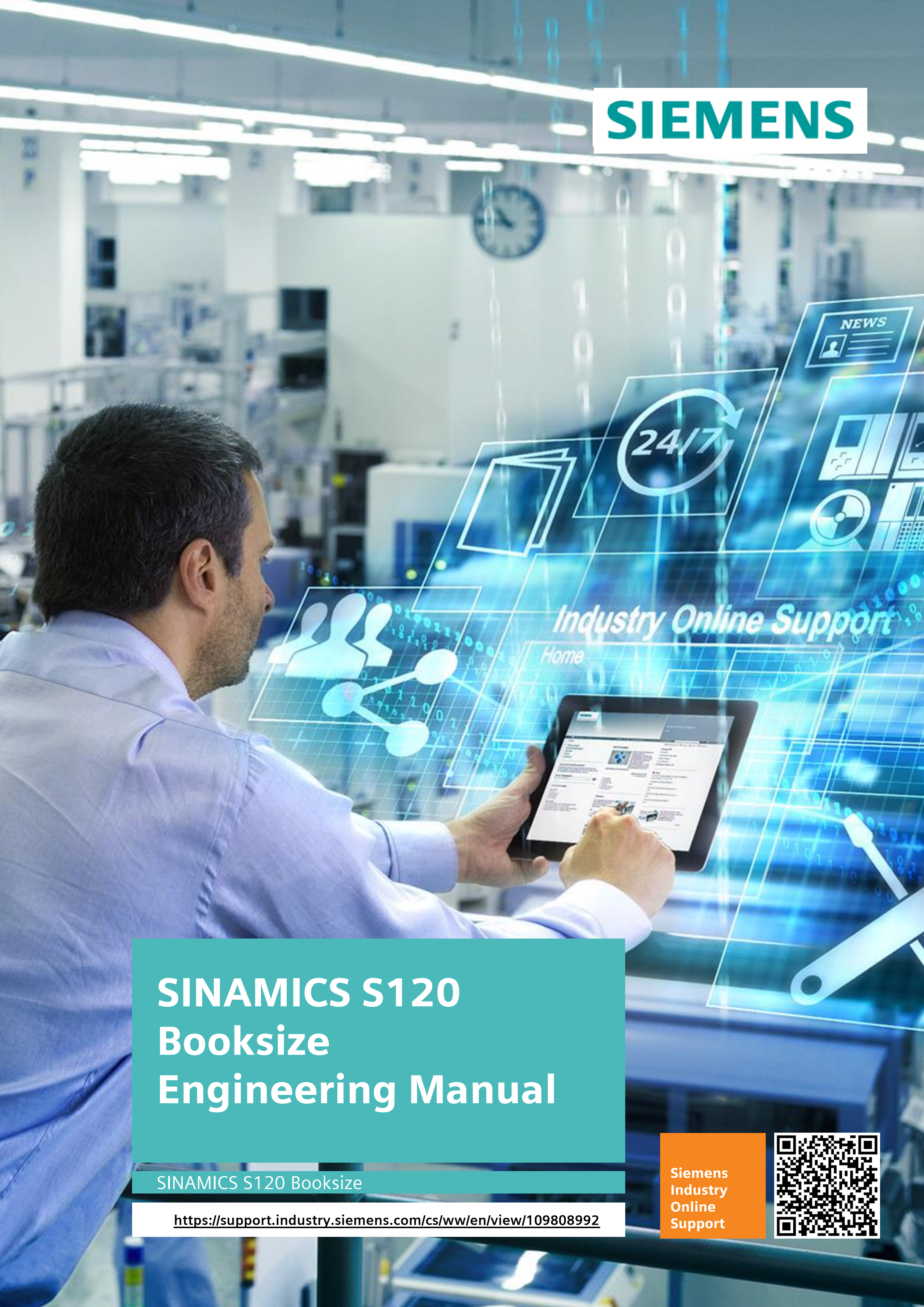
SIEMENS



SINAMICS S120 Booksize Engineering Manual

SINAMICS S120 Booksize

https://support.industry.siemens.com/cs/ww/en/view/109808992

Siemens
Industry
Online
Support

Legal information

Use of application examples

Application examples illustrate the solution of automation tasks through an interaction of several components in the form of text, graphics and/or software modules. The application examples are a free service by Siemens AG and/or a subsidiary of Siemens AG ("Siemens"). They are non-binding and make no claim to completeness or functionality regarding configuration and equipment. The application examples merely offer help with typical tasks; they do not constitute customer-specific solutions. You yourself are responsible for the proper and safe operation of the products in accordance with applicable regulations and must also check the function of the respective application example and customize it for your system.

Siemens grants you the non-exclusive, non-sublicensable and non-transferable right to have the application examples used by technically trained personnel. Any change to the application examples is your responsibility. Sharing the application examples with third parties or copying the application examples or excerpts thereof is permitted only in combination with your own products. The application examples are not required to undergo the customary tests and quality inspections of a chargeable product; they may have functional and performance defects as well as errors. It is your responsibility to use them in such a manner that any malfunctions that may occur do not result in property damage or injury to persons.

Disclaimer of liability

Siemens shall not assume any liability, for any legal reason whatsoever, including, without limitation, liability for the usability, availability, completeness and freedom from defects of the application examples as well as for related information, configuration and performance data and any damage caused thereby. This shall not apply in cases of mandatory liability, for example under the German Product Liability Act, or in cases of intent, gross negligence, or culpable loss of life, bodily injury or damage to health, non-compliance with a guarantee, fraudulent non-disclosure of a defect, or culpable breach of material contractual obligations. Claims for damages arising from a breach of material contractual obligations shall however be limited to the foreseeable damage typical of the type of agreement, unless liability arises from intent or gross negligence or is based on loss of life, bodily injury or damage to health. The foregoing provisions do not imply any change in the burden of proof to your detriment. You shall indemnify Siemens against existing or future claims of third parties in this connection except where Siemens is mandatorily liable.

By using the application examples you acknowledge that Siemens cannot be held liable for any damage beyond the liability provisions described.

Other information

Siemens reserves the right to make changes to the application examples at any time without notice. In case of discrepancies between the suggestions in the application examples and other Siemens publications such as catalogs, the content of the other documentation shall have precedence.

The Siemens terms of use (https://support.industry.siemens.com) shall also apply.

Security information

Siemens provides products and solutions with Industrial Security functions that support the secure operation of plants, systems, machines and networks.

In order to protect plants, systems, machines and networks against cyber threats, it is necessary to implement – and continuously maintain – a holistic, state-of-the-art industrial security concept. Siemens' products and solutions constitute one element of such a concept.

Customers are responsible for preventing unauthorized access to their plants, systems, machines and networks. Such systems, machines and components should only be connected to an enterprise network or the Internet if and to the extent such a connection is necessary and only when appropriate security measures (e.g. firewalls and/or network segmentation) are in place.

For additional information on industrial security measures that may be implemented, please visit https://www.siemens.com/industrialsecurity.

Siemens' products and solutions undergo continuous development to make them more secure. Siemens strongly recommends that product updates are applied as soon as they are available and that the latest product versions are used. Use of product versions that are no longer supported, and failure to apply the latest updates may increase customer's exposure to cyber threats.

To stay informed about product updates, subscribe to the Siemens Industrial Security RSS Feed at: https://www.siemens.com/industrialsecurity.

Table of contents

1 Engineering SINAMICS S120 Booksize

1.1 Line connection variants

1.1.1 Options when connecting the line supply for Booksize Line Modules

A distinction is made between the following line connection versions:

- Line Modules are directly connected to the line supply
- Line Modules are connected via an autotransformer
- Line Modules are connected via an isolation transformer

DANGER

Danger to life due to electric shock if an isolating transformer is not used

To maintain safe electrical separation, for high voltages, an isolating transformer must be used.

For voltages higher than > 3 AC 480 V +10 %, install an isolation transformer to bring the voltage into the permissible range of
3 AC 380 V to 3 AC 480 V ±10% (-15% < 1 min).

WARNING

Fire hazard for the motor due to overload of the insulation

There is higher stress on the motor insulation as a result of a ground fault in an IT line system or a line system with grounded line conductor.

A possible result is the failure of the insulation with a risk for personnel as a result of smoke and fire.

- For IT line systems, use a monitoring device that signals an insulation fault.
- Correct the fault as quickly as possible in IT systems so the motor insulation is not overloaded.
- For line supplies with grounded line conductor, use an isolating transformer with grounded neutral point (on the secondary side) between the line supply and the drive system.

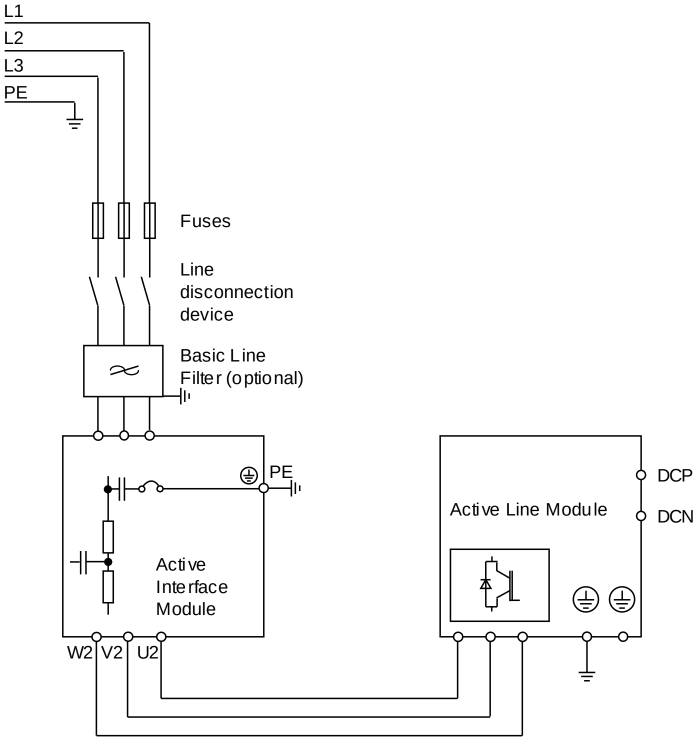
1.2 Operating Booksize Line Modules directly on the line supply

The SINAMICS S Booksize converter system is rated for direct operation on TN, TT and IT line systems with rated voltages of 3 AC 380 V to 3 AC 480 V ±10% (-15% < 1 min) 50 Hz to 60 Hz and overvoltage Category III according to EN 61800-5-1.

Grounded TN and TT line systems can be implemented with grounded neutral point or grounded line conductor. For line supplies with grounded line conductor, carefully observe the notes on increased motor insulation stress, provided in the corresponding equipment manuals and this manual.

Direct connection to the line supply is shown in the following diagram using an Active Line Modules Booksize as example.

Fig. 1-1



Even if there is no system-side transformer in this particular case, the information in the following chapter should be taken into consideration for the line-side transformer used to supply the plant or system.

1.3 Operation on a transformer

1.3.1 Safety information

WARNING

Electric shock or fire due to overcurrent protective devices that trip too late or not at all

Overcurrent protective devices that trip too late or not all can cause electric shock or fire.

- In the case of a conductor-conductor or conductor-ground short-circuit, ensure that the short-circuit current at the point where the converter is connected to the line supply corresponds as a minimum to the requirements of the protective device used.
- The short-circuit current must not exceed the SCCR or the ICC of the converter and the interrupting capacity of the protective equipment.
- You must additionally use a residual current device (RCD) if, for a conductor-ground short circuit, the required short-circuit current is not reached. Especially for TT systems, frequently the required short-circuit current cannot be reached as a result of an excessively high loop impedance.

NOTICE

Destruction or damage to additional loads as a result of undesirable line harmonics

Line harmonics can occur if line filters that differ from those listed in the catalogs and manuals are used. These can destroy or damage other loads connected to the line supply. Conformance with IEC 61800-3 is only confirmed in conjunction with the assigned line filters.

- Only use the line filter specifically assigned to the device.

NOTICE

Destruction or damage to additional loads when incorrectly connected

Other loads can be destroyed or damaged when incorrectly connecting the line filter.

- Connect additional loads upstream of the SINAMICS line filter (if required, via a separate line filter).

Note

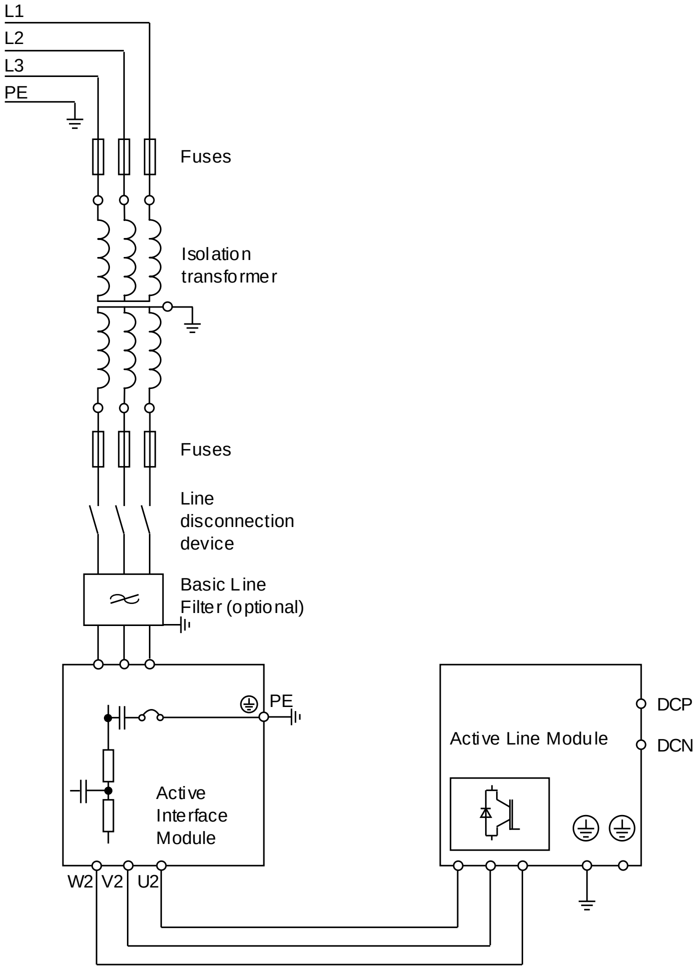
If a transformer is used for Booksize Line Modules, this does not replace the external line reactor or the Active Interface Module.

1.3.2 Line supply connection conditions for Booksize Line Modules

1.3.2.1 Transformer design for connecting Booksize Line Modules to the line supply

A transformer should be used for connecting Booksize Line Modules to the line supply. The following diagram shows connecting a Booksize Active Line Module to an isolation transformer as example:

Fig. 1-2



Two important constraints must be taken into consideration when selecting the correct transformer.

1. The relative short-circuit power at the Line Module connection point
2. The minimum rated transformer power taking into consideration the supplementary transformer losses as a result of line-side harmonic currents

Definition of terminology

PCC "Point of Common Coupling" is the point where the customer's line supply is connected with the power grid. Typically, this is the power utility transfer point, and can be on the medium-voltage or low-voltage side.

IPC "In-Plant Point of Coupling" is the point where the converter and/or Line Module is connected to the customer's power supply.

Relative short-circuit power of the connection point

To avoid disturbing other loads or the Line Module, the line impedance of the connection point must not exceed certain maximum values.

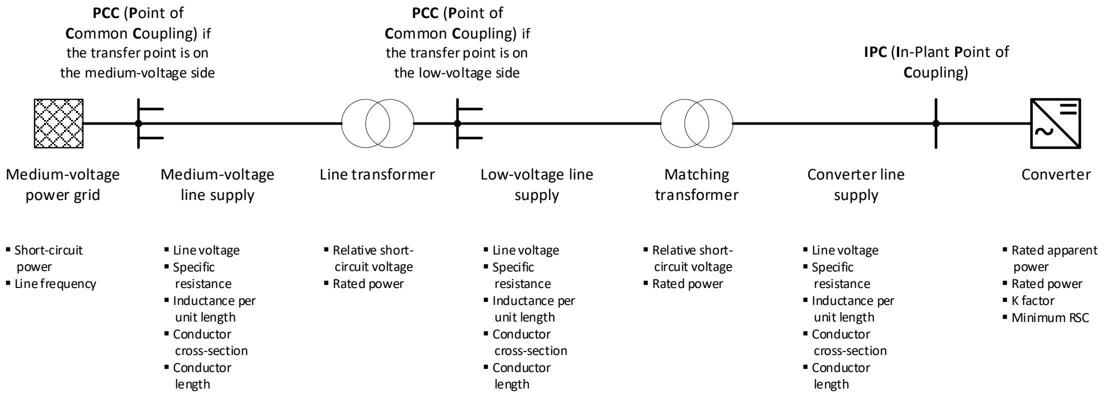
The line impedance defines the short-circuit power of the connection point and is an important parameter for evaluating line harmonics. This means that the line impedance can be expressed using the short-circuit power; the short-circuit power does not represent the actual physical power when a short-circuit occurs, as it links line voltage and short-circuit current variables, which do not occur together.

The relative short-circuit power RSC is used for evaluation.

According to EN 60146-1-1, the relative short-circuit power (RSC) is defined as the ratio of the short-circuit power $S_{K\ line\_IPC}$ of the customer's line supply to the rated apparent power (fundamental apparent power) $S_{converter}$ of the converter at the point where it is connected to the line supply IPC (In-Plant Point of Coupling).

$$RSC = \frac{S_{K\ line\_IPC}}{S_{Converter}}$$

Fig. 1-3 $S_{k\text{-line-IPC}}$ at connection point IPC and influencing quantities for RSC



The rated input current of the Line Module at 3 AC 380 V is used as basis to determine the fundamental apparent power $S_{converter}$. The actual supply voltage is not relevant here.

Minimum relative short-circuit power RSC as a function of the Line Module

Depending on the specific SINAMICS S120 Line Module Booksize being used, the following minimum relative line short-circuit power levels must be maintained:

Table 1-1

S120 Line Modules Booksize	RSC required
Basic Line Modules	≥ 30
Smart Line Modules	≥ 70
Active Line Modules with Active Interface Module	≥ 30
Active Line Modules in the Smart Mode	≥ 70

If a TN line system is specified on the secondary side, then a transformer with grounded neutral point must be used. However, the loop resistance must be low enough that fuses are ruptured as fast as required.

Recommendations for fusing Booksize Line Modules are provided here:

https://support.industry.siemens.com/cs/de/de/view/109749282

Minimum rated power of the matching transformer

For Booksize Line Modules, factor k, which takes into consideration the effect of the supplementary losses in the transformer due to line-side harmonic currents, must be applied with:
k = 1.27

This means that the rated transformer power must be higher than the rated Line Module power by a factor of 1.27.

1.3.3 Notes on calculation variants

Two calculation examples are shown below. One is used to dimension a matching transformer, the other to check an existing line connection with transformer.

For a more precise calculation, data on cable lengths and cross-sections along with the short-circuit power at the PCC (Point of Common Coupling) are required. Wherever possible, typical quantities are specified in order to make a rough estimate for typical constellations.

Additional factors that influence the line impedance, such as additional transformers, are not taken into consideration in the following calculation examples. However, when required, these can be simply supplemented corresponding to the calculation formula applied.

Only a very simplified calculation is possible, especially if the cable length between the transformer and Line Module and the short-circuit power of the medium-voltage line supply (grid) are not known. However, it should be noted that for unfavorable preconditions, calculated values can be substantially wrong, resulting in a negative behavior in subsequent operation. As a consequence, it is recommended that in these cases, typical values or worst-case values should be used in the calculation.

The calculation examples are provided with formula fields in which you can enter your own values, therefore making calculations simple.

Note

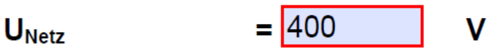
Carefully check the correctness of the calculation results. Incorrect or extreme input values can lead to results that are not plausible.
An extensive plausibility check of the values is not made.

Notes relating to the integrated calculation function

Using the marking function for formula fields, you can color-code the input and output fields for required and optional data.

Input fields are written in **bold** and framed in red when the formula fields are activated.

Fig. 1-4

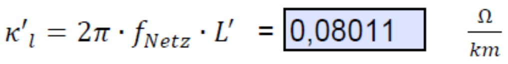


U_{Netz} = 400 V

Some input fields are in the form of drop-down list; however, you can still enter your own values.

Output fields of the calculation are *italicized,* and have a gray background when the formula fields are activated:

Fig. 1-5



$\kappa'_l = 2\pi \cdot f_{Netz} \cdot L'$ = 0,08011 $\frac{\Omega}{km}$

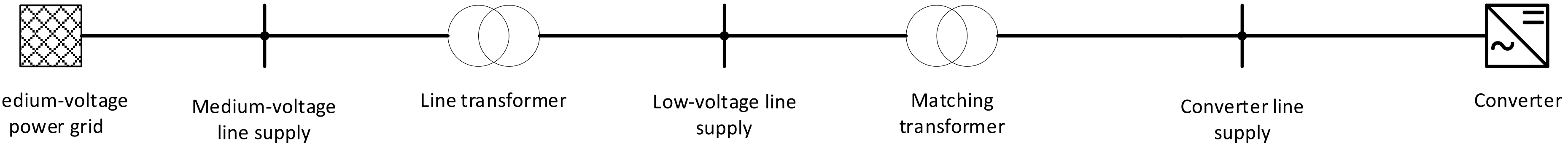
Note

It is possible that the use of formula fields and their color marking must first be activated in the appropriate program used to display pdf files.

1.3.4 Dimensioning a matching transformer

1.3.4.1 Overview of a typical line supply topology

Fig. 1-6



1.3.4.2 Required data

Medium-voltage power grid:

- Voltage of the medium-voltage line supply

  $U_{MV\ line}$ = 20.0 **kV**
- Line frequency

  f = 50 **Hz**
- Short-circuit power of the power grid

  S''_{k_line} = 50.00000 **MVA**

  In Germany, the short-circuit powers in medium-voltage line supplies are generally between 20 and 500 MVA - and typically between 50 and 200 MVA.

Medium-voltage line supply:

- Inductance value per unit length of the medium-voltage cable according to data sheet information[1]

  $\mathbf{L'_{MV\ line}}$ **=** 1.0500 $\frac{\mu H}{m}$

- Length of the medium-voltage cable

  $\mathbf{l_{MV\ line}}$ **=** 5.0 **km**

- specific resistance of the medium-voltage cable [2]

  $\boldsymbol{\rho_{MV}}$ **=** 0.02941 $\Omega \frac{mm^2}{m}$

- Conductor cross-section of one phase of the medium-voltage connection

  $\mathbf{q_{MV}}$ **=** 120 **mm²**

---

[1] This value is very dependent on the geometrical structure of the cable and/or the conductor. The following approximate values can be used if more precise data are not available:

0.25 $\frac{\mu H}{m}$ for cables and conductors,

0.38 $\frac{\mu H}{m}$ for busbars,

1.05 $\frac{\mu H}{m}$ for outdoor overhead cables

[2] specific resistances of copper, aluminum and aluminum alloy

$\frac{1}{54}\Omega\frac{mm^2}{m}$ for copper

$\frac{1}{34}\Omega\frac{mm^2}{m}$ for aluminum

$\frac{1}{31}\Omega\frac{mm^2}{m}$ for aluminum alloy

Line transformer

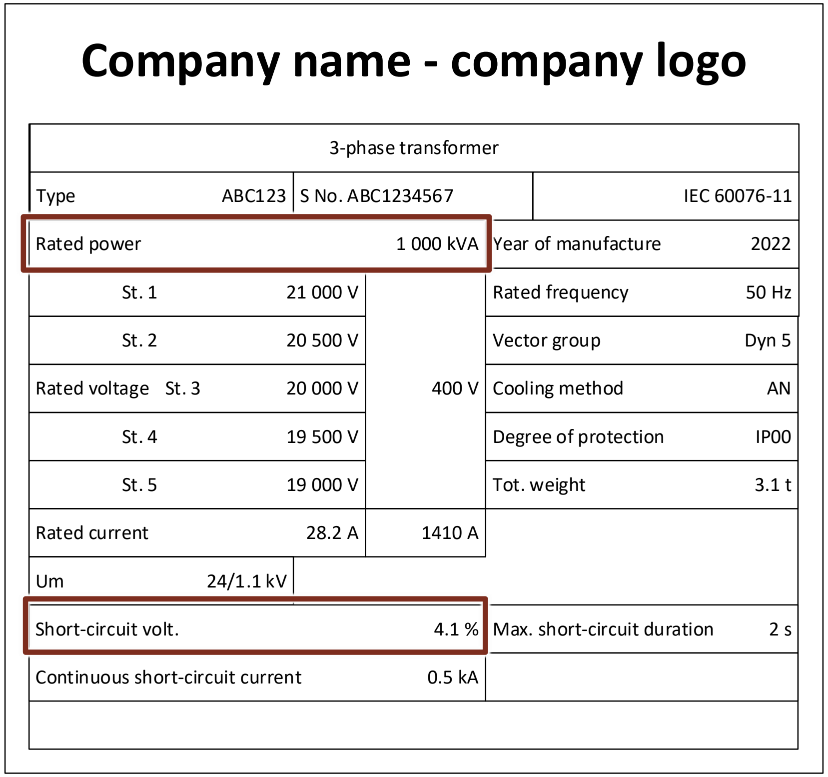
- Relative short-circuit voltage of the line transformer

  $u_{k\_line\ transformer}$ = 6.0 **%**

- Rated apparent power of the line transformer

  $S_{line\ transformer}$ = 1.6000 **MVA**

Fig. 1-7 Example of a transformer rating plate



Company name - company logo

3-phase transformer				
Type	ABC123	S No. ABC1234567		IEC 60076-11
Rated power	1 000 kVA		Year of manufacture	2022
St. 1	21 000 V	400 V	Rated frequency	50 Hz
St. 2	20 500 V		Vector group	Dyn 5
Rated voltage St. 3	20 000 V		Cooling method	AN
St. 4	19 500 V		Degree of protection	IP00
St. 5	19 000 V		Tot. weight	3.1 t
Rated current	28.2 A	1410 A		
Um	24/1.1 kV			
Short-circuit volt.	4.1 %		Max. short-circuit duration	2 s
Continuous short-circuit current	0.5 kA			

Low-voltage line supply:

- Voltage of the low-voltage line supply

  $\mathbf{U_{LV\ line}}$ **=** 690 **V**
- Inductance value per unit length of the low-voltage cable according to data sheet information[3]

  $\mathbf{L'_{LV\ line}}$ **=** 0.2550 $\frac{\mu H}{m}$
- Length of the low-voltage cable

  $\mathbf{l_{LV\ line}}$ **=** 25.0 **m**
- specific resistance of the low-voltage cable [4]

  $\boldsymbol{\rho_{LV}}$ **=** 0.01852 $\Omega \frac{mm^2}{m}$
- Conductor cross-section of one phase of the low-voltage connection

  $\mathbf{q_{LV}}$ **=** 200.0 **mm²**

---

[3] This value is very dependent on the geometrical structure of the cable and/or the conductor. The following approximate values can be used if more precise data are not available:

0.25 $\frac{\mu H}{m}$ for cables and conductors,

0.38 $\frac{\mu H}{m}$ for busbars,

1.05 $\frac{\mu H}{m}$ for outdoor overhead cables

[4] specific resistances of copper, aluminum and aluminum alloy

$\frac{1}{54}\Omega\frac{mm^2}{m}$ for copper

$\frac{1}{34}\Omega\frac{mm^2}{m}$ for aluminum

$\frac{1}{31}\Omega\frac{mm^2}{m}$ for aluminum alloy

Line supply for the converter:

- Voltage of the converter line supply

  $\mathbf{U_{FC\ line}}$ = 400 **V**

- Inductance value per unit length of the converter connecting cable according to data sheet information [5]

  $\mathbf{L'_{FC\ line}}$ = 0.2550 $\frac{\mu H}{m}$

- Cable length to the converter

  $\mathbf{l_{FC\ line}}$ = 35.0 **m**

- Specific resistance of the converter connecting cable [6]

  $\boldsymbol{\rho_{FC}}$ = 0.01852 $\Omega\frac{mm^2}{m}$

- Cross-section of one phase of the converter connection

  $\mathbf{q_{FC}}$ = 75.0 **mm²**

- Minimum relative short-circuit power for the type of infeed corresponding to Table 1-1

  $\mathbf{RSC_{min}}$ = 30

- Rated input current of the Line Module for a 380 V line supply voltage

  $\mathbf{I_{rated\_Line\_Module}}$ = 192 **A**

- Rated power of the Line Module for the selected supply voltage

  $\mathbf{P_{rated\_Line\_Module}}$ = 120 **kW**

- k factor – takes into account the supplementary losses in the transformer due to harmonic currents - for Booksize Line Modules, k = 1.27

  $\mathbf{k_{infeed}}$ = 1.27

---

[5] This value is very dependent on the geometrical structure of the cable and/or the conductor. The following approximate values can be used if more precise data are not available:
0.25 $\frac{\mu H}{m}$ for cables and conductors,
0.38 $\frac{\mu H}{m}$ for busbars,

[6] specific resistances of copper, aluminum and aluminum alloy
$\frac{1}{54}\Omega\frac{mm^2}{m}$ for copper
$\frac{1}{34}\Omega\frac{mm^2}{m}$ for aluminum
$\frac{1}{31}\Omega\frac{mm^2}{m}$ for aluminum alloy

1.3.4.3 Calculations

Supporting calculations

The rated apparent power of the Line Module is:

$$S_{Rated_{Converter}} = U_{Line\ supply} \cdot I_{Rated_{Line_{Module}}} \cdot \sqrt{3} \quad = 133.02 \quad \text{kVA}$$

The specific reactance value of the medium-voltage cable is obtained as follows:

$$k'_{MV} = 2\pi \cdot f \cdot L'_{MV\ line} \quad = 0.00032987 \quad \frac{\Omega}{m}$$

In turn, the reactance of the medium-voltage cable is calculated as follows:

$$X_{MV} = k'_{MV} \cdot l_{MV\ line} \quad = 1.649335 \quad \Omega$$

The active resistance of the medium-voltage cable is calculated as follows:

$$R_{MV} = \frac{\rho_{MV}}{q_{MV}} \cdot l_{MV\ line} \quad = 1.225417 \quad \Omega$$

The specific reactance of the low-voltage cable is calculated as follows:

$$k'_{LV} = 2\pi \cdot f \cdot L'_{LV\ line} \quad = 0.00008011 \quad \frac{\Omega}{m}$$

In turn, the reactance of the low-voltage cable is calculated as follows:

$$X_{LV} = k'_{LV} \cdot l_{LV\ line} \quad = 0.002003 \quad \Omega$$

The active resistance of the low-voltage cable is calculated as follows:

$$R_{LV} = \frac{\rho_{LV}}{q_{LV}} \cdot l_{LV\ line} \quad = 0.002315 \quad \Omega$$

The specific reactance value of the converter connecting cable is calculated as follows:

$$k'_{FC} = 2\pi \cdot f \cdot L'_{FC\ line} \quad = 0.00008011 \quad \frac{\Omega}{m}$$

In turn, the reactance of the converter connecting cable is calculated as follows:

$$X_{FC} = k'_{FC} \cdot l_{FC\ line} \quad = 0.002804 \quad \Omega$$

The active resistance of the converter connecting cable is calculated as follows:

$$R_{FC} = \frac{\rho_{FC}}{q_{FC}} \cdot l_{FC\ line} \quad = 0.008643 \quad \Omega$$

Calculating the relative impedances using the %/MVA technique

- Impedance of the medium-voltage power grid

$$Z_{Line\ supply} = \frac{1.1}{S''k_{Line\ supply}} = 2.200 \quad \frac{\%}{MVA}$$

- Impedance of the medium-voltage cable

$$Z_{MV\ cable} = \frac{\sqrt{X_{MV}^2 \cdot R_{MV}^2}}{U_{MV\ line}^2} = 0.514 \quad \frac{\%}{MVA}$$

- Impedance of the line transformer

$$Z_{Line\ supplytransformer} = \frac{u_{k\ line\ transformer}}{S_{Line\ transformer}} = 3.750 \quad \frac{\%}{MVA}$$

- Impedance of the low-voltage cable

$$Z_{LV\ cable} = \frac{\sqrt{X_{LV}^2 \cdot R_{LV}^2}}{U_{LV\ line}^2} = 0.643 \quad \frac{\%}{MVA}$$

- Impedance of the converter connecting cable

$$Z_{FC\ cable} = \frac{\sqrt{X_{FC}^2 \cdot R_{FC}^2}}{U_{FC\ line}^2} = 5.679 \quad \frac{\%}{MVA}$$

Calculating the required apparent power of the matching transformer

To determine the required apparent transformer power, it is still necessary to define the required relative short-circuit voltage of the matching transformer:

$u_{k\_matching\ transformer}$ = 4.0 **%**

Note

DIN EN 60076-5 lists recognized minimum values according to power classes. In the typical power range for matching transformers from 25 to 630 kVA for SINAMICS S120 Booksize, the minimum value is 4%. Up to power ratings of 2500 kVA, this value increases up to 6%. This is the reason that here it is recommended to specify typical values from 4% to 6%.

The maximum permissible line impedance (from the minimum RSC and converter apparent power) and the existing impedances result in a maximum permissible impedance of the matching transformer and thus the required minimum apparent power for a given u_k:

$$S_{transformer\_RSC} = \frac{u_{k\_Matching\ transformer}}{\frac{1.1}{RSC_{min}} \cdot S_{Rated_{Converter}} - Z_{Line\ supply} - Z_{MV-Cable} - Z_{Line\ transformer} - Z_{LV-Cable} - Z_{FC-Cable}} = \quad 270.7 \quad \text{kVA}$$

a minimum value of the transformer apparent power is obtained from the k factor for the infeed type:

$$S_{Transformer\_\mathrm{min}\_k} = k \cdot P_{Rated_{Line_{Module}}} = \quad 152.4 \quad \text{kVA}$$

The minimum apparent power of the transformer is obtained from the maximum of the two values above:

$$S_{Transformer\_\mathrm{Minimum}} = \quad 270.7 \quad \text{kVA}$$

The minimum apparent power the matching transformer is therefore defined.

In the next step, you can define the selected apparent power of the transformer in order to determine the resulting RSC.

$S_{Matching\ transformer\_selection}$ = 480.0000 kVA

its impedance together with the selected u_k is obtained as:

$$Z_{Matching\ transformer} = \frac{u_{k\_matching\ transformer}}{S_{Matching\ transformer\_selection}} = 8.333 \quad \frac{\%}{MVA}$$

The short-circuit power at the connection point IPC is therefore obtained as:

$$S''_{k\_IPC} = \frac{1.1}{Z_{Line\ supply}+Z_{MV-Cable}+Z_{Line\ transformer}+Z_{LV-Cable}+Z_{Matching\ transformer}+Z_{FC-Cable}} = 5.209 \quad \text{MVA}$$

With the selected matching transformer, a relative short-circuit power at the connection point IPC is therefore obtained as:

$$RSC_{IPC} = \frac{S''_{k\_IPC}}{S_{Rated_{Converter}}} = 39$$

Further, the expected short-circuit currents at connection point IPC can be determined:

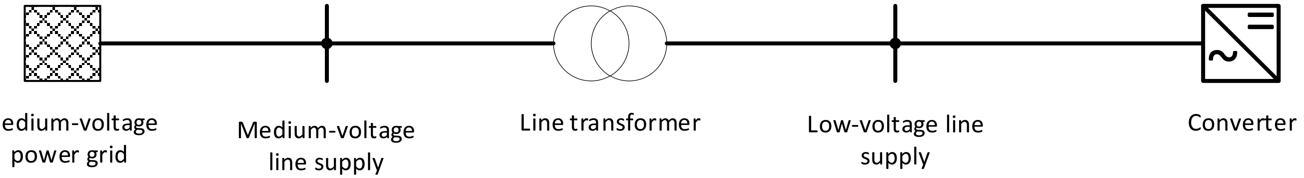
$$I''_{k\_IPC} = \frac{S''_{k\_IPC}}{\sqrt{3} \cdot U_{FC\ line}} = 7.518 \quad \text{kA}$$

$$I''_{k2\_IPC} = \frac{\sqrt{3}}{2} \cdot I''_{k\_IPC} = 6.511 \quad \text{kA}$$

1.3.5 Checking the relative line short-circuit power RSC of an existing line connection

1.3.5.1 Overview of a typical line supply topology

Fig. 1-8



1.3.5.2 Required data

Medium-voltage power grid:

- Voltage of the medium-voltage line supply

  $U_{MV\ line}$ **=** 20.0 **kV**
- Line frequency

  f **=** 50 **Hz**
- Short-circuit power of the power grid

  S''_{k_line} **=** 20.00000 **MVA**

  In Germany, the short-circuit powers in medium-voltage line supplies are generally between 20 and 500 MVA - and typically between 50 and 200 MVA.

Medium-voltage line supply:

- Inductance value per unit length of the medium-voltage cable according to data sheet information[7]

  $\mathbf{L'_{MV\ line}} = 1.0500\ \mathbf{\frac{\mu H}{m}}$

- Length of the medium-voltage cable

  $\mathbf{l_{MV\ line}} = 5.0\ \mathbf{km}$

- specific resistance of the medium-voltage cable[8]

  $\boldsymbol{\rho_{MV}} = 0.02941\ \boldsymbol{\Omega \frac{mm^2}{m}}$

- Conductor cross-section of one phase of the medium-voltage connection

  $\mathbf{q_{MV}} = 120\ \mathbf{mm^2}$

---

[7] This value is very dependent on the geometrical structure of the cable and/or the conductor. The following approximate values can be used if more precise data are not available:
$0.25\ \frac{\mu H}{m}$ for cables and conductors,
$0.38\ \frac{\mu H}{m}$ for busbars,
$1.05\ \frac{\mu H}{m}$ for outdoor overhead cables

[8] specific resistances of copper, aluminum and aluminum alloy
$\frac{1}{54}\Omega\frac{mm^2}{m}$ for copper
$\frac{1}{34}\Omega\frac{mm^2}{m}$ for aluminum
$\frac{1}{31}\Omega\frac{mm^2}{m}$ for aluminum alloy

Line transformer

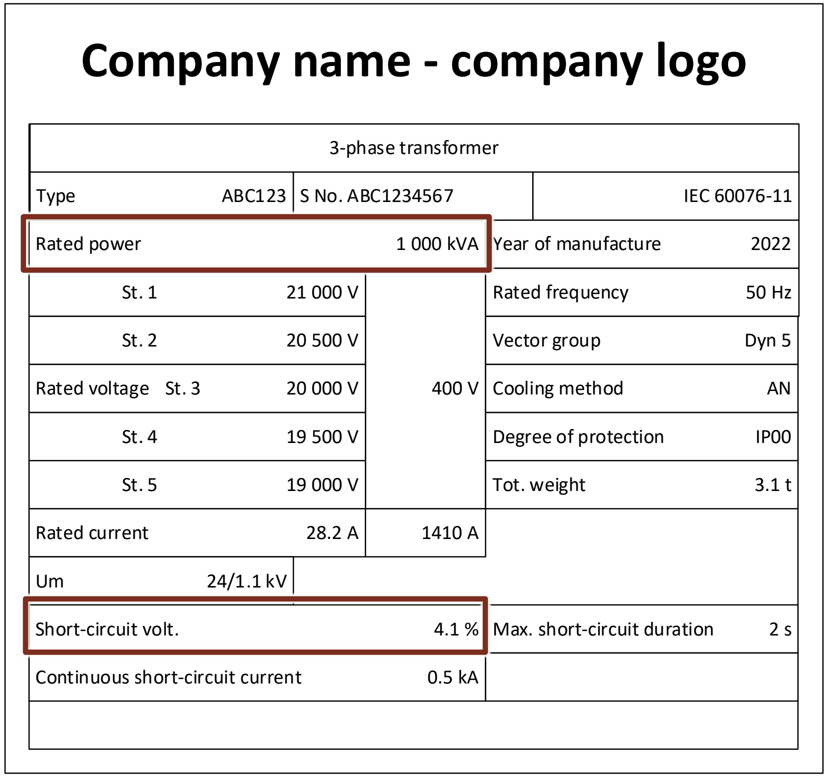
- Relative short-circuit voltage of the line transformer

  $u_{k\_line\ transformer}$ = 4.1 **%**

- Rated apparent power of the line transformer

  $S_{line\ transformer}$ = 1000.0000 **MVA**

Fig. 1-9 Example of a transformer rating plate



Company name - company logo

3-phase transformer				
Type	ABC123	S No. ABC1234567		IEC 60076-11
Rated power	1 000 kVA		Year of manufacture	2022
St. 1	21 000 V	400 V	Rated frequency	50 Hz
St. 2	20 500 V		Vector group	Dyn 5
Rated voltage St. 3	20 000 V		Cooling method	AN
St. 4	19 500 V		Degree of protection	IP00
St. 5	19 000 V		Tot. weight	3.1 t
Rated current	28.2 A	1410 A		
Um	24/1.1 kV			
Short-circuit volt.	4.1 %		Max. short-circuit duration	2 s
Continuous short-circuit current	0.5 kA			

Low-voltage line supply:

- Voltage of the low-voltage line supply

  $\mathbf{U_{LV\ line}} = 400\ \mathbf{V}$

- Inductance value per unit length of the low-voltage cable according to data sheet information[9]

  $\mathbf{L'_{LV\ line}} = 0.2550\ \mathbf{\frac{\mu H}{m}}$

- Length of the low-voltage cable

  $\mathbf{l_{LV\ line}} = 55.0\ \mathbf{m}$

- specific resistance of the low-voltage cable [10]

  $\boldsymbol{\rho_{LV}} = 0.01852\ \boldsymbol{\Omega \frac{mm^2}{m}}$

- Conductor cross-section of one phase of the low-voltage connection

  $\mathbf{q_{LV}} = 2000.0\ \mathbf{mm^2}$

---

[9] This value is very dependent on the geometrical structure of the cable and/or the conductor. The following approximate values can be used if more precise data are not available:
$0.25\ \frac{\mu H}{m}$ for cables and conductors,
$0.38\ \frac{\mu H}{m}$ for busbars,
$1.05\ \frac{\mu H}{m}$ for outdoor overhead cables

[10] specific resistances of copper, aluminum and aluminum alloy
$\frac{1}{54}\,\Omega\frac{mm^2}{m}$ for copper
$\frac{1}{34}\,\Omega\frac{mm^2}{m}$ for aluminum
$\frac{1}{31}\,\Omega\frac{mm^2}{m}$ for aluminum alloy

Converter connection at the low-voltage line supply:

- Inductance value per unit length of the converter connecting cable according to data sheet information [11]

  $L'_{FC\ line}$ = 0.2550 $\frac{\mu H}{m}$

- Cable length to the converter

  $l_{FC\ line}$ = 35.0 **m**

- Specific resistance of the converter connecting cable [12]

  ρ_{FC} = 0.01852 $\Omega\frac{mm^2}{m}$

- Cross-section of one phase of the converter connection

  q_{FC} = 75.0 **mm²**

- Minimum relative short-circuit power for the type of infeed corresponding to Table 1-1

  RSC_{min} = 30

- Rated input current of the Line Module for a 380 V line supply voltage

  $I_{rated\_Line\_Module}$ = 192 **A**

- Rated power of the Line Module for the selected supply voltage

  $P_{rated\_Line\_Module}$ = 120 **kW**

- k factor – takes into account the supplementary losses in the transformer due to harmonic currents - for Booksize Line Modules, k = 1.27

  k_{infeed} = 1.27

---

[11] This value is very dependent on the geometrical structure of the cable and/or the conductor. The following approximate values can be used if more precise data are not available:
0.25 $\frac{\mu H}{m}$ for cables and conductors,
0.38 $\frac{\mu H}{m}$ for busbars,

[12] specific resistances of copper, aluminum and aluminum alloy
$\frac{1}{54}\Omega\frac{mm^2}{m}$ for copper
$\frac{1}{34}\Omega\frac{mm^2}{m}$ for aluminum
$\frac{1}{31}\Omega\frac{mm^2}{m}$ for aluminum alloy

1.3.5.3 Calculations

Supporting calculations

The rated apparent power of the Line Module is:

$S_{Rated_{Converter}} = U_{Line\ supply} \cdot I_{Rated_{Line_{Module}}} \cdot \sqrt{3}$ = 133.02 kVA

The specific conductance value of the medium-voltage cable is:

$k'_{MV} = 2\pi \cdot f \cdot L'_{MV\ line}$ = 0.00032987 $\frac{\Omega}{m}$

In turn, the reactance of the medium-voltage cable is calculated as follows:

$X_{MV} = k'_{MV} \cdot l_{MV\ line}$ = 1.649335 Ω

The active resistance of the medium-voltage cable is calculated as follows:

$R_{MV} = \frac{\rho_{MV}}{q_{MV}} \cdot l_{MV\ line}$ = 1.225417 Ω

The specific conductance value of the low-voltage cable is:

$k'_{LV} = 2\pi \cdot f \cdot L'_{LV\ line}$ = 0.00008011 $\frac{\Omega}{m}$

In turn, the reactance of the low-voltage cable is calculated as follows:

$X_{LV} = k'_{LV} \cdot l_{LV\ line}$ = 0.004406 Ω

The active resistance of the low-voltage cable is calculated as follows:

$R_{LV} = \frac{\rho_{LV}}{q_{LV}} \cdot l_{LV\ line}$ = 0.000509 Ω

The specific conductance value of the converter connecting cable is calculated to be:

$k'_{FC} = 2\pi \cdot f \cdot L'_{FC\ line}$ = 0.00008011 $\frac{\Omega}{m}$

In turn, the reactance of the converter connecting cable is calculated as follows:

$X_{FC} = k'_{FC} \cdot l_{FC\ line}$ = 0.002804 Ω

The active resistance of the converter connecting cable is calculated as follows:

$R_{FC} = \frac{\rho_{FC}}{q_{FC}} \cdot l_{FC\ line}$ = 0.008643 Ω

Calculating the relative impedances using the %/MVA technique

- Impedance of the medium-voltage power grid

$$Z_{Line\ supply} = \frac{1.1}{S''k_{Line\ supply}} = 5.500 \quad \frac{\%}{MVA}$$

- Impedance of the medium-voltage cable

$$Z_{MV\ cable} = \frac{\sqrt{X_{MV}^2 \cdot R_{MV}^2}}{U_{MV\ line}^2} = 0.514 \quad \frac{\%}{MVA}$$

- Impedance of the line transformer

$$Z_{Line\ supplytransformer} = \frac{u_{k\ line\ transformer}}{S_{Line\ transformer}} = 0.004 \quad \frac{\%}{MVA}$$

- Impedance of the low-voltage cable

$$Z_{LV\ cable} = \frac{\sqrt{X_{LV}^2 \cdot R_{LV}^2}}{U_{LV\ line}^2} = 2.772 \quad \frac{\%}{MVA}$$

- Impedance of the converter connecting cable

$$Z_{FC\ cable} = \frac{\sqrt{X_{FC}^2 \cdot R_{FC}^2}}{U_{FC\ line}^2} = 5.679 \quad \frac{\%}{MVA}$$

Calculating the relative line short-circuit power RSC at the converter connection point

The short-circuit power at the connection point IPC is:

$$S''_{k\_IPC} = \frac{1.1}{Z_{Line\,supply}+Z_{MV-Cable}+Z_{Line\,transformer}+Z_{LV-Cable}+Z_{FC-Cable}} = 7.603 \qquad \text{MVA}$$

The relative short-circuit power at the connection point IPC is therefore:

$$RSC_{IPC} = \frac{S''_{k\_IPC}}{S_{Rated_{Converter}}} \qquad = 57$$

Further, the expected short-circuit currents at connection point IPC can be determined:

$$I''_{k\_IPC} = \frac{S''_{k\_IPC}}{\sqrt{3} \cdot U_{FC\,line}} \qquad = 10.973 \qquad \text{kA}$$

$$I''_{k2\_IPC} = \frac{\sqrt{3}}{2} \cdot I''_{k\_IPC} \qquad = 9.503 \qquad \text{kA}$$

2 Examples and tips

2.1 Missing data or other line supply topologies

How can I estimate the RSC if the line supply connection point is unknown?

For various applications, it is possible that the data of the line connection point for end users is not precisely known. This is especially the case for the line short-circuit power or various cable lengths, which are frequently not known. For the following simplified calculations, in some cases the determined RSC can be significantly higher than the real value. As a consequence, an appropriate reserve must always be taken into consideration. Exceptions are appropriately marked.

Additional possibilities for making an estimate exist:

1. The line short-circuit power is not known.
   In the power range of SINAMICS S120 Line Modules Booksize, in European line supplies/grids, the line short-circuit power is typically very high when compared to the apparent power of the Line Module; this means the influence of this value on the relative short-circuit power is low.
   Assume a typical value of S''_{k_line} = 50 MVA.

2. The cable length is unknown.
   Unknown cable lengths, especially in the low-voltage line supply, can have a significant impact on the relative short-circuit power. As a consequence, in these cases, for the final installation location, a maximum length of the supply cable must be defined, and this value should be used for the calculation.
   If this is not possible, then cable lengths are specified as being 0 m. This means that the impedances are no longer taken into consideration in the calculations.

3. The transfer point of the power utility company is at the low-voltage level and therefore there is no data available about the medium-voltage grid. In this case, insert the short-circuit power in the formulas as before. The length of the medium-voltage cable should then be inserted as $l_{MV\ line}$ = 0 km. The medium-voltage grid voltage remains at the preassigned value, or is simply set higher than zero, as it is no longer incorporated in the calculation without the cable length. In this case, this does not result in any inaccuracy in the calculation.

4. There is no additional line transformer after the transfer point in the low-voltage supply. In this case, enter $u_{k\_line\ transformer}$ = 0 % in the formulas above. Also in this case, this does not result in any inaccuracy in the calculation.

How can I make rough estimates only using the transformer data?

If, in addition to the transformer data, no additional data for determining the line impedance is available, then the relative line short-circuit power can only be very roughly estimated.

$$RSC \approx \frac{S_{transformer}}{\sqrt{3} \cdot I_{Rated_{Converter}} \cdot U_{supply} \cdot u_{k_{transformer}}} \cdot 100\%$$

2.2 Operation on a generator

How can I estimate the relative line short-circuit power when directly operated on a generator?

As the ohmic resistance of the generator when compared to the inductive resistance is very low, it can be neglected for the calculation.
As a consequence, the calculation is only made with the relative subtransient reactance of the generator X''_d.
For a simplified calculation, the following applies for the generator impedance:

$Z_{Generator} = \frac{X''_{d-Generator}}{S_{Generator}}$ in $\frac{\%}{MVA}$

With the formulas used in Chapter "1.3.4.3 Calculations", the formula can be switched over for the line short-circuit power at connection point IPC as follows:

$$S''_{k\_IPC\_Generator} = \frac{1.1}{Z_{Generator} + Z_{FC\ cable}}$$

The relative short-circuit power at the connection point IPC is therefore:

$$RSC_{IPC} = \frac{S''_{k\_PCC}}{\sqrt{3} \cdot I_{Rated_{Converter}} \cdot U_{supply}}$$

How can I estimate the relative line short-circuit power when operated on a generator via a matching transformer?

Also here, the relative subtransient reactance of the generator X''_d is required.
For the calculation, the following applies for the generator impedance:

$Z_{Generator} = \frac{X''_{d-Generator}}{S_{Generator}}$ in $\frac{\%}{MVA}$

With the formula for the generator impedance and the other formulas used in Chapter "1.3.4.3 Calculations", the short-circuit power at connection point IPC is as follows:

$$S''_{k\_IPC} = \frac{1.1}{Z_{Generator} + Z_{Transformer\ feeder\ cable} + Z_{Matching\ transformer} + Z_{FC-Cable}}$$

The relative short-circuit power at the connection point IPC is therefore:

$$RSC_{IPC} = \frac{S''_{k\_IPC}}{\sqrt{3} \cdot I_{Rated_{Converter}} \cdot U_{supply}}$$

3 Appendix

3.1 Application Support

Siemens AG
Digital Industries
Factory Automation
Application Center 1
DI FA PMA APC 1
Geraetewerk
Frauenauracher Str. 80
91056 Erlangen, Germany
mailto: tech.team.motioncontrol@siemens.com

3.2 Links and references

Table 3-1

No.	Subject
\1\	Siemens Industry Online Support https://support.industry.siemens.com
\2\	Link to the entry page of the application example https://support.industry.siemens.com/cs/ww/en/view/109808992
\3\	Configuration Manual SINAMICS G130, G150, S120 Chassis, S120 Cabinet Modules, S150 https://support.industry.siemens.com/cs/ww/en/view/83180185

3.3 Change documentation

Table 3-2

Version	Date	Change
V1.0	04/2022	First Edition