

DC Insulation Resistance of PV Systems

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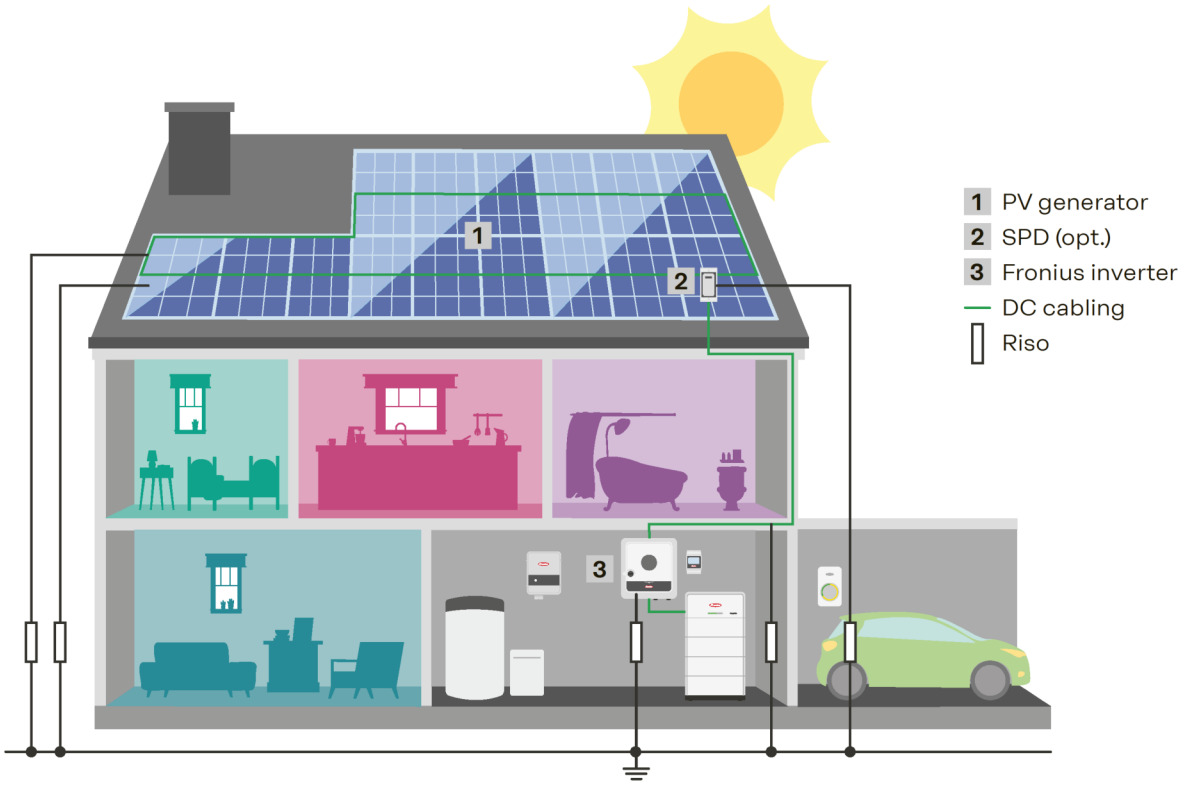
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1 What is Insulation Resistance?



Each single component of the PV system has individual insulation resistance to ground. Combined, this results in the total insulation resistance of the PV system (R_{iso}).
Usually this leads to very small and harmless residual currents.

In case of an insulation fault the fault-current could reach a dangerous level where it might have the potential to cause damage (e.g. fire) or personal injury. Therefore, the insulation resistance respectively the residual current has to be observed.

2 What does the Inverter do?

The inverter has to determine whether or not the whole PV system has sufficient insulation resistance between live parts and accessible parts.
In the morning the inverter measures this 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 the appropriate state code and also send a message if online.

The threshold level for Riso to be observed 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.

3 Relevant Standards

3.1 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 1 000V should not connect to the mains if the R_{iso} is less than 33,3kΩ (= 1 000V / 30mA).

Notes:

A new version of this standard is in preparation (Edition 2). In this version the requirement for specific values is removed. The requirement is "outsourced" to a specific standard called IEC 63112 (see hereafter).
The thresholds have to be defined in specific installation standards like the IEC 60364-7-712 mentioned hereafter.

National derivates from the IEC 62109-2 may continue to require compliance with the threshold mentioned above.

IEC 63112: Photovoltaic (PV) arrays – Earth fault protection equipment – Safety and safety related functionality

This standard defines the requirements an equipment for earth insulation monitoring has to meet and how to react if determined insulation thresholds are not met.

The thresholds are not defined here in, they have to be defined in standards requiring earth fault protection like IEC 60364-7-712. (also the IEC 63112 contains an example table in accordance with IEC 60364-7-712)

3.2 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 minimum insulation resistance thresholds for certain PV array sizes (see table below):

Max PV array DC rating at STC kW	R_{iso} lower 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, to improve the safety of the PV system.

3.3 For the 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 Riso 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.

3.4 Past Standards (not longer applicable):

Outdated inverter standards defined that the R_{iso} may not be less than 1kΩ * V_{max_PV}. This resulted in a value of 1 000kΩ for inverters with a V_{max_PV} of 1 000Vdc.

3.5 Contradiction of the Standards:

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

Standards dealing with protection from electric shock, require that fault currents do not exceed 30mA.

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

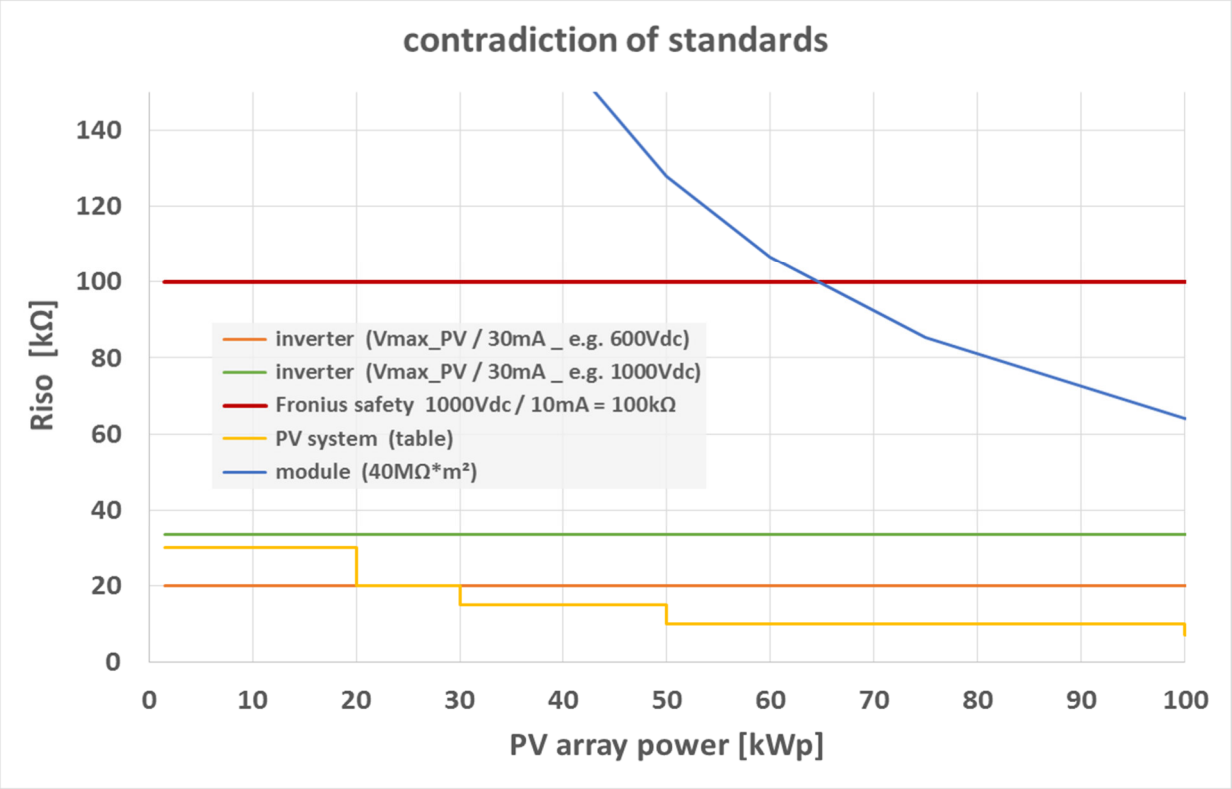


Chart 1: Insulation resistances from different standards.

4 Fronius Inverter R_{iso} Threshold Levels

Most standards dealing with protection from electric shock require that fault currents do not exceed 30mA.

Following the recommendations to set higher thresholds to improve safety, Fronius decided to set the default threshold levels of Riso to higher values than required as a minimum.

For inverters up to 15kW a preset value tolerating no higher fault currents than 10mA resulting in a value of Riso = 100kΩ (= 1 000V / 10mA) is used which still leaves enough margin to prevent false trippings. *

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 diagram shows, PV arrays below 65kWp shall always have a higher insulation resistance when complying with the module standards.

For inverters larger than 15kW the preset values are chosen lower following the tendency of the table of IEC 60364-7-712. Still the values are higher than the minimum requirements, to improve safety.

Please find the presets and device limit values of the Riso thresholds for each inverter series in appendix A.

In old installations the old 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

5 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 * 1 000Vdc; see clause 3.4).

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.

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.: 15kWp PV array, 30 * 500Wp modules (1 134 * 1 800 mm²; R_{iso_module} = 40MΩm²)

A = 30 * 2m² = 60m²

R_{iso_array} = 40MΩm² / 60m² = 0,67 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). (See also the table from IEC 60364-7-712)

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

6 Appendix A
Preset Values and Device Limit Values of R_{iso} Thresholds

	R_{iso} threshold level	
	preset* [kΩ]	device limit [kΩ]
Fronius Argeno	**36**	**36 - 1 000**
Fronius Tauro (ECO)	**34**	**10 - 10 000**
Fronius Verto (Plus)	**34**	**34 - 10 000**
Fronius Symo & Primo Gen24 SC (Plus)	**100**	**100 - 10 000**
Fronius Symo & Primo Gen24 (Plus)	**100**	**100 - 10 000**
Fronius Eco -S	**100**	**100 - 10 000**
Fronius Symo Hybrid -S	**100**	**100 - 10 000**
Fronius Symo Advanced -M	**100**	**100 - 10 000**
Fronius Symo -M	**100**	**100 - 10 000**
Fronius Symo -S	**100**	**100 - 10 000**
Fronius Primo	**1 000**	**1 000 - 10 000**
Fronius Galvo	**600**	**100 - 10 000**

*May deviate for some specific setups and devices.