Guidance on proper residual current device selection for solar inverters

by K. Ajith Kumar and Jim Eichner

Executive summary

Some country-specific installation codes require a Type B Residual Current Device (RCD) in the AC circuit external to the photovoltaic (PV) inverter to protect against ground faults. Inadequate or improperly functioning ground fault protection can pose a danger to people and property. This document describes the various types of RCDs and explains the role of the residual current detection functions in PV inverters. Guidance is provided regarding selection of the proper external RCD for the AC circuit.

Schneider Electric

Introduction

"Residual current" refers to the leakage current from an electrical system to the ground, often as a result of a "ground fault". Leakage currents can flow through a human body to ground resulting in a risk of electric shock, injury or burns, and can cause overheating and risk of fire.

A Residual Current Device (RCD) is used to detect these currents and disconnect the circuit from the source automatically when the values of these residual currents exceed the pre-defined limits. A Residual Current Monitoring Unit (RCMU) is similar to a RCD except it does not contain the disconnection function, and can only activate an alarm.

The residual current may be a pure alternating current (AC), a pure direct current (DC), or a current with both AC and DC components. The proper functioning of the RCD or RCMU is only ensured if the type of RCD or RCMU is matched to the type of residual current expected: AC, DC, or mixed.

In some jurisdictions, RCD's are required to be installed on AC circuits in which PV inverters are connected. In a grid-tied PV system with a non-isolated inverter, it is possible for a ground fault on the PV system to cause DC residual current in the AC part of the system. Therefore, if an RCD is required on the AC circuit, its proper selection requires awareness of the properties of the inverter.

Also needed is awareness of the fact that many inverters also contain RCD or RCMU functions to protect against or warn of ground faults in the PV array, and of the limitations of such PV residual current functions.

Definitions

Following is a list of definitions for key terms utilized in this white paper:

- **Residual current:** A vector sum of the currents flowing in the normally current-carrying conductors of a mains circuit, expressed as an RMS value (as defined in EN/IEC 62109-1).
- **Residual Current Device (RCD):** A mechanical switching device or association of devices designed to make, carry, and break currents under normal service conditions and to cause the opening of the contacts when the residual current attains a given value under specified conditions (as defined in IEC 60755).
- **Residual Current Monitoring Unit (RCMU):** A device which monitors the residual current in an electrical installation and activates an alarm when the residual current exceeds the operating value of the device (as defined in IEC 62020).

RCD types

The IEC 60755 standard specifies three different types of RCDs, defined by their ability to sense, properly trip, and withstand different types of current:

- Type AC – sensitive to residual sinusoidal alternating current (AC).
- Type A – sensitive to residual sinusoidal alternating current (AC) or pulsed direct current (DC).
- Type B – sensitive to residual AC, pulsed DC, or smooth DC currents.

For the purposes of this paper, the key fact is that only Type B RCDs are able to withstand and properly function in the presence of a DC residual current component exceeding 6 mA.

These different types of RCDs are marked with specific symbols, as defined in IEC 60755 (see **Figure 1**).

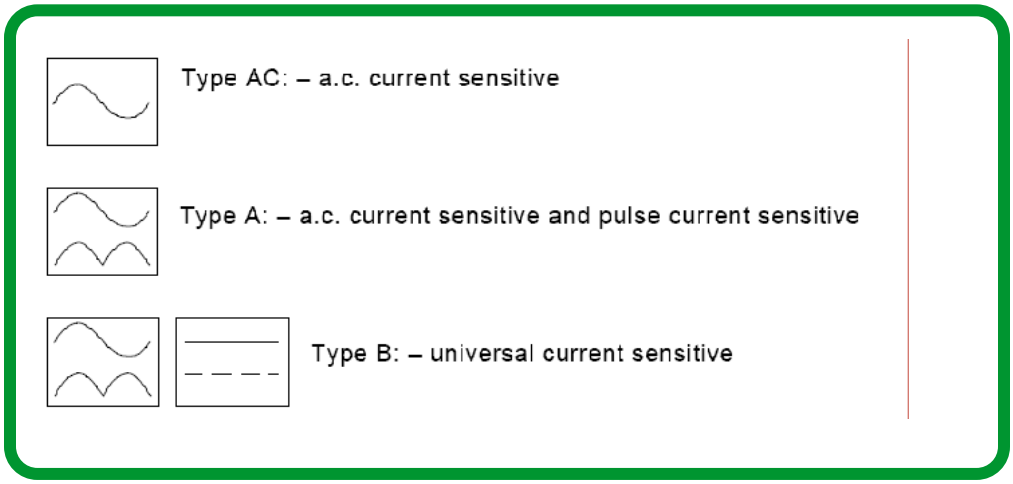


Figure 1
Symbols that indicate the type of RCD in use

Inverter RCD/RCMU's

As noted above, in order to protect against ground faults, photovoltaic (PV) systems are required by numerous regulations to be provided with residual current detection and/or monitoring. To fulfill this function, RCD's and/or RCMUs are often integrated into PV inverters.

Typically, the RCD/RCMU's integrated into non-isolated grid-tied inverters are required to have both a continuous residual current detector set at 300mA (or higher for larger systems) and a sudden change detector with limits as listed in **Table 1 (**based on DIN/VDE 0126-1-1, EN/IEC 62109-2, and other standards).

Table 1
Existing standards for RCMU's that are integrated into photovoltaic inverters

Residual current sudden change	Maximum time to inverter disconnection from the mains
30 mA	0.3 seconds
60 mA	0.15 seconds
150 mA	0.04 seconds

As can be seen by these numbers, the RCD/RCMU in a typical non-isolated inverter does not by itself prevent DC residual currents exceeding 6 mA.

It is important to note that the RCMU in the inverter can only help protect against residual current on the array side of the Inverter. Therefore, the RCMU does not replace the requirement in some regulations for the AC circuit to also be protected by an RCD. The RCMU helps protects the PV circuit, while the RCD protects the AC circuit.
However, the presence of a non-isolated inverter, which provides a connection between the DC and AC electrical systems, affects the choice of which type of RCD is needed, as described in the next section.

Inverter impact on RCD selection

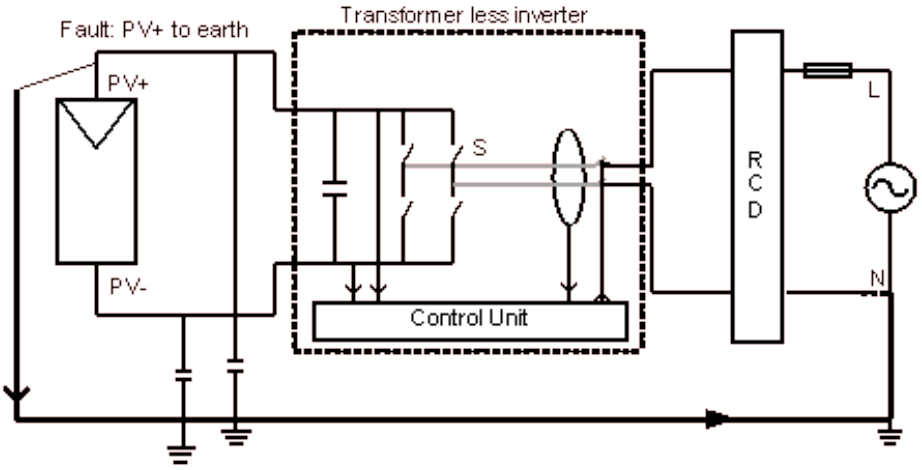
Buyers and installers of photovoltaic solutions often pose the following questons:

1. Can the RCD/RCMU internal to the inverter replace the RCD for the AC circuit?
2. Do we need to install an external Type A, Type AC, or Type B RCD?

The answer to the first questions is “no”. The RCD/RCMU in the inverter cannot protect the circuit between the mains and the inverter — the protection needs to be at the source (mains) end of the circuit — so for regulations requiring RCD protection of the AC circuit, an external RCD is still required.

Regarding the second question, we need to understand how the inverter affects RCD selection, and properly interpret the regulations governing RCD selection.

Depending on the design of the inverter, it may or may not provide a current path through which DC residual currents can flow in the AC circuit. An inverter with isolation between the AC and DC circuits cannot pass DC residual currents through to the AC side. An inverter without isolation can pass DC residual currents through to the AC side, unless the design of the inverter prevents this in some manner.



Consider a PV system containing a non-isolated inverter and an AC mains circuit with an earthed (grounded) neutral. A ground fault in the DC part of the system will create DC residual current that can flow from ground into the AC mains circuit, by way of the AC neutral-to-earth connection, and back to the DC circuit through the non-isolated inverter. The RCMU in the inverter will detect this current. However, as **Table 1** illustrates, the RCMU is allowed to be set for residual currents much higher than the 6mA maximum tolerated by a Type A or Type AC RCD. Therefore the use of a Type A or Type AC RCD would only be acceptable if the RCMU were set to trip at 6mA or less, or if the inverter or system contained some other device that opened the circuit at this threshold.

Regulations such as VDE-100-0712 and IEC 60364-7-712 state:

> “Where an electrical installation includes a PV power supply system without at least simple separation between the AC side and the DC side, an RCD installed to provide fault protection by automatic disconnection of supply shall be type B according to IEC 60755, amendment 2. Where the PV inverter by construction is not able to feed DC fault currents into the electrical installation, an RCD of type B according to IEC 60755 amendment 2 is not required.”

Purchasers and specifiers of inverters for use in systems that conform to these regulations must carefully determine whether or not the inverter prevents or limits DC residual currents into the AC circuit. They must also determine the maximum resulting DC residual current on the AC circuit, before determining the type of RCD required on the AC circuit. While inverter manufacturers usually specify the RCD type that may be used with their inverters, it is a sensible precaution to check with them to determine the maximum DC residual current their inverter can allow to flow into the AC circuit, and how they limit such current.

Conclusion

It must be noted that not all installation codes require an RCD on the AC circuit of an inverter installation. Where an RCD is required, or used on the AC circuit, however, selection of type AC, A, or B must be based on knowledge of the type of residual currents that can be present in the AC circuit.

In an inverter installation, the possibility of a DC component of residual current on the AC circuit is present, unless the inverter limits this (e.g., if the inverter is isolated by design or if a special design is in place that specifically limits the DC residual current).

Proper operation of the RCD is only ensured if a Type B RCD is selected, unless the inverter design limits the DC residual currents to 6 mA or less. The RCD or RCMU in a PV inverter protects the PV array and therefore does not replace the RCD on the AC side of the inverter. Furthermore, the RCMU in a typical non-isolated inverter is set for 300 mA steady residual currents, and for sudden changes in residual current of 30 mA and larger, and therefore does not by itself prevent DC residual currents exceeding 6 mA on the AC side of the system.

About the authors

Ajith Kumar is a Staff Compliance Engineer at Schneider Electric's residential and small commercial solar inverter design center. He holds a bachelor's degree in Electrical Engineering and master's degree in Operations Management.

Jim Eichner is Compliance Engineering manager for Schneider Electric's solar business, and has worked extensively on international standards development for solar inverters and systems. He holds a bachelor's degree in Electrical Engineering.