Criteria for Selecting a Residual-Current Device

Use of Residual-Current Devices for

SUNNY BOY, SUNNY MINI CENTRAL and SUNNY TRIPOWER

Content

When installing inverters, there are often uncertainties when using a residual-current device. For PV plants, above all DIN VDE 0100-410 (IEC 60364-4-41:2005) and DIN VDE 0100-712 (IEC60364-7-712:2002) may be applied. Residual-current devices are used as protection against indirect contact (personal safety).

1 Definition

1.1 Protective Measure According to DIN VDE 0100-410 (IEC 60364-4-41:2005)

According to this standard, a measure protecting against electric shock consists of two safety precautions:

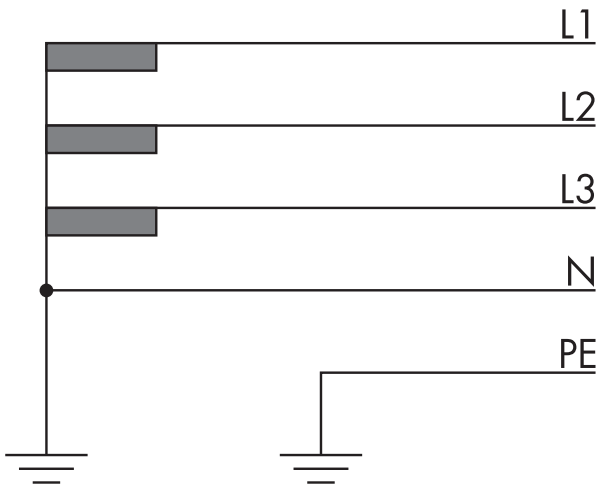
- Basic protection: protection from direct contact.
- Fault protection: protection in the event of a fault. This safety precaution takes effect when the basic protection ceases to be effective and prevents physical damage.

The installation of a PV plant on the AC side is generally protected through automatic disconnection of supply.

Apart from the insulation of live parts as basic protection, fault protection is also established through protective electric bonding and through a disconnection device. It must disconnect within the specified time after occurrence of the fault (at 230 V_{AC}: 0.2 s in TT grounding systems or 0.4 s in TN grounding systems).

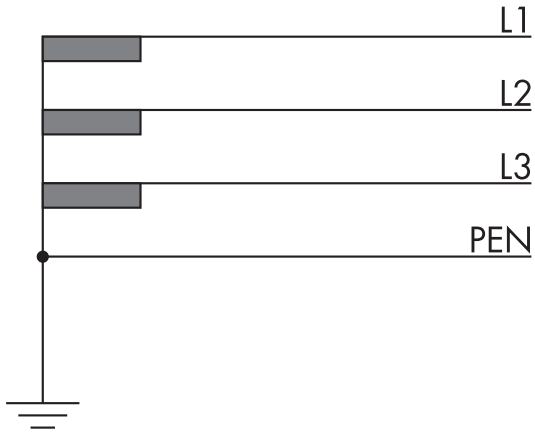
1.2 Grounding Systems

TT Grounding System

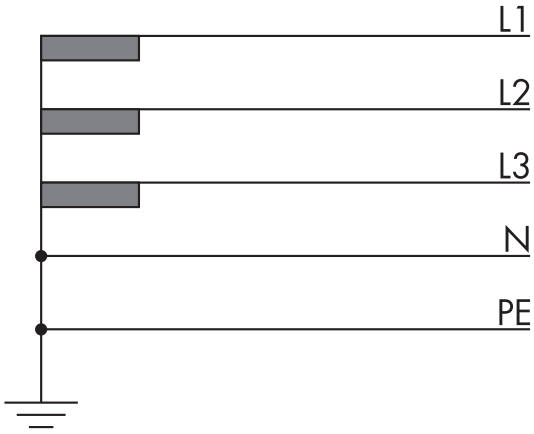


TN Grounding Systems

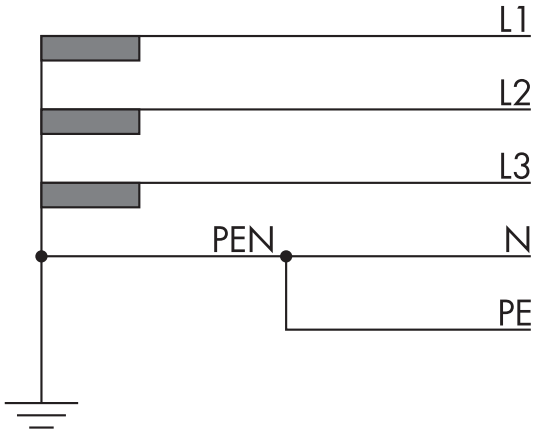
TN-C Grounding System



TN-S Grounding System



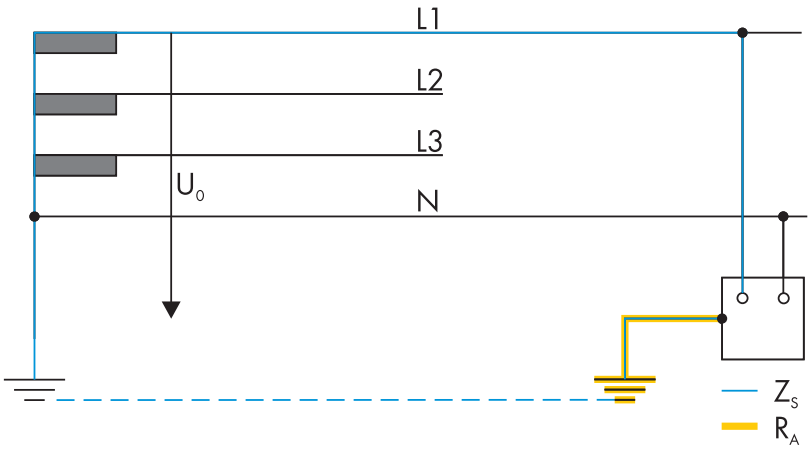
TN-C-S Grounding System



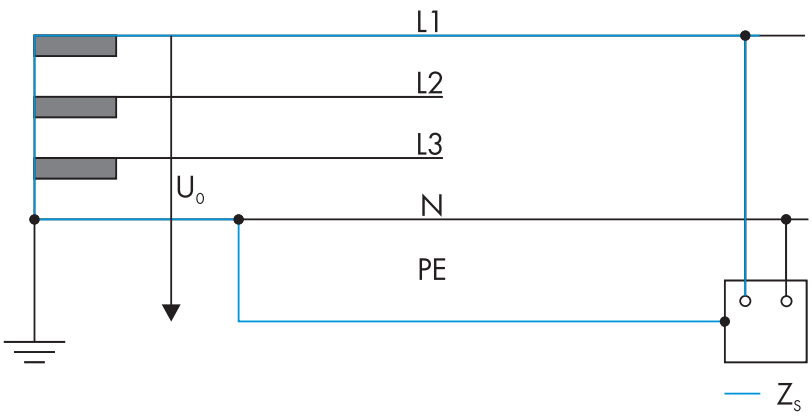
1.3 Abbreviations, Symbols and Formula Symbols

- LS — Miniature circuit-breaker
-  — Circuit symbol for miniature circuit-breaker
- RCD — Residual-current device
- RCMU — (All-pole sensitive) residual-current monitoring unit
- I_a — Current causing automatic disconnection within the required time (short-circuit protection)

  If the miniature circuit-breaker has B-characteristics, this will be 5 times the nominal current (I_{nom}) of the miniature circuit-breaker. In case of C-characteristics, it will be 10 times as high, e.g. LS C16 A => I_a = 160 A.
- I_{nom} — Nominal current of the miniature circuit-breaker
- $I_{\Delta f}$ — Rated residual current of the residual-current device
- R_A — Total resistance of the ground electrode and protective conductor of the exposed conductive part to be protected
- U_0 — Nominal AC voltage of the line conductor to ground
- Z_S — Loop impedance of the error loop (consisting of power source, line conductor to the fault location and protective conductor between fault location and power source)
- R_A and Z_S in TT grounding system



- Z_S in TN grounding system



2 Disconnection Options

Automatic disconnection can be established through protective electric bonding combined with a miniature circuit-breaker or a residual-current device in accordance with DIN VDE 0100-410 (IEC 60364-4-41:2005).

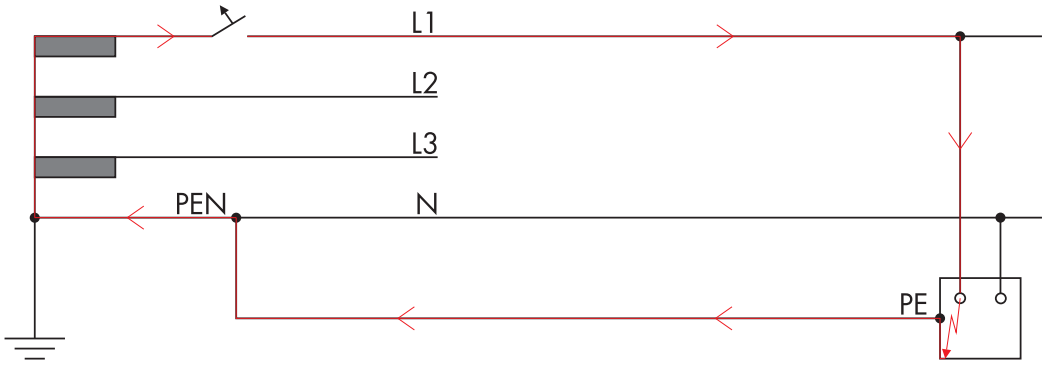
2.1 Automatic Disconnection via Miniature Circuit-Breaker

A miniature circuit-breaker can guarantee the automatic disconnection if the following conditions are met:

- TN grounding system:

  If $Z_S \leq \frac{U_0}{I_a}$, then the miniature circuit-breaker can guarantee protection through automatic disconnection.

- TT grounding system:
  - A residual-current device is required as primary fault protection.
  - If $Z_S \leq \frac{U_0}{I_a}$, then the miniature circuit-breaker can also guarantee protection through automatic disconnection.



Example: Disconnection through miniature circuit-breaker in case of a fault in the TN-C-S grounding system

2.2 Automatic Disconnection via Residual-Current Device

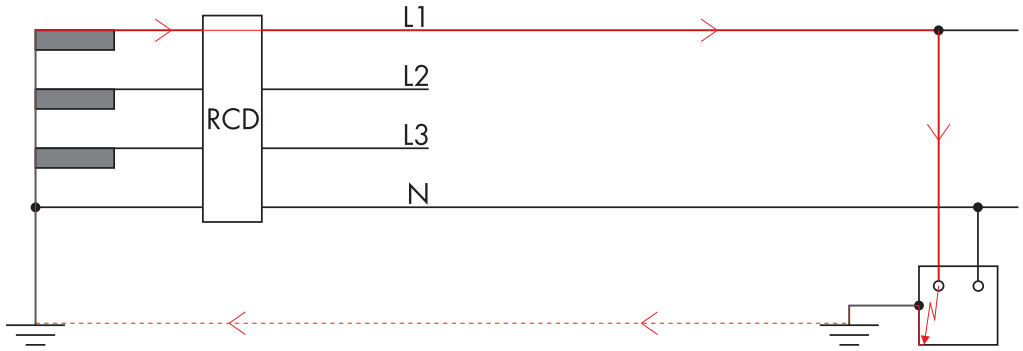
A residual-current device guarantees automatic disconnection if the following conditions are fulfilled:

- TN grounding system:

  In the TN grounding system, the residual currents are much higher than the rated residual current IΔf of the residual-current device. This means that the disconnection times must always be maintained with the residual-current device.

Residual-current devices must not be used in in TN-C grounding systems.

- TT grounding systems:
  - A residual-current device is required as primary fault protection.
  - If $R_A < \frac{50\ V}{I_{\Delta f}}$, the residual-current device can guarantee protection through automatic disconnection.



Example: Disconnection by residual-current device in case of a fault in the TT grounding system

2.3 Selecting Disconnection Options

It must be examined whether the miniature circuit-breaker provided for line protection is sufficient for automatic disconnection (see Section 2.1 "Automatic Disconnection via Miniature Circuit-Breaker" (page 5)).

- If this is the case, a current flows via the error loop (depending on the extent of the loop impedance) which is greater than the operating current I_a (short-circuit protection). The miniature circuit-breaker can therefore disconnect within the required times.
- If loop impedance is too high, a residual-current device must also be installed (except in the TN-C grounding system).

3 Other Reasons for Using a Residual-Current Device

3.1 Outdoor Installations

There is widespread opinion that a residual-current device must always be used for outdoor installations. In accordance with DIN VDE 0100-410 (IEC 60364-4-41:2005), this only applies to final circuits for outdoor portable electric equipment with a rated current of up to 32 A.

3.2 Requirements of the Grid Operator

Some grid operators adjust the general technical connection requirements (TCR) for their grid and therefore deviate from the standards. These specific technical connection requirements may therefore also require the use of a residual-current device.

If the grid operator requires a residual-current device, the type and use conditions are governed by the technical connection requirements (TCR). However, grid operators often do not explicitly require the use of a residual-current device, but just a "standard-compliant installation".

3.3 Necessity due to Other Standards

Depending on the installation site and local conditions, a residual-current device may be necessary due to other standards or regulations.

If the installation is located in a barn or in wooden cabins, for example, DIN VDE 0100-482 (IEC 60364-4-42:2001-08) also applies. In that case, a residual-current device with a rated residual current of max. 300 mA is required for fire protection reasons.

The various influences can only be assessed by the installer on site. Standard installations and special features of PV plants are explained in Section 4 "Selecting the Residual-Current Device for a PV Plant" (page 8).

3.4 Additional Protection

SMA Solar Technology AG recommends always installing a residual-current device as additional protection in order to achieve the highest possible degree of safety. It can also provide the function of an all-pole disconnecting switch, which is frequently required for other reasons.

4 Selecting the Residual-Current Device for a PV Plant

Besides the criteria mentioned before, there are further reasons for the selection of a residual-current device in PV plants.

4.1 Requirement as per DIN VDE 0100-712 (IEC60364-7-712:2002)

If intended as fault protection (see Section 2.2 "Automatic Disconnection via Residual-Current Device" (page 6)), DIN VDE 0100-712 requires a type B residual-current device for transformerless inverters.

This requirement also applies to inverters with HF transformers, since there is no galvanic isolation between the AC current side and the DC voltage side.

This requirement does not apply to inverters with LF transformers.

One exception to this is if the manufacturer of the inverter can exclude the possibility of DC residual currents in the system. If necessary, type A residual-current devices can be used.

All SMA inverters with transformer, including SB 2000HF-30, SB 2500HF-30, SB 3000HF-30, and the transformerless SMA inverters listed below are not capable of feeding-in DC residual currents due to their design. They fulfill this requirement in accordance with DIN VDE 0100-712 (IEC60364-7-712:2002).

Sunny Boy:

SB 240-10, Multigate-10, SB 1300TL-10, SB 1.5-1VL-40, SB 1600TL-10, SB 2100TL, SB 2.5-1VL-40, SB 2500TLST-21, SB 3000TL-20, SB 3000TL-21, SB 3000TLST-21, SB 3600TL-21, SB 3600SE-10, SB 4000TL-20, SB 4000TL-21, SB 5000TL-20, SB 5000TL-21, SB 5000SE-10, SB 6000TL-21

Sunny Mini Central:

SMC 6000TL, SMC 7000TL, SMC 8000TL, SMC 9000TL-10, SMC 9000TLRP-10, SMC 10000TL-10, SMC 10000TLRP-10, SMC 11000TL-10, SMC 11000TLRP-10

Sunny Tripower:

STP 5000TL-20, STP 6000TL-20, STP 7000TL-20, STP 8000TL-10, STP 8000TL-20, STP 9000TL-20, STP 10000TL-10, STP10000TL-20, STP 12000TL-10, STP 12000TL-20, STP 15000TL-10, STP 15000TLHE-10, STP 15000TLEE-10, STP 17000TL-10, STP 20000TLHE-10, STP 20000TL-30, STP 20000TLEE-10, STP 25000TL-30

The possibilities of faults were examined without taking the integrated residual-current monitoring unit (RCMU) into account. When examining these faults in terms of the currently valid installation standards, no danger in combination with a type A upstream residual-current device can occur. Accordingly, faults that would otherwise require the use of a type B residual-current device due to the inverter can be excluded.

The integrated all-pole sensitive residual-current monitoring unit (RCMU) results in additional safety. For inverters with grounding conductor monitoring, this must be activated. These statements also apply to versions of the listed devices with deviating power.

4.2 Operational Differential Currents

When operating a transformerless inverter, differential currents occur due to the insulation resistance and capacities of the PV array. In order to prevent unintentional triggering during operation, the rated residual current of the residual-current device must be at least 100 mA.

For every connected inverter, a rated residual current of 100 mA must be provided. The rated residual current of the residual-current device must be equal to at least the sum of the rated residual currents of the connected inverters. That means that, if, for example, 3 transformerless inverters are connected, the rated residual current of the residual-current device must be at least 300 mA.

For the inverter types SB 1300TL-10, SB 1600TL-10, SB 2100TL, SMC 6000TL, SMC 7000TL and SMC 8000TL, only the following residual-current devices must be used:

- Residual-current device type A by ABB, type F202A-xx/0,x or F204A-xx/0,x
- Residual-current device type A by Siemens, type 5SM1.... or 5SM3....

Other residual-current devices by other manufacturers are currently being tested.

In this case it must be taken into account that the operating currents resulting from the differential DC currents during operation can be slightly higher than the rated residual current of the residual-current device used (0 - 30%). By contrast to the conditions explained in Section 2.2 "Automatic Disconnection via Residual-Current Device" (page 6) for the use of a residual-current device, in this case, the following applies:

If $R_A < \frac{50\ V}{1{,}3 \times I_{\Delta f}}$, then the residual-current device can guarantee protection through automatic disconnection.

If the use of the residual-current devices suggested above is not possible, we recommend using other inverters.

When taking into account the criteria mentioned above, PV plants can be installed both in compliance with the appropriate standard and in a cost-optimized way. The suitability of the above-mentioned transformerless SMA inverters for type A residual-current devices in particular facilitate a low-cost installation.

5 Calculation Examples

The selection of suitable electric equipment as fault protection through automatic disconnection is illustrated in 2 examples below. It is always assumed that the necessary protective electric bonding is being carried out simultaneously. The values used are examples which cannot be used as guideline values for the respective grounding system or application.

5.1 Calculation Example 1

1 Sunny Boy SB 2100TL; fused with a miniature circuit-breaker B16A; TN grounding system; loop impedance Zs = 1.5 Ω; barn roof:

- LS B16A has a short-circuit operating current I_a of 80 A

  (B-characteristics: factor 5; I_{nom} of the miniature circuit-breaker = 16 A => 5 x 16 A = 80 A).
- At 230 V, 153 A can flow through the fault loop ($\frac{230\ V}{1{,}5\ \Omega} = 153{,}3\ A$).
- The 153 A are higher than the required 80 A operating current of the miniature circuit-breaker. Therefore, the miniature circuit-breaker will disconnect safely within the specified time.
- LS B16A suffices as fault protection against indirect contact.
- However, since it is a barn, in this case an additional type A residual-current device with a rated residual current of max. 300 mA must be installed. That is required in accordance with DIN VDE 0100-482 (IEC 60364-4-42:2001-08) for fire protection reasons.

5.2 Calculation Example 2

3 Sunny Mini Centrals SMC 6000TL; fused with one miniature circuit-breaker C32A each; TT grounding system; loop impedance Zs = 0.2 Ω; R_A = 1.1 Ω:

- LS C32A has a short-circuit operating current of 320 A (C-characteristics: factor 10; Inom of the miniature circuit-breaker = 32 A => 10 x 32 A = 320 A).
- At 230 V, 177 A can flow through the fault loop ($\frac{230\ V}{1{,}3\ \Omega} = 177\ A$).
- The 177 A are lower than the required 320 A operating current of the miniature circuit-breaker. Therefore, the miniature circuit-breaker will **not disconnect safely** within the specified time.
- LS C32A is **not** sufficient as fault protection against indirect contact.

  First option: use of another miniature circuit-breaker (if possible)

  - If using a miniature circuit-breaker B32A, the short-circuit operating current would be 160 A (B-characteristics: factor 5; I_{nom} of the miniature circuit-breaker = 32 A => 5 x 32 A = 160 A).
  - The operating current of the miniature circuit-breaker with B-characteristics would be less than the 177 A which would flow in the event of a fault. Therefore, these miniature circuit-breakers would disconnect within the specified time.
  - The miniature circuit-breaker B32A suffices as fault protection against indirect contact.

  Second option: use of a residual-current device

  - In case no other miniature circuit-breaker can be employed, a residual-current device must be used for fault protection.
  - Since 3 transformerless inverters are being used, the rated residual current according to Section 4.2 "Operational Differential Currents" (page 9) must be at least 300 mA. A residual-current device with a rated residual current $I_{\Delta f}$ of 500 mA is selected.
  - In addition, it should be tested according to the condition of 4 b (see page 9), whether the protective effects are sufficient:
  - $R_A = 1{,}1\ \Omega < \frac{50\ V}{1{,}3 \times I_{\Delta f}}$, thus $R_A < \frac{50\ V}{1{,}3 \times 0{,}5\ A} = 76{,}9\ \Omega$
  - A type A residual-current device with a rated residual current IΔf of 500 mA guarantees fault protection against indirect contact.