Criteria for Selecting a Residual-Current Device

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

Content

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:

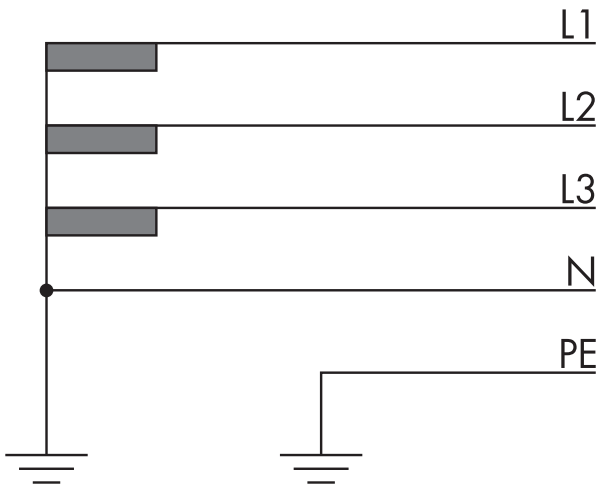
- Basic protection: protection from direct contact.
- Fault protection: protection in the event of a fault. This safety precaution takes effect when the basic protection ceases to be effective and prevents physical damage.

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 systems or 0.4 s in TN systems).

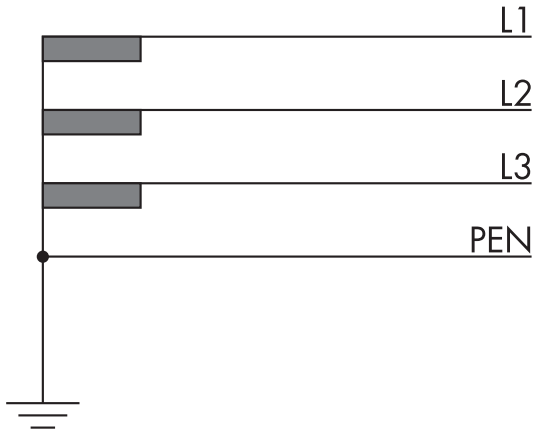
1.2 Grid configurations

TT system

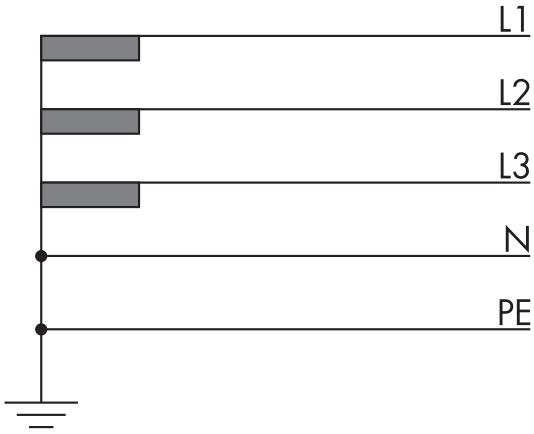


TN systems

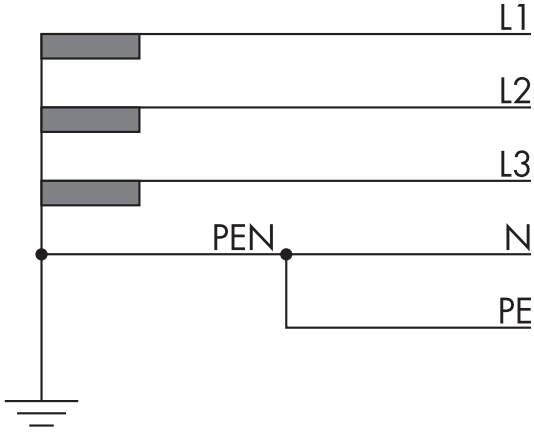
TN-C system



TN-S system



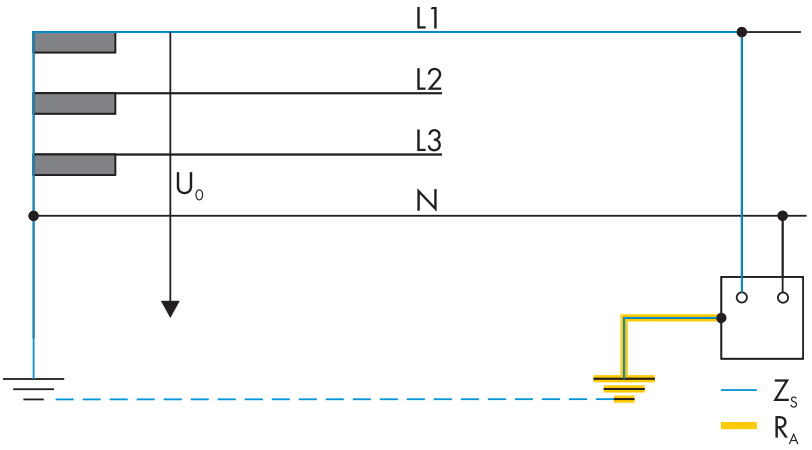
TN-C-S system



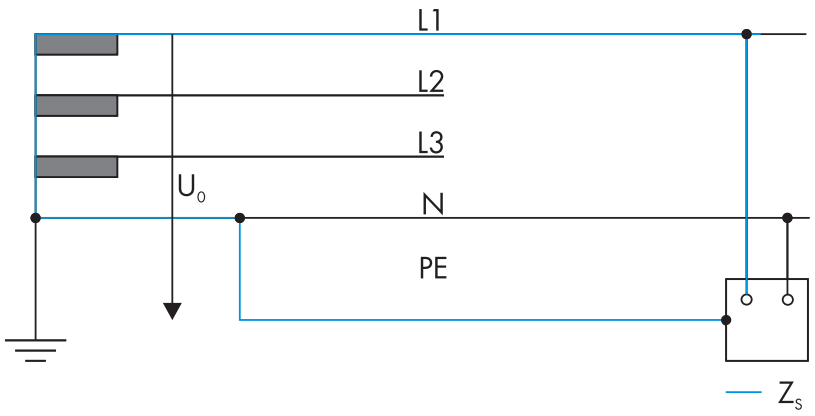
1.3 Abbreviations, Symbols and Formula Symbols

- Circuit breaker — 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).

  In case of B-characteristics of the miniature circuit breaker, this will be 5 times the nominal current (I_{nom}) of the circuit breaker. In case of C-characteristics, it will be 10 times as high, e.g. circuit breaker 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 fault 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 system



- Z_S in TN 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:

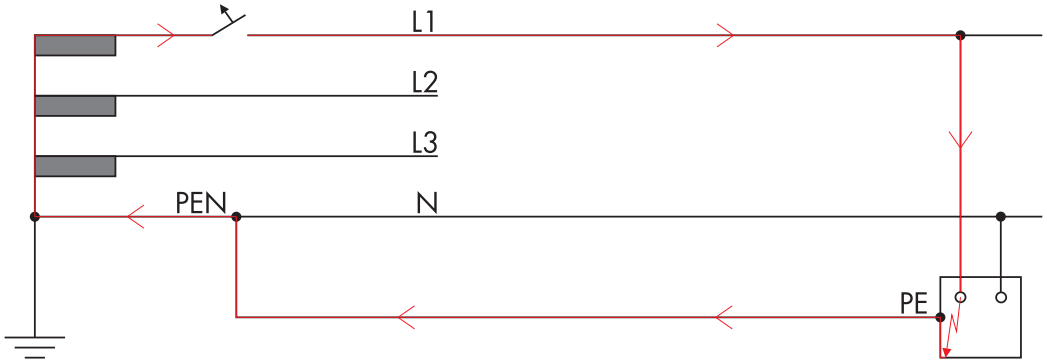
- TN system:

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

- TT system:

  – 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 system

2.2 Automatic Disconnection through a Residual-Current Device

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

- TN system:

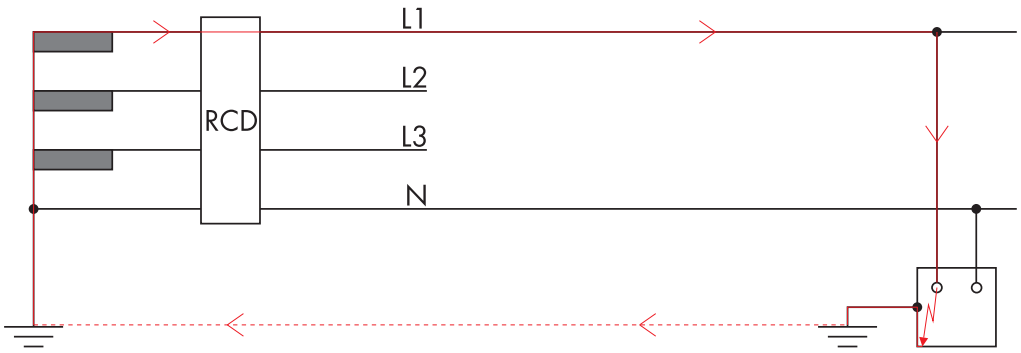
  In the TN system, the residual currents are much higher than the rated residual current IΔf of the residual-current device, which means that the disconnection times must always be maintained with the residual-current device.

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

- TT systems:

  – 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 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 6)).

- If this is the case, a current flows over the fault 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 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), however, this only applies to final circuits with outlets or fixed and portable equipment with a rated current not greater than 32 A. This requirement therefore does not apply to fixed and not portable inverters.

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 9).

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)

A residual-current device of type B must be used for the protection of the AC circuit. An exception to this requirement applies if the inverter manufacturer approves the inverter for other RCD types.

Many SMA inverter are approved for use with residual-current devices of type A. A list of these inverters can be found in our Manufacturer's Declaration "Usage of residual-current devices (RCD) of type A with Sunny Boy, Sunny Boy Storage, Sunny Island and Sunny Tripower inverters".

4.2 Operational Differential Currents

When operating a transformerless inverter, differential currents occur due to the insulation resistance and capacities of the PV array. To prevent undesired tripping during operation, only residual-current devices compatible with the respective inverter may be used. This information can be found in the operating manual of the inverter.

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 configuration 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:

- The circuit breaker 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 ($\frac{230\ V}{1{,}5\ \Omega}$ = 153,3 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 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. 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 circuit breaker C32A each; TT system; loop impedance Zs = 0.2 Ω; R_A = 1.1 Ω:

- The circuit breaker 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.
- The circuit breaker 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 circuit breaker 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.
  - A residual-current device of type A with a rated residual current IΔf of 500 mA fulfills the requirement described in section 2.2 "Automatic Disconnection through a Residual-Current Device" (Page 6). It provides fault protection against indirect contact and is compatible with the inverter operating manual according to the operating manual.