Technical Information

Circuit breakers

Dimensioning of Suitable Circuit Breakers for Inverters under PV-Specific Influences

1 Introduction

The selection of the right circuit breaker depends on various influencing factors. In PV systems particularly, the impact of certain factors is stronger than in customary electrical installations. If these factors are ignored, it increases the danger of the circuit breaker tripping under normal operating conditions. It is therefore important to pay special attention to these factors, as this is the only way to ensure reliable operation of the PV system and maximum possible grid feed-in.

The following pages describe the factors that must be taken into account when selecting a circuit breaker, the specific influences affecting PV systems, and the consequences of an incorrectly designed circuit breaker. At the end of this document, you will find a table summarizing the maximum permissible fuse protection of the SMA inverters Sunny Boy, Sunny Mini Central and Sunny Tripower.

2 Influencing Factors for the Selection of Suitable Circuit Breakers

2.1 General Influencing Factors

The general requirements for the selection of circuit breakers are determined by standards and country-specific provisions. In the following, generally applicable influencing factors to be considered when selecting a suitable circuit breaker are listed:

Factors influencing the ampacity of the cable:

- **Type of cable used**
  The ampacity of the cable used depends on the cable cross-section, cable material, and cable type (insulation, number of conductors, etc.). The circuit breaker must therefore limit the electric current to an extent at which the ampacity cannot be exceeded.
- **Ambient temperature around the cable**
  An increase in the ambient temperature around the cable will diminish the ampacity.
- **Type of cable routing**
  If the cable is laid in insulation material, for instance, its ampacity will be diminished. The worse the heat dissipation from the cable to the outside, the lower its ampacity.
- **Bundling of cables**
  If cables are laid close together, they will be subject to mutual heating. The ampacity is reduced due to the heating of the cables.

Other influences on dimensioning:

- **Loop impedance**
  Under fault conditions, the loop impedance of the cable limits the current. This must not have any impact on the tripping times of the circuit breaker.
- **Mutual heating of circuit breakers**
  If circuit breakers are arranged too close to each other, they will be subject to mutual heating. Excessive heat impact will cause them to trip below their nominal current.
- **Ambient temperature at the circuit breaker**
  At higher ambient temperatures around the circuit breaker, less heat can be dissipated. Thus, the circuit breaker will trip below its nominal current.
- **Selectivity**
  Consecutively installed fuses/circuit breakers must be mutually compatible to avoid involuntary tripping of upstream fuse devices.
- **Type of connected device**
  Depending on the start-up behavior of the connected device, different characteristics must be used to avoid involuntary tripping.

2.2 PV-Specific Influencing Factors

In the case of PV systems, some of the previously mentioned influencing factors have an above-average effect on the selection of the circuit breaker. In the following, the PV-specific influencing factors which need to be considered when selecting suitable circuit breakers are listed:

Factors influencing the ampacity of the cable:

- **Ambient temperature around the cable**

  In the case of PV systems, cables are often laid outdoors (open-site systems, flat roof systems, etc.). It is normally assumed that the ambient temperature outdoors will be higher than for installations in buildings. The ampacity is reduced due to the increase of the ambient temperature.

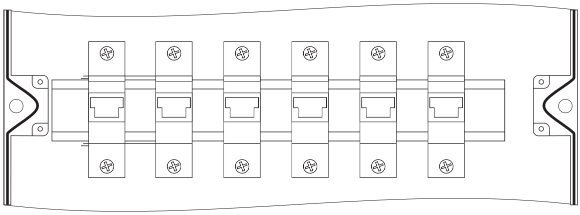
- **Mutual heating of circuit breakers**

  In PV systems, inverters simultaneously feeding in their maximum current (simultaneity) are often also connected to neighboring circuit breakers. This causes the circuit breakers to heat up faster which may lead to premature tripping. In order to ensure sufficient heat dissipation and prevent premature tripping, larger clearances must be maintained between the individual circuit breakers.

  To calculate heat losses, a correction factor is specified in the technical data of the circuit breaker. With a row of nine devices, for instance, this correction factor can be specified as 0.77. The circuit breaker with a nominal current of 50 A will then behave as if its nominal current was 0.77 x 50 A = 38.5 A.

  If this current is not sufficient, a circuit breaker with a higher nominal current can be used. Always remember that, depending on the situation (no simultaneity), the fuse will not trip until its nominal current is reached. In this case, the connected cable must either have an appropriate ampacity or it will need to be replaced by a cable with a larger cross-section.

  Another possibility is to increase the distance between the circuit breakers. This allows more heat to dissipate, thus preventing undesired tripping.



- **Ambient temperature at the circuit breaker**

  Due to the previously described simultaneity, the distribution board in which the circuit breaker is installed can heat up more than is normal for customary installations. Since the distribution boards in PV systems are often installed in the open air, higher temperatures in the distribution board are to be reckoned with.

  Data on screening factors for this influence is specified in the technical data of the circuit breaker.

- **Type of connected device**

  Refer to the installation manual for the appropriate characteristics of the respective inverter. The load-disconnection properties of a circuit breaker can be used to disconnect the inverter from the utility grid under load.

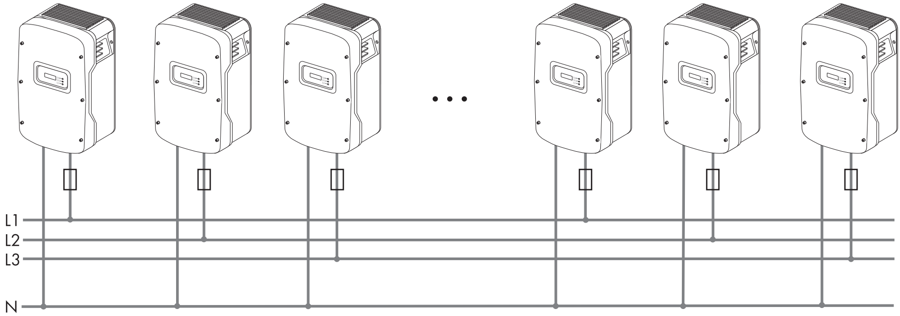
  A screw type fuse element, e.g. DIAZED fuse or NEOZED fuse does not have load-disconnection properties and can therefore be used as cable protection, but must **not** be used as a switch-disconnector.

  When disconnecting under load, the fuse element can be destroyed or its functionality impaired due to contact erosion. No additional loads must be connected between the circuit breaker and the inverter.

3 Calculation Example

Example for the thermal rating of a circuit breaker in a PV system in parallel grid operation.

PV system with nine Sunny Mini Central 7000HV inverters and three inverters per line conductor.



Required technical specifications of the Sunny Mini Central 7000HV:

- Maximum output current = 31 A
- Maximum permissible fuse protection of the Sunny Mini Central = 50 A
- The selection of the cable as well as the type of routing, ambient temperatures and other marginal conditions limit the maximum fuse protection of the cable.

In this example, it is assumed that the selected cable (6 mm^2) as routed here can carry a nominal current of 32.2 A.

Selection of Circuit Breakers

Example for the thermal selection of a 40 A circuit breaker with B-type tripping characteristic with no gap between the circuit breakers.

- The maximum possible nominal current of the cable used and the maximum possible fuse protection of the Sunny Mini Central limit the maximum possible nominal current of the circuit breakers.
- In our example, 40 A are assumed.
- In addition, you must check the thermal capacity of the circuit breakers.

Load factors as per datasheet specifications:

- Reduction due to permanent load > 1 h = 0.9
  Continuous loads of more than one hour are possible in the PV sector
- Reduction due to consecutive installation of nine circuit breakers without gap = 0.77
  If only one circuit breaker is used, this factor equals 1
- Increase in nominal current due to ambient temperatures of 40 °C in the distribution board = 1.07
  Due to the fact that the circuit breakers are rated for 50 °C

Result:

The nominal load current of the circuit breaker is derived as follows:

Ibn = 40 A x 0.9 x 0.77 x 1.07 = 29.7 A

Conclusion:

In this example, the selected circuit breaker cannot be used, since the maximum ampacity for fault-free operation is lower than the maximum output current of the inverter used. **The circuit breaker is being tripped at rated operation.**

Solution 1:

Use a 50 A circuit breaker. As a result, the maximum ampacity is 37.1 A
(Ibn = 50 A x 0.9 x 0.77 x 1.07 = 37.1 A) so the circuit breaker will not trip in rated operation. Note that the selected cable with a cross-section of 6 mm^2 **cannot** be used for this solution. Use a cable with a larger cross-section. The ampacity of the cable must be suitable for the selected fuse protection.

Solution 2:

Increase the distance between the circuit breakers to 8 mm and use a 40 A circuit breaker. The reduction factor is 0.98 instead of 0.77. As a result, the maximum current-carrying capacity is 37.7 A (Ibn = 40 A x 0.9 x 0.98 x 1.07 = 37.7 A) so the circuit breaker will **not** trip in rated operation. Note that the selected cable with a cross-section of 6 mm^2 cannot be used for this solution. The ampacity of the cable must be suitable for the selected fuse protection.

4 Maximum permissible fuse protection

The following table summarizes the maximum permissible fuse protection for the various SMA inverters:

Inverter type	Maximum fuse protection (electrical current strength)
SBS2.5-1VL-10	16 A
SB1.5-1VL-40 / SB2.0-1VL-40 / SB2.5-1VL-40	16 A
Multigate-10	16 A
SB 1200 / 1700	16 A
SB 1300TL-10 / 1600TL-10 / 2100TL	16 A
SB 2500 / 3000	16 A
SB 2500TLST-21 / 3000TLST-21	32 A
SB 2000HF-30 / 2500HF-30 / 3000HF-30	25 A
SB3.0-1AV-40 / SB3.6-1AV-40 / SB4.0-1AV-40 / SB5.0-1AV-40	32 A
SB3.0-1AV-41 / SB3.6-1AV-41 / SB4.0-1AV-41 / SB5.0-1AV-41 / SB6.0-1AV-41	32 A
SB 3300TL HC	32 A
SB 3300 / 3800	25 A
SB 3000TL-20 / 4000TL-20 / 5000TL-20	32 A
SB 3000TL-21 / 3600TL-21 / 4000TL-21 / 5000TL-21 / 6000TL-21	32 A
SB 3600SE-10 / 5000SE-10	32 A
SMC 4600A / 5000A / 6000A	40 A
SMC 7000HV	50 A
SMC 6000TL / 7000TL / 8000TL	50 A
SMC 9000TL-10 / 10000TL-10 / 11000TL-10	80 A
SMC 9000TLRP-10 / 10000TLRP-10 / 110000TLRP-10	80 A
STP3.0-3AV-40 / STP4.0-3AV-40 / STP5.0-3AV-40 / STP6.0-3AV-40	32 A
STP 5000TL-20 / 6000TL-20 / 7000TL-20 / 8000TL-20 / 9000TL-20 / 10000TL-20 / 12000TL-20	32 A
STP8.0-3AV-40 / STP10.0-3AV-40	32 A
STP 8000TL-10 / 10000TL-10 / 12000TL-10 / 15000TL-10 / 17000TL-10	50 A

Inverter type	Maximum fuse protection (electrical current strength)
STP 15000TLEE-10 / 20000TLEE-10	50 A
STP 15000TL-30 / 20000TL-30 / 25000TL-30	50 A
STP 50-40	100 A
STP 60-10	125 A
SHP 75-10	160 A