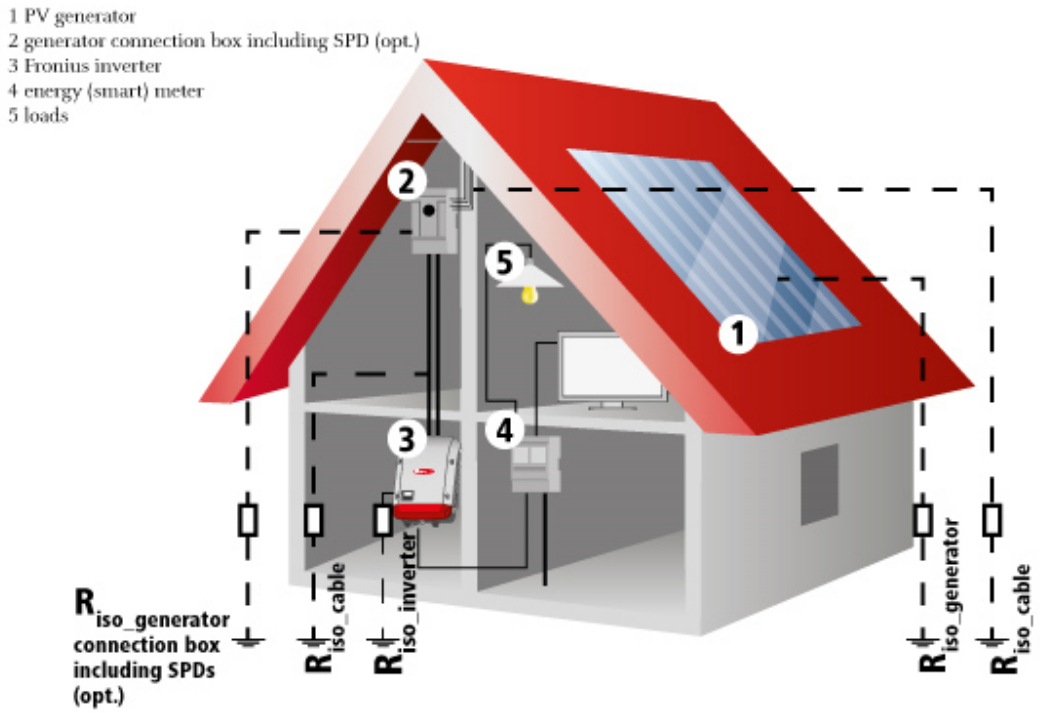
DC Insulation Resistance of PV Systems

with Fronius Inverters

White Paper

Version 1 08/2017

WHAT IS INSULATION RESISTANCE?



Each single component of the PV system has an insulation resistance to ground. Combined this results in the insulation resistance of the PV system (R_{iso}).
Usually this leads to very small and harmless fault currents.
In the event of a fault this ensures very small and harmless fault currents.

On rare occasions the fault current can reach a dangerous level which may cause damage (e.g. fire) or personal injury. Therefore the insulation resistance has to be above a certain value to ensure fault currents stay below a dangerous level.

WHAT DOES THE INVERTER DO?

The inverter has to determine whether or not the whole PV system is sufficiently insulated between live parts and accessible parts.
In the morning the inverter measures the insulation resistance and will turn on if the resistance level is okay.
If the resistance level is insufficient, the inverter will not connect to the mains and will indicate (and also send) the appropriate state code.

The threshold level for R_{iso} is specified in different, relevant standards.
However, these standards each define different threshold values resulting from different approaches.

After the startup, the inverter monitors the insulation conditions with an approved, integrated RCMU unit.

RELEVANT STANDARDS

For the inverter:

IEC 62109-2: Safety of power converters for use in photovoltaic power systems – Part 2: Particular requirements for inverters

This standard requires that the insulation resistance of the PV system shall not be less than $R_{iso} = (V_{max\_PV} / 30\ mA)$.

For example, an inverter with a maximum DC input voltage of 1000V should not connect to the mains if the R_{iso} is less than 33.3kΩ (= 1000V / 30mA).

For the PV system:

IEC 60364-7-712: Low voltage electrical installations – Part 7-712: Requirements for special installations or locations – Solar photovoltaic (PV) power supply systems

This standard specifies the insulation resistance for certain PV array sizes (see table below):

PV array rating kW	R limit kΩ
≤ 20	30
> 20 and ≤ 30	20
> 30 and ≤ 50	15
> 50 and ≤ 100	10
> 100 and ≤ 200	7
> 200 and ≤ 400	4
> 400 and ≤ 500	2
> 500	1

It also recommends, where possible, to use higher values than the ones stated, to increase the safety of the PV system.

For PV modules:

IEC 61215-2: Terrestrial photovoltaic (PV) modules - Design qualification and type approval – Part 2: Test procedures

This standard requires the insulation resistance of a module shall not be less than 40MΩm².
This definition makes the R_{iso} of a real PV system dependent on the area of the PV array.
The larger the array, the lower the insulation resistance may be and of course will be.

Past standards (no longer applicable):

In previous inverter standards it was defined that the calculation of R_{iso} may not be less than $1k\Omega * V_{max\_PV}$. This resulted in a value of 1MΩ for inverters with a V_{max_PV} of 1000Vdc.

Contradiction of the standards:

It is obvious that these thresholds somewhat contradict each other (see diagram below).

Most international and national standards dealing with personal protection, require that fault currents do not exceed 30mA (also the reference value of the standard IEC 62109-2 for inverters).

Of course, it is always allowed to use a higher value for R_{iso} than stated in the standards, as this may increase the safety of the PV system.

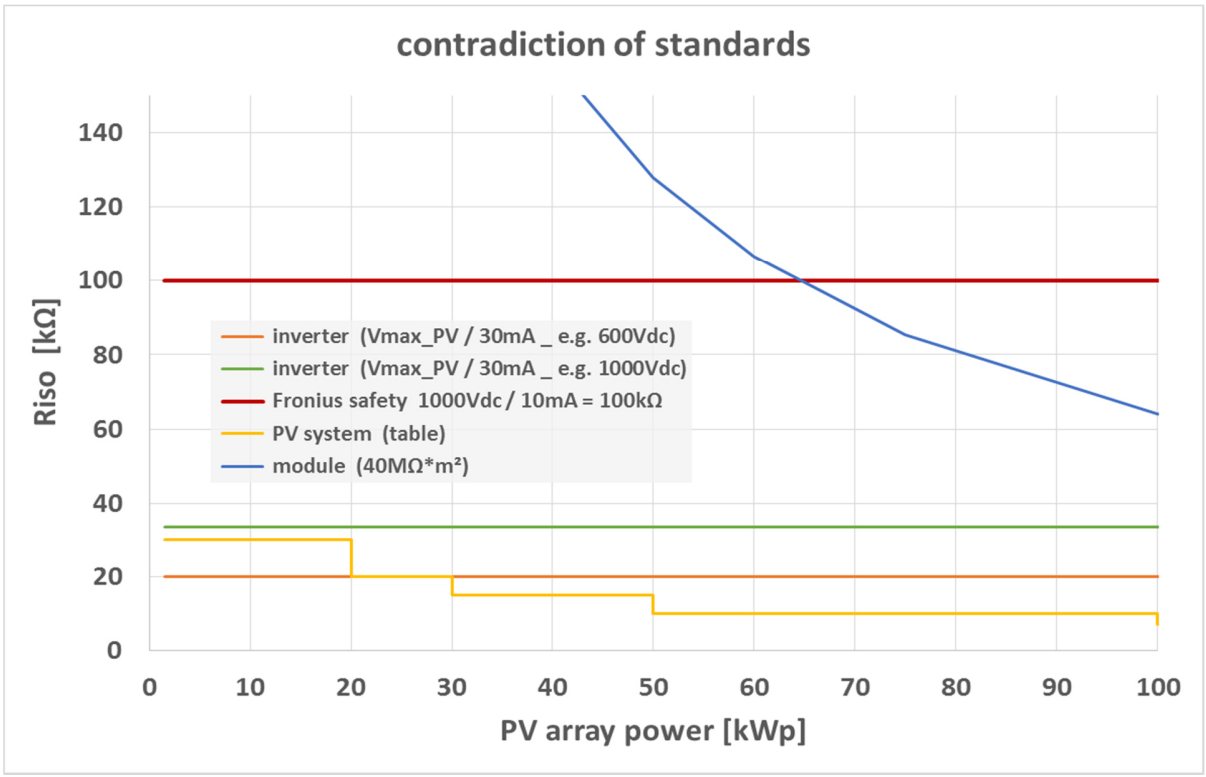


Chart 1: Insulation resistances from different standards.

FRONIUS INVERTER R_{ISO} THRESHOLD LEVELS

Most international and national standards dealing with personal protection, require that fault currents do not exceed 30mA (also the reference value of the standard IEC 62109-2 for inverters).

From a safety perspective, Fronius decided to set the threshold levels of R_{iso} to a value tolerating no higher fault currents than 10mA resulting in a value of R_{iso} = 100kΩ (= 1000V / 10mA).*

This level is set to achieve best results regarding safety and ensure that there are no issues regarding the minimum allowed module insulation resistances. As the chart shows, PV arrays below 65kWp shall always have a higher insulation resistance when complying with the module standards.

Please find the presets and device limit values of the R_{iso} thresholds for each inverter series in appendix A.

In old installations the inverters may have different settings according to the applicable standards at this time.
It has to be clarified with all parties involved (system owner, authorities, manufacturers, installer,…) whether or not it is allowed to adjust these thresholds, and by how much.

*May deviate for certain setups and devices. See also appendix A

HOW TO DEAL WITH STATE 475 (LOW DC ISOLATION)

If a Fronius inverter displays state 475, it is essential that the PV system is thoroughly tested for ground faults by a qualified electrician.

As mentioned, according to previous standards, inverters had to ensure that the R_{iso} shall not be less than 1MΩ (= 1kΩ * 1000Vdc).

However, a PV array with more than 40m² could have an insulation resistance below 1MΩ without any isolation fault. This is in accordance with the PV module standards threshold of 40MΩm² (still applicable).

Depending on the PV module rated power and the real R_{iso} of the modules, a rather small PV system could have low insulation resistances causing the inverter to stay disconnected and not start up.

E.g.: 10kWp PV array, 40 * 250Wp modules (1000 * 1600 mm²; R_{iso_module} = 40MΩm²)

A = 40 * 1,6m² = 64m²

R_{iso_array} = 40MΩm² / 64m² = 0,625 MΩ (= to low)

➔ The inverter (according to previous standards) will not connect to the mains and will indicate a state 475.

Correct from the perspective of the inverter, but without any real insulation fault. Most of the time there will be no such issues as the insulation resistance of modules is typically higher than 40MΩm². However, there are circumstances where this situation can occur, especially in larger PV systems.

If the low insulation value in these PV systems is not caused by a ground fault but by the system design, it might be possible to lower the default insulation threshold to an appropriate level for the system.

It has to be clarified with all parties involved (system owner, authorities, manufacturers, installer,...) whether or not it is allowed to adjust these thresholds (and by how much).

ADJUSTING THE INSULATION RESISTANCE (R_{ISO}) THRESHOLD LEVEL

The measured R_{iso} value can be read on the inverter display under the menu item INFO.

If it is determined as necessary to lower the DC insulation threshold, then this is possible via the inverter display:

- Press the 3rd button from left (2nd from right) 5 times.
- Enter the code 22742 and press enter (4th button from left) to confirm and access the service menu "BASIC".
- Select the sub-menu "Insulation Settings" and press enter.
- Select the sub-menu "Error Threshold" and press enter.
- Adjust the threshold accordingly and press enter to confirm.
- You can now exit the service menu (press the 3rd button).

If sufficient DC power is available, and the inverter detects no further critical safety issues, then it will automatically begin its start-up procedure and begin feeding-in.

Please find for each inverter series the preset and device limit R_{iso} thresholds in appendix A.

APPENDIX A
PRESET VALUES AND DEVICE LIMIT VALUES OF R_{ISO} THRESHOLDS

	R_{iso} threshold level*	
	preset [kΩ]	device limit [kΩ]
Fronius Galvo 1.5-1 …. Galvo 3.1-1	600	100
Fronius Primo 3.0-1 …. Primo 8.2-1	1000	1000
Fronius Symo 3.0-3-S …. Symo 4.5-3-S	100	100
Fronius Symo 3.0-3-M …. Symo 20.0-3-M	100	100
Fronius Symo Hybrid 3.0-3-S …. Symo Hybrid 5.0-3-S	100	100
Fronius Eco 25.0-3-S …. Eco 27.0-3-S	100	100

*May deviate for certain setups and devices.

Fronius International GmbH

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Wels, 9th August 2017