DIFFERENTIAL PROTECTION IN PHOTOVOLTAIC INVERTERS

salicru

Introduction

Mains-connected photovoltaic inverters require EMI filters to suppress the electromagnetic interference generated by the device. Without these filters, the interference would filter to the electricity grid, in breach of current regulations. Their use helps avoid these filtrations, although this in turn introduces earth leakage currents due to the existence of capacitors between phases and earth that involve leaks when powered. These leakage currents, along with those of different loads that EMC filters might carry, which may increase if the facility is equipped with power converters that switch to high frequency, in addition to the earthing capacity of the photovoltaic panels which can also produce leakage currents, may cause the sudden undesirable tripping of the differential protection if the sensitivity threshold of the residual current device installed is exceeded, thus highlighting the importance of choosing the correct residual current device for installation as electric shock protection in the photovoltaic plant.

The document expounds the recommendation by SALICRU regarding the type and sensitivity of the necessary differential protection in the facility of its inverters, and the regulations on which it is based.

Regulatory framework

The *"Additional Technical Instructions" ITC-BT-24 "Protection from Direct and Indirect Contacts", ITC-BT-40 "Low-Voltage Generating Installations"* of the specific Low-Voltage Electro-technical Regulation and the draft published in the Spanish Official State Gazette of *ITC-BT-53 "Installations of direct current systems"* include the requirements to be met by residual current devices (RCD) in mains-connected photovoltaic installations, where their installation is necessary to offer electric shock protection. *Royal Decree 244/2019, of 5 April*, replaces ITC-BT-24, adding to its Section 4.3:

> **The specifications of ITC-BT-40 are applicable to all interconnected self-consumption installations, whatever their power**. All low-voltage distribution network-connected generating installations must be equipped with devices that limit the injection of direct current and the generation of overvoltages, and must prevent the islanding of said distribution network so that the connection of the generation installation does not affect the normal functioning of the mains or the quality of supply to customers connected to it.
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> […]
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> In all production installations near to consumption installations, as defined in Royal Decree 244/2019, of 5 April, regulating the administrative, technical and financial conditions for the self-consumption of electrical energy, **the connection shall be made via a control and protection board that includes the necessary type A differential protection to ensure the contact voltage is not dangerous to people. When these generating installations are accessible to the general public or are located in residential areas of similar, the differential protection of the generation circuits shall be 30 mA.**
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> […]
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> All generators for supply with self-consumption and with surpluses, regardless of their power, and generators for supply with self-consumption and without surpluses of **installed power over 800 VA, which are connected to lower installations or to recipient user installations** shall do so along **an independent, dedicated circuit from a control and protection board that includes type A differential protection**, which shall be **30 mA in residential installations or those accessible to the general public** in residential areas or similar.

Implications

The foregoing can be summarised as the mandatory nature of installing Type A differential protection or higher in any photovoltaic installation, with a sensitivity of the residual current device (RCD) of:

- **30 mA for homes and installations accessible to the general public.** or
- which guarantees a **safe contact voltage for personal protection in all other cases.**

The installation of an RCD with a sensitivity of 30 mA is ensured as sufficient protection for homes and installations accessible to the general public in ITC-BT-24:

> The use of residual current devices, the assigned operating differential current of which is below or equal to 30 mA, is recognised as supplementary protection in the event of failure of the other protection from direct contact or in the event of carelessness by users.

In the absence of explicit reference in the REBT to non-residential or inaccessible installations, the Regulation refers to current European regulations. *Part 7-712 of* Standard *UNE-HD 60364-7-712:2017 on Low-Voltage electrical installations*: *Requirements for special installations or locations - Solar photovoltaic (PV) power supply systems)* indicates, in Section *712.530.3.101 Residual current devices,* that:

> Where a residual current device is used to protect the alternating current photovoltaic power circuit, the residual current device must be type B, in accordance with Standard EN 62423 or EN 60947-2, unless:
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> • The inverter provides at least a single separation between the alternating current side and the direct current side; or
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> • The installation provides at least a single separation between the inverter and the residual current device by way of separate windings of a transformer; or
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> • The inverter does not require a type B residual current device, as indicated by the manufacturer of the inverter.

To this end, and in compliance with the requirement of Standard *UNE-EN 62109-1=2011-ES*, SALICRU declares that **its inverters can cause a current with a direct component. When used for protection in the case of direct or indirect contact, a protection device (RCD) or control device (MCR) operated by the residual current only allows for a type B RCD or MCR on the inverter power supply side.**

Regarding the sensitivity of RCDs, Standards *UNE-EN 62109-1:2011* and *UNE-EN 62109-2: 2013*, official versions in Spanish of European Standard *EN 62109-2: 2011*, adopting the International Standard *IEC 62109-2:2011*, specify the specific requirements for inverters with regard to the Safety of Power Converters for use in Photovoltaic Power Systems. More specifically, Section 4.8.3.1 of Standard *UNE-EN 62109-2: 2013* indicates that:

> Arrays disconnected and connected to earth can create a fire risk if earth leakage permitting excessive currents flowing to conductive parts or structures not intended to carry current occurs. The requirements in this section foresee additional protection from fire risks **through the application of RCDs** […] **or monitoring for permanent excessive residual current** […], except where none is required in an isolated inverter where the isolation provided restricts the current available to less than:
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> – 300 mA RMS for inverters with a permanent rated output power ≤ 30 kVA; or
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> – **10 mA RMS per kVA of permanent rated output power for inverters with permanent output power ranges > 30 kVA;**
>
> when tested with 4.8.3.3 [Fire hazard residual current type test for isolated inverters].

In SALICRU inverters, detection of the residual current is guaranteed through the internal measurement of a Hall-effect transformer, adjusted so that its measurements limit, through firmware, the response time to rapid changes in residual current according to Standard *RCD IEC 61008-1* and, in the event of failure, inform of such on the display and stop the inverter. SALICRU therefore guarantees that the maximum transient leakage of its inverters does not exceed 10 mA RMS per kW of rated power required by regulations under permanent

operations.

This safety requirement **in installations not accessible to the general public or housing** is therefore covered if it is ensured that a fault current between a phase and mass does not involve a contact voltage between the live mass and ground of over the conventional voltage rating of 50 V. In other words, if an earth measurement is ensured that fulfils the inequality

$$UI \leq I\Delta n \cdot Z0$$, where

UI = conventional voltage rating = 50 V,

IΔn = fault current guaranteeing the opening of the residual current device within an appropriate time to offer the required protection, and

Z0 = fault loop impedance, sum of impedances of earthing connection and earthing conductor of the masses in Ω.

In the case of **installations in housing or accessible to the general public**, which require the installation of an RCD with a sensitivity* below 30 mA, (inverters with a rated power Pn > 30 kVA), S**ALICRU recommends the installation of the inverter circuit as a dedicated circuit, with an exclusive RCD parallel to the main RCD of the interior installation** to avoid, due to a lack of vertical ampere selectivity between protections, sudden undesired tripping of RCDs upstream from that of the inverter, and sympathy trips of other parallel RCDs in the installation due to a lack of horizontal selectivity.

If, however, **the inverter is installed in series with the header RCD** (dedicated circuit, parallel to the remaining circuits of the home and downstream from the main RCD), replacement of the header RCD upstream with a DDR with a sensitivity that is at least twice the sum of expected leakage current downstream is recommendable, as specified by the REBT in ITC-BT-24, to ensure ampere selectivity, and the installation of timed residual current devices (type S, for example) in series with the general DDRs and with an operating time that is equal to or below 1 s to guarantee time selectivity.

In this latter case, if a DDR with a sensitivity of less than 30 mA is installed in a home or is accessible to the general public and does not fulfil the earthing measurement condition for a contact voltage that is not hazardous to people, protection of the unprotected section must be ensured by insulation, barrier, obstacles or installation out of reach, according to the provisions of *ITC-BT-24 of the REBT.*

(* Sensitivity being understood as the capacity to detect leakage currents, so that high sensitivity corresponds to a low fault current detection level and low sensitivity to a high leakage current level).

Therefore, for example, in an installation of the SALICRU EQX2-100010-T series with a rated power of 100 kVA in premises accessible to the general public, only a earthing resistance measurement of less than 50Ω would allow for the installation of the DDR required for each parallel inverter in the installation of IΔn = 1 A sensitivity upstream from the inverter and parallel to the header DDR of the premises. Under these conditions, protection from electric shock on the section of the AC installation between the inverter and the mains connection point would be ensured, without the need for additional measures to protect from direct contact, and with the need to improve the quality of the earthing connection or to install additional protection where the measurement does not offer the appropriate safety for people.