Insulation Resistance (R_{iso}) of Non-Galvanically Isolated PV Plants

with SUNNY MINI CENTRAL 9000TL/10000TL/11000TL

Content

PV plants with transformer-less inverters are not galvanically isolated from the grid in feed-in operation. As per the standard DIN VDE 0126-1-1, they must not exceed a certain threshold before grid connection. The prescribed threshold for such PV plants during the creation of this standard was based on established installation specifications (for example 1 k Ω /V). At the time of the creation of this standard the typical output magnitudes of the PV plants were significantly lower than today. With the increasing size of a PV plant, the insulation resistance (R_{iso}) has become smaller and smaller as a result of the necessary larger generator area and the parallel switching of many PV modules. This can lead to the inverter not connecting to the grid due to the insulation resistance of the entire PV plant being too low, even though all components work without problems.

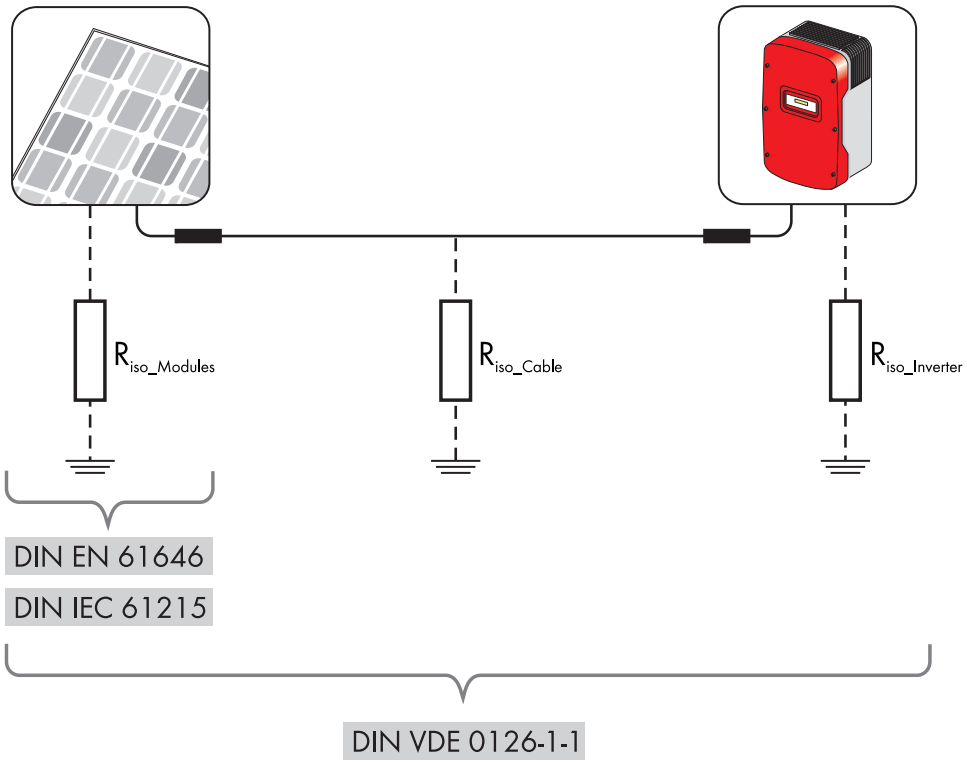
Together with the professional association, SMA Solar Technology AG developed a solution that takes into account the reduced insulation resistance of larger PV plants. At the same time, this solution meets the protection target of the standard, identifying insulation failures.

1 What is meant by R_{iso}?

Every PV plant has both before grid connection and in feed-in operation a distinct potential against ground. Only sufficient insulation against ground prevents current from the PV plant leaking to ground and rules out the dangers associated with touching and additional losses. The total ground current, also known as leakage current, is made up of the contribution of all system components together:

- PV modules
- DC cable
- Inverter

For a given system voltage, this leakage current translates into an effective insulation resistance, which is designated by R_{iso}.



In transformer-less inverters, the continuous measurement of R_{iso} in operation is not possible due to this missing galvanic isolation. Thus transformer-less inverters must measure the R_{iso} before grid connectionand monitor the residual current during operation.

2 Differentiating from other phenomena

The measurement of the R_{iso} may not be confused with the problem of the capacitive discharge currents (see technical information "Capacitive Discharge Currents" at www.SMA.de/en). Prerequisite for the latter is the reaction of the grid frequency on the PV plant. Hence, capacitive discharge currents only occur during operation.

The R_{iso} is measured, however, before connecting to the grid. In operation, the residual current monitoring runs via the all-current sensitive residual current monitoring unit (RCMU). Hence, it is a question of two different phenomena.

3 Standard specifications for the R_{iso}

The following regulations exist for the R_{iso}:

- For PV modules (DIN EN 61646; DIN IEC 61215):

  Per m² module surface area: R_{iso} > 40 MΩ m²

  This means that a PV module with a module surface area of 1 m² must have a minimum insulation resistance of 40 MΩ, a PV module with a surface area of 2 m², however, only a minimum of 20 MΩ.

- For inverters without galvanic isolation (transformer-less) in accordance with DIN VDE 0126-1-1:

  As the heart of the PV plant, the inverter monitors the insulation resistance of the entire system (all PV modules, DC cabling, installation and inverter). As mentioned above, this is particularly important in PV plants without galvanic isolation from the grid, since a single short circuit can lead to personal injury or damage. Since the magnitude of the currents is decisive in the event of such damages, the prescribed R_{iso} is dependent on the maximum input voltage of the inverter.

  As per DIN VDE 0126-1-1, the following applies: **R_{iso} > 1 kΩ / V, but at least 500 kΩ**.

  DIN VDE 0126-1-1 does not include any specifications for the insulation resistance of PV plants with galvanic isolation from the grid.

4 R_{iso} of several PV modules

In a PV plant, the insulation resistances of all PV modules of an inverter form a parallel connection against ground and can therefore be added reciprocally:

$$R_{iso} = \frac{1}{\frac{1}{R_{Module\_1}} + \frac{1}{R_{Module\_2}} + ... + \frac{1}{R_{Module\_n}}}$$

For identical PV modules this equation simplifies to:

$$R_{iso} = \frac{R_{Module}}{\text{Number of modules}}$$

The overall resistance of the PV plant against ground lowers with the quantity of connected PV modules.

Standard conflict

In a typical PV plant with a system voltage of 700 V the standard for PV modules above a module surface area of around 60 m² comes into conflict with the standard for inverters (40 M Ω m²/60 m² = 667 k Ω). Even with faultless functional capability the prescribed R_{iso} can no longer be achieved under certain conditions. With a module efficiency of 10 %, 60 m² only corresponds to 6 kW, with a module efficiency of 5 %, this figure is only 3 kW.

5 New formula for the R_{iso} threshold

The previous specifications of the standards disregard relevant factors such as the efficiency of PV modules or the power of the inverter. For this reason, efforts are being made on a national and international level (IEC) to harmonize the existing insulation specifications in the standards.

Together with the German professional association, SMA Solar Technology AG developed a formula different to DIN VDE 0126-1-1 for the insulation resistance. The new R_{iso} threshold is inversely proportional to the power of the inverter and corresponds to the R_{iso} threshold of 40 M Ω m² required by DIN EN 61646 and DIN IEC 61215 with a module efficiency of 5 %:

R_{iso} = 2000 k Ω * kW/$P_{DC\_inverter}$

This power-dependent R_{iso}, which deviates from the standard VDE 0126-1-1, was accepted by the professional association, as it fulfils the underlying standard protection target. However, the value has to be at least 200 kΩ, as smaller insulation resistances can cause dangerous residual current. Particularly with PV plants with over 10 kW and with additional insulation problems in the cables and plug connectors, disturbances may occur from time to time, even with the new regulation.

6 What was measured until now?

The PV plant is a system made up of many components, all of which make a contribution to the above defined R_{iso}. A determination of this value is thus dependent on measurement algorithm and measurement circuit. In addition an integrated measurement technology must operate low-loss. Furthermore, there are further measurement errors as a result of the tolerances of the installed electronic components.

The inverter type Sunny Mini Central SMC 9000TL/10000TL/11000TL is equipped with a measurement technology that goes well beyond the test conditions demanded in the standard and is capable of identifying insulation errors that can be difficult to detect. In order to meet the limiting value of 700 k Ω required by DIN VDE 0126-1-1, the devices were delivered with a limiting value of 900 k Ω .

SMA inverters with transformers can also measure the insulation resistance. As other regulations apply for galvanic isolation, they do not refuse the grid connection, but only display a warning message.

7 What has changed?

As of December 1, 2010, SMA Solar Technology AG delivers the Sunny Mini Central 9000TL/10000TL/ 11000TL with a firmware where the limiting values for the insulation resistance were adapted to the new general conditions. SMA Solar Technology offers this firmware as a free update on request for all previously delivered inverters. The new thresholds ensure that the PV plants run safely and only actual insulation failures (module break, marten bites) are reported as a disturbance.

If required, please contact the SMA service line: Serviceline@SMA.de.