Circuit Breaker

Sizing of Suitable Circuit Breakers

for inverters under PV-specific conditions

Content

The selection of the correct circuit breaker depends on various factors. Especially in case of PV plants, some factors have a stronger impact than in customary electrical installations.

Ignoring these factors increases the danger that the circuit breaker will trip during normal operating conditions. It is therefore important to take these factors especially into account; only this will ensure a reliable operation of the PV plant and maximum possible grid feed-in.

The following pages describe the factors that must be taken into account when selecting a circuit breaker, the special factors for PV plants, and the consequences of an incorrectly designed circuit breaker. In the end of this document you will find a table providing an overview of the maximum permissible fuse protection of the SMA inverters Sunny Boy, Sunny Mini Central and Sunny Tripower.

1 Influencing Factors when Selecting Suitable Circuit Breakers

1.1 General Influencing Factors

The general requirements for the selection of a circuit breaker are determined by standards and country-specific provisions.

In the following, generally applicable influencing factors are listed that must be taken into consideration during the selection of an appropriate circuit breaker:

Factors on 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 the extent that this is not exceeded.

- **Ambient temperature at the cable**

  Increased ambient temperature on the cable leads to an ampacity reduction.

- **Cable routing**

  If the cable is laid in insulation material, for example, its ampacity is reduced. The worse the cable heat dissipation to the outside, the lower is its ampacity.

- **Bundling of cables**

  If cables are laid close together, they heat up each other. The ampacity is reduced due to the heating of the cables.

Other influences on dimensioning:

- **Loop impedance**

  The loop impedance of the cable limits the current under fault conditions. 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 heat up each other. During excessive heat impairment, the circuit breakers already trip below their nominal current.

- **Ambient temperature at the circuit breaker**

  Due to increased ambient temperature at the circuit breaker, less heat can be dissipated. The circuit breaker thus trips at a current below its nominal current.

- **Selectivity**

  Consecutively installed fuses/circuit breakers must be harmonised with one another to avoid unwanted trips of upstream fuse devices.

- **Type of the connected device**

  Depending on the start-up behavior of the connected device, different characteristics must be used to avoid false tripping.

1.2 PV-Specific Influencing Factors

In case of PV plants, some of the previously mentioned influencing factors can affect the selection of the circuit breaker more than usual.

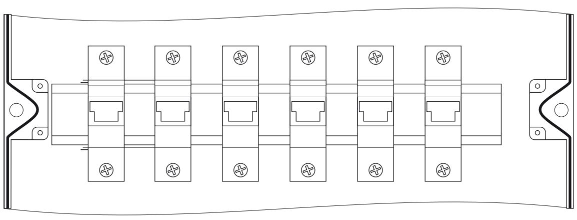
In the following, PV-specific influencing factors are listed that must be taken into consideration during the selection of an appropriate circuit breaker:

- **Ambient temperature at the cable**

  In case of PV plants, cables are often laid outside (open-site systems, flat roof systems, etc.). A higher outdoor temperature is usually presumed than for installations in buildings. The ampacity is reduced due to the increase of the ambient temperature.

- **Mutual heating of circuit breakers**

  In case of PV plants, inverters are often connected to neighboring circuit breakers which simultaneously feed in their maximum current (simultaneity). Therefore, the circuit breakers heat up faster and premature tripping can be caused. In order to ensure sufficient heat dissipation and prevent premature tripping, larger clearances must be maintained between the individual circuit breakers.



  The deduction for heat impairment is designated as adding factor. This factor is specified in the technical data of the circuit breaker. With an arrangement of nine devices, for example, the adding factor can be 0.77. The circuit breaker with a nominal current of 50 A behaves 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, for example, can be used. It is to be taken into account that the fuse only trips with its nominal current, depending on the situation (no simultaneity). In this case, the connected cable must also have an appropriate ampacity or be replaced with a cable with a larger cross-section.

Another possibility is to increase the clearance between the circuit breakers. This allows to dissipate more heat, 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 customary for ordinary installations.

  Since the distribution boards in PV plants are often set up outside of buildings, higher temperatures in the distribution board can be expected.

  Specifications on screening factors for this influence are specified in the technical data of the circuit breaker.

- **Type of the connected device**

  Refer to the installation manual for the appropriate characteristic 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 may therefore be used as cable protection, but must **not** be used as switch-disconnector.

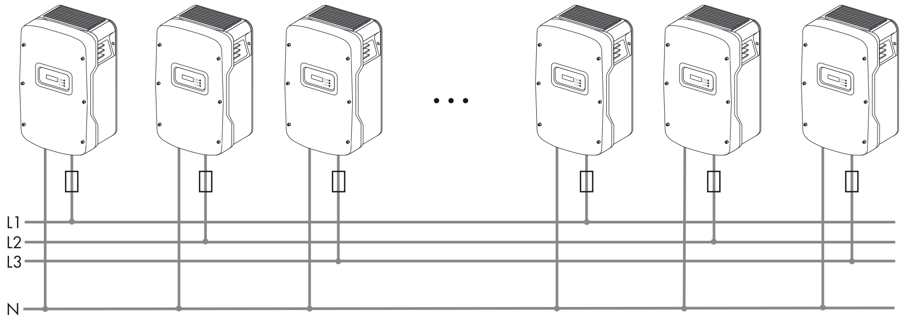
  When disconnecting under load, the fuse element can be destroyed or its functionality may be impaired due to contact erosion.

  No additional loads must be connected between the circuit breaker and the inverter.

2 Calculation Example

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

PV plant with nine Sunny Mini Central 7000 HV 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 its routing method, ambient temperatures and other underlying conditions limit the maximum fuse protection of the cable.

  In our example we assume that the selected cable (6 mm^2) is ideally routed and can take a nominal current of 32.2 A.

Selection of the Circuit Breakers

- The maximum possible nominal current for the cable used and the maximum possible fuse protection of the Sunny Mini Central limit the maximum possible nominal current for the circuit breakers.

An example for the thermal selection of a 40 A circuit breaker with tripping characteristics B with no clearance between the circuit breakers.

- In our example, 40 A is assumed.
- Additionally, check the thermal suitability of the circuit breakers.

Load factors according to data sheet specifications:

- Reduction due to permanent load > 1 h = 0.9

  (Permanent loads of more than one hour are possible in photovoltaics.)
- Reduction factor when nine circuit breakers are arranged directly next to each other = 0.77

  (When only one circuit breaker is used, this factor equals to 1.)
- Increase in nominal current as a result of 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 calculated as:

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

Conclusion:

The selected circuit breaker cannot be used in this example since the maximum current-carrying capacity for fault-free operation is lower than the maximum output current of the inverter used. **The circuit breaker will trip in rated operation.**

Solution 1:

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

Solution 2:

Increase the distance between the circuit breakers to 8 mm. The reduction factor is 0.98 instead of 0.77. As a result, the maximum current-carrying capacity is 33 A (Ibn = 40 A x 0.9 x 0.98 x 1.07 = 37.7 A) and the circuit breaker will **not** trip in rated operation. Observe that the selected cable of 6 mm^2 must not be used for this solution. The current-carrying capacity of this cable must be suitable for the selected fuse protection.

3 Maximum Permissible Fuse Protection

The following table presents an overview of the maximum permissible fuse protection for the different SMA inverters:

Inverter type	**Maximum fuse protection (electrical current strength)**
Sunny Boy 1200	16 A
Sunny Boy 1700	16 A
Sunny Boy 2100TL	16 A
Sunny Boy 2500	16 A
Sunny Boy 3000	16 A
Sunny Boy 2000HF	25 A
Sunny Boy 2500HF	25 A
Sunny Boy 3000HF	25 A
Sunny Boy 3300	25 A
Sunny Boy 3800	25 A
Sunny Boy 3300TL HC	32 A
Sunny Boy 4000TL	32 A
Sunny Boy 5000TL	32 A
Sunny Mini Central 4600A	40 A
Sunny Mini Central 5000A	40 A
Sunny Mini Central 6000A	40 A
Sunny Mini Central 7000HV	50 A
Sunny Mini Central 6000TL	50 A
Sunny Mini Central 7000TL	50 A
Sunny Mini Central 8000TL	50 A
Sunny Mini Central 9000TL	80 A
Sunny Mini Central 10000TL	80 A
Sunny Mini Central 11000TL	80 A
Sunny Mini Central 9000TL RP	80 A
Sunny Mini Central 10000TL RP	80 A
Sunny Mini Central 11000TL RP	80 A
Sunny Tripower 8000TL	50 A
Sunny Tripower 10000TL	50 A
Sunny Tripower 12000TL	50 A
Sunny Tripower 15000TL	50 A
Sunny Tripower 17000TL	50 A