Criteria for Selecting a Residual-Current Device

Use of Residual-Current Devices for **SUNNY BOY, SUNNY ISLAND, SUNNY BOY STORAGE and SUNNY TRIPOWER**

Contents

When installing inverters, there are often uncertainties when using a residual-current device. For PV systems, DIN VDE 0100-410 (IEC 60364-4-41) and DIN VDE 0100-712 (IEC 60364-7-712) can be consulted. 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)

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

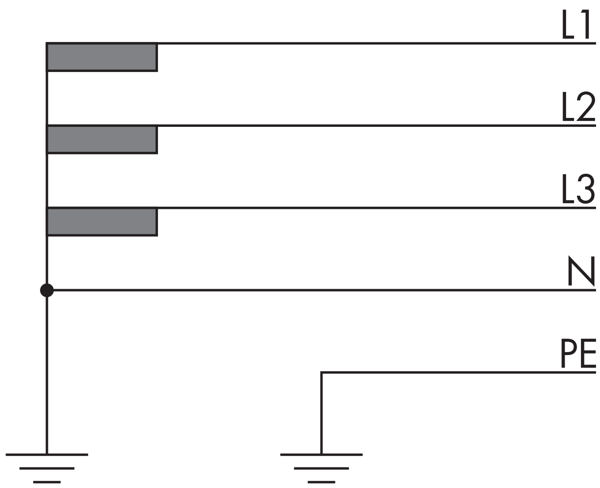
- Basic protection: protection from direct contact.
- Fault protection: protection in the event of a fault. This safety precaution takes effect when the basic protection ceases to be effective and prevents physical damage.

The installation of a PV system 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 grid configurations or 0.4 s in TN grounding systems).

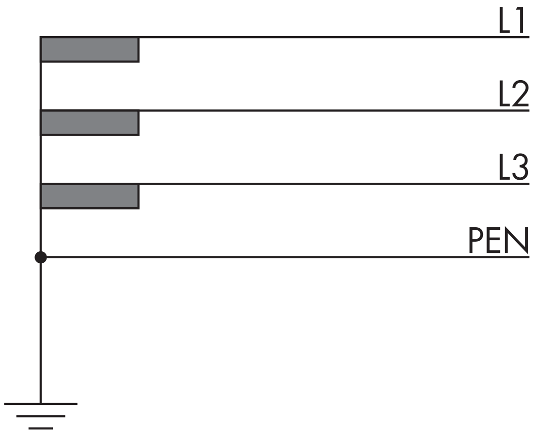
1.2 Grid configurations

TT grid configuration

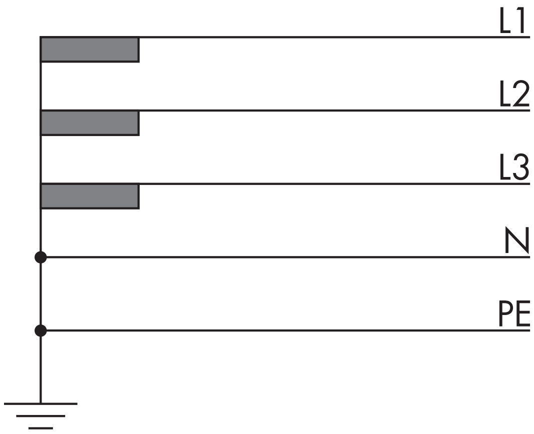


TN grounding systems

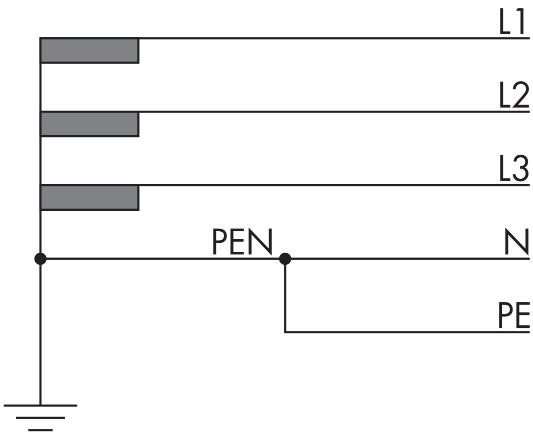
TN-C grid configuration



TN-S grid configuration



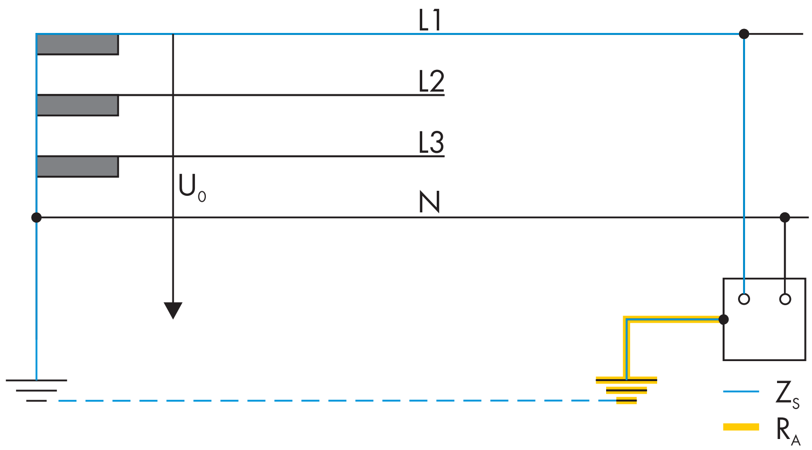
TN-C-S grid



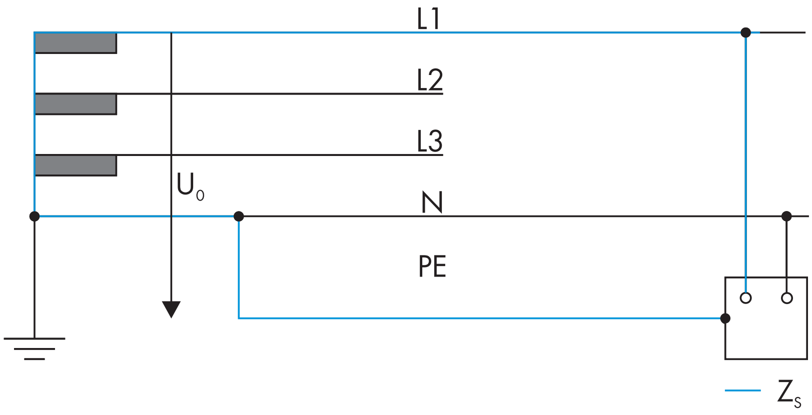
1.3 Abbreviations, Symbols and Formula Symbols

- LS — Circuit breaker
-  — Circuit symbol for 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).

  In case of B-characteristics of the line circuit breaker, this will be 5 times the nominal current (I_{nom}) of the LS. 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 circuit breaker
- $I_{\Delta f}$ — Rated residual current of the residual-current device
- R_A — Total resistance of the ground electrode and grounding conductor of the exposed conductive part to be protected
- V_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 grounding conductor between fault location and power source)
- R_A and Z_S in TT grid configurati on



- Z_S in TN grounding system



2 Options for disconnection

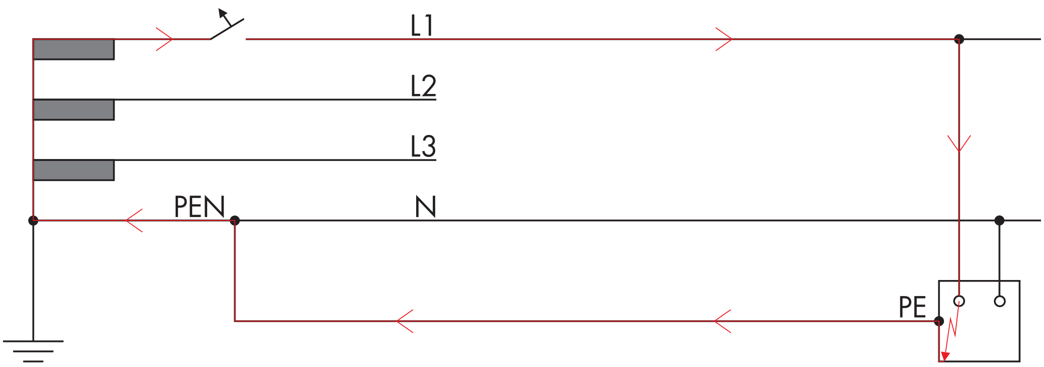
Automatic disconnection can be established through protective electric bonding combined with a circuit breaker or a residual-current device in accordance with DIN VDE 0100-410 (IEC 60364-4-41).

2.1 Automatic Disconnection via a Circuit Breaker

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



Example: Disconnection through circuit breaker in case of fault in the TN-C-S grid configuration

2.2 Automatic Disconnection through a Residual-Current Device

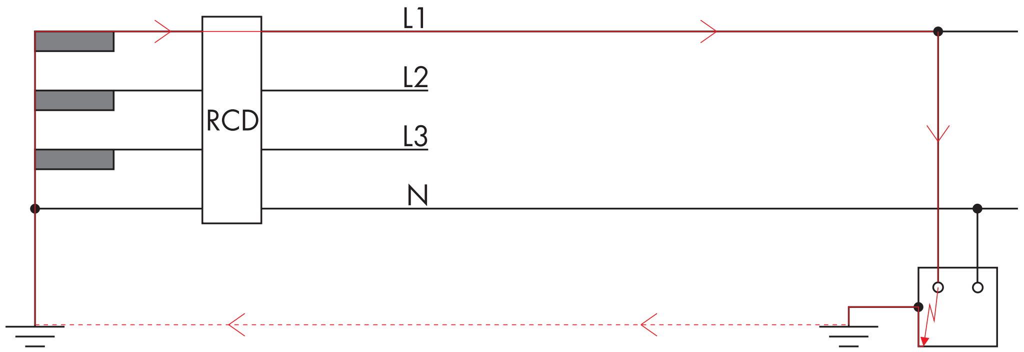
A residual-current device guarantees automatic disconnection if the following conditions are fulfilled:

- 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, which 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 grid configurations:
  - A residual-current device is required as primary fault protection.
  - If $R_A < \frac{50\ V}{I_{\Delta f}}$, then 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 circuit breaker provided for line protection is sufficient for automatic disconnection (see Section 2.1 "Automatic Disconnection via a Circuit Breaker" (Page 5)).

- If this is the case, a current flows over the error loop (depending on the extent of the loop impedance) which is greater than the triggering current I_a (short circuit protection). The 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), 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

Individual grid operators adapt the generally valid technical connection requirements 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 carried out in a barn or in wooden cabins, for example, DIN VDE 0100-482 (IEC 60364-4-42) 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 systems are explained in Section 4 "Selecting the Residual-Current Device for a PV System with and without Battery Inverter" (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. This device can also serve as an all-pole circuit breaker, which is frequently required for other reasons.

4 Selecting the Residual-Current Device for a PV System with and without Battery Inverter

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

4.1 Requirement from DIN VDE 0100-712:2016 (HD 60364-7-712:2016)

If intended as fault protection (see Section 2.2 "Automatic Disconnection through a Residual-Current Device" (Page 6)), DIN VDE 0100-712:2016 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 then be used.

All SMA inverters listed below are not capable of feeding-in DC residual currents due to their design. They fulfill the requirement in accordance with DIN VDE 0100-712:2016 (HD60364-7-712:2016).

Sunny Boy:

SB1.5-1VL-40, SB2.0-1VL-40, SB2.5-1VL-40, SB3.0-1AV-41, SB3.6-1AV-41, SB4.0-1AV-41, SB5.0-1AV-41, SB6.0-1AV-41

Sunny Boy Storage:

SBS2.5-1VL-10, SBS3.7-10, SBS5.0-10, SBS6.0-10

Sunny Island:

SI4.4M-12, SI6.0H-12, SI8.0H-12

Sunny Tripower:

STP 5000TL-20, STP 6000TL-20, STP 7000TL-20, STP 8000TL-20, STP 9000TL-20, STP10000TL-20, STP 12000TL-20, STP 15000TL-30, STP 20000TL-30, 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 min. 100 mA.

For each connected inverter, a rated residual current of 100 mA has to 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, three transformerless inverters are connected, the rated residual current of the residual-current device must be at least 300 mA.

By taking the abovementioned criteria into account, PV systems can be set up in compliance with the standards and at the same time in a cost-optimized manner. 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 two examples below. It is always assumed that the protective equipotential bonding required for this is carried out. The values used are examples which cannot be used as guideline values for the respective grid configuation or application.

5.1 Calculation Example 1

1 Sunny Boy SB2.5-1VL-40; fused with a 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 circuit breaker = 16 A => 5 x 16 A = 80 A).
- At 230 V, 153 A can flow through the fault loop ($\frac{230\ \text{V}}{1{,}5\ \Omega} = 153{,}3\ \text{A}$).
- The 153 A are higher than the required 80 A operating current of the circuit breaker. Therefore, the circuit breaker will disconnect safely within the specified time.
- The circuit breaker 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. This is required in accordance with DIN VDE 0100-482 (IEC 60364-4-42) for fire protection reasons.

5.2 Calculation Example 2

STP 15000TL-30; fused with one LS C32A each; TT grid configuration; 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 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 circuit breaker. Therefore, the circuit breaker will **not** disconnect **safely** within the specified time.
- LS C32A is **not** sufficient as fault protection against indirect contact.

  1st option: Use of another circuit breaker (if possible)

  – If using a circuit breaker B32A, the short-circuit operating current would be 160 A (B-characteristics: factor 5; I_{nom} of the circuit breaker = 32 A => 5 x 32 A = 160 A).

  – The operating current of the circuit breaker with B-characteristics would be less than the 177 A which would flow in the event of a fault. This would disconnect the circuit breakers within the specified time.

  – The LS B32A suffices as fault protection against indirect contact.

  2nd option: Use of a residual-current device

  – In case no other circuit breaker can be employed, a residual-current device must be used for fault protection.

  – Since one transformerless inverter is 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 from 4 b (see page 9), whether the protective effects are sufficient:

  – $R_A = 1,1\ \Omega < \frac{50\ V}{1,3 \times I_{\Delta f}}$ In other words, the $R_A < \frac{50\ V}{1,3 \times 0,5\ A} = 76,9\ \Omega$

  – A type A residual-current device with a rated residual current IΔf of 500 mA guarantees fault protection against indirect contact.