APPLICATION NOTE:
FUNCTIONAL GROUNDING OF A Q.SMART PHOTOVOLTAIC SYSTEM - PROCEDURE AND SAFETY

VERSION 1.0, APRIL 2011

1 INTRODUCTION

1.1 GENERAL SAFETY ADVICE

For fire safety reasons, the maximum permitted leakage current of 50 mA in case of grounding must not be exceeded. Any rules and laws for personal security remain unaffected.

1.2 BACKGROUND

Due to increased demand of Q.SMART solar modules in non-temperate regions, we have subjected our modules to further tests in cooperation with VDE to ensure that they meet our strict performance requirements in such climates which go beyond those specified in the IEC standards. We have undertaken this in order to guarantee reliable and safe long-term operation of Q.SMART Photovoltaic Systems (PV Systems) .
Among others, endurance tests were performed at elevated temperatures in high-humidity conditions (in the vicinity of dew point 14). Solibro has found that the stability of the solar module's active layer was significantly improved with the imposition of negative grounding (functional grounding). In cooperation with VDE, we have decided to require grounding in countries with warm climates in order to ensure that our guarantee can be safely met. This does not affect Q.SMART modules used in temperate climatic regions. A list indicating the regions where functional grounding is required can be found in the respective valid installation manual.

This measure is being undertaken purely as a precaution. Arrays already in use can therefore be left in their present state. Although we do not expect degradation of systems in previously-installed systems, we advise our valued customers to contact Q-Cells' Customer Service in case of concern.

Since our grounding recommendation was worked out in coordination with VDE, it is a part of the Q.SMART certification. All new arrays erected with Q.SMART modules are therefore subject to this grounding specification.

1.3 SAFETY RELEVANCE

On a grounded PV generator, even a simple short-circuit to ground is sufficient to produce ground fault currents. Such a short-circuit to ground can result, for example, from glass breakage in combination with moisture.
On thin film modules glass breakage can occur from improper handling or installation, incorrect design or implementation of the substructure or tension in the glass, which can never be fully excluded as a matter of the design. This always results in affected modules losing their safety class 2 rating (protective insulation in compliance with DIN EN 61140 (VDE 0140-1): 2007-03) and requires immediate replacement of the module in the field. Measures will be discussed herein to minimize the potential hazard posed by such defective modules up until the time they are replaced, and to limit the danger resulting from ground faults. Ground fault currents greater than 30 mA for a period of 0.4 s may pose a lethal hazard. Ground fault currents greater than 100 mA may pose an increased fire hazard.
Generally such hazards should be minimized.

1.4 RANGE OF APPLICATION

This application note explains functional grounding of Q-Cells Q.SMART solar modules. Terms seen herein that are followed by superscripts are defined in Chapter 5.
This application note serves as a supplement to the installation instructions for Q.SMART solar modules and is intended primarily for electricians with expert knowledge of solar systems. PV grounding should be accomplished only by such persons, in compliance with the safety regulations in the installation instructions and in accordance with local electrical codes. In reference to the installation instructions issued by Q-Cells SE, Q-Cells does not accept any liability for damages resulting from incorrect handling or failure to observe the recommendations described herein.

2 SUMMARY

- In regions where functional grounding is not required, it is not required to ground PV systems that employ inverters with transformers. Hard grounding is allowed for the framed Q.SMART module when this is in accordance with local regulations and abide by the requirements of the respective inverter manufacturer. Hard grounding is defined here as the functional grounding of the negative pole without the inclusion of a resistor or fuse. Hard grounding must always be performed with components allowed for use by the inverter manufacturer. This declaration of hard grounding for framed modules contradicts our current installation manual. There are no safety-relevant concerns in this regard.
- If it is essential to ground a PV generator as a result of our specifications or local regulations, the grounded conductor should be monitored by an additional safety device to ensure that ground fault currents >30 mA are prevented or that ground fault currents >50 mA within a time period 0.4 s are detected and prevented with certainty, or that insulation monitoring can replace this function. A simple ground fault safety device is not sufficient.
- Transformerless inverters with flying inductor topology, on which one pole of the PV generator is permanently grounded, can be used generally and in all regions with Q.SMART modules. However in such cases it should be clarified with the inverter manufacturer for safety reasons whether all of the conductors connected to the inverter should be disconnected from the grid in the event of a fault.
- Conventional transformerless inverters or the quiet-rail topology can be used in all European regions where no functional grounding is required, when they have an all-phase residual current monitoring unit (RCMU) capable of disconnecting the inverter from the grid when fault currents > 30 mA are present for longer than 0.4 s. This is usually the case for all units approved in Germany, however this should be checked when planning the system.
- RCMU's that come pre-installed in some transformerless inverters should be set up according to our recommendations herein. For those transformerless inverters without a pre-installed RCMU, it is necessary to install an all-phase residual current monitoring unit (RCMU or RCD Type B) in the system, to completely disconnect the system from the grid in the event of AC or DC ground faults (all external conductors and the neutral conductor) when currents exceed 30 mA for longer than 0.4 s.
- Transformerless inverters with quiet-rail topology, on which the potential of the negative generator pole can be fixed to positive values by appropriate selection of the string voltage, can be used anywhere.
- In regions requiring functional grounding, the potentials are to be measured at the time of start-up. It is permissible to operate the system only when the negative generator pole has a non-negative potential with respect to PE.

3 PRELIMINARY CONSIDERATIONS: RELEVANT GRID TOPOLOGIES

When a PV generator is grounded, it is possible, under certain circumstances, for two completely different types of grids (DC grid and AC grid) to be connected electrically to one another over an intended ground connection. The alternating switching states of the bridge circuit result in transformerless inverters being connected to a second ground circuit at least 25 times per second. For this reason it is not permissible to use transformerless inverters with grounded PV generators. On the other hand the PV generators‘ DC network can no longer be operated without a ground, so that ground fault currents can occur. The following section provides a brief summary of the grid topologies relevant for PV systems. It is intended to show which conductors are connected to ground potential in each grid topology.

Few specifications exist for DC grids.
According to EN 50162 7.3,

- All poles of DC grids are to be fused (L(+) and L(-)) and provided with a residual current monitoring unit, when operated without a ground, or
- One pole (L(+)) is to be fused when L(-) is grounded. The ground is to be connected to one point only. Ground connections (potential compensation), cable paths and pipes are not to be used to conduct return currents. See EN 50162 for exceptions.

Observe all local electrical regulations regarding grounding of such grids.

The grid classes (Chapters 3.1 to 3.5) described below are to be observed for low voltage and medium voltage AC power grids in Europe.

3.1 TN-C GRID (FRENCH: TERRE NEUTRE COMBINE)

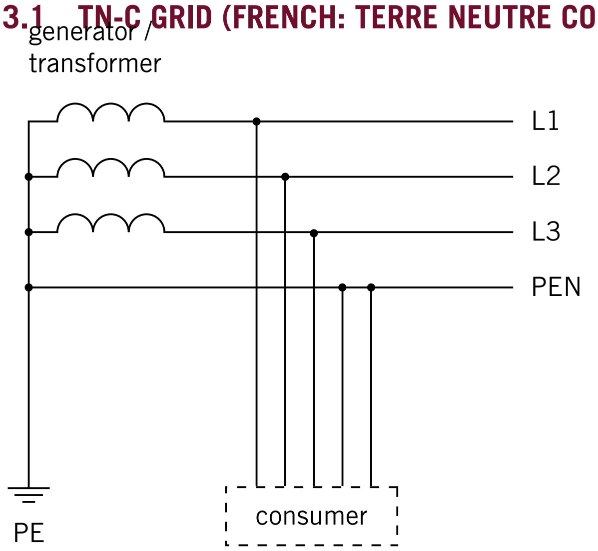

Figure 1: Circuit diagram of a TN-C grid.

A TN-C grid (Fig. 1) uses one combination ground designated PEN, which serves as protective earth as well as neutral conductor. All conductive housing parts in this grid are connected to the neutral conductor. Since an equalizing current flows through the neutral conductor when the load is asymmetric (unequal load on external conductors L1, L2, L3), there is a voltage drop to ground depending on the resistance of the PEN conductor. In the event of a discontinuity in the PEN conductor (infinitely high resistance) the full external conductor voltage to ground is present on the housing. For this reason, TN-C grids are permissible only with conductor cross-sections > 10 mm² (reduction of breakage hazard). There are no rights of continuance for older systems.

3.2 TN-S GRID (FRENCH: TERRE NEUTRE SEPARE)

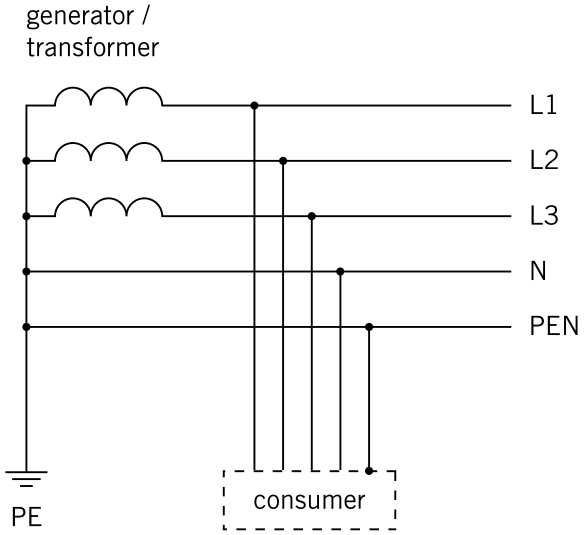

Figure 2: Circuit diagram of a TN-S grid.

In TN-S grids (Fig. 2) a separate PE protective earth is routed along with the other conductors as a safety measure. TN-S grids are safer than TN-C grids, because the protective feature remains intact even in the event of conductor discontinuity. In this case there is no voltage drop to ground over the conductive housing.

3.3 TN-C-S GRID (FRENCH: TERRE NEUTRE SEPARE COMBINE)

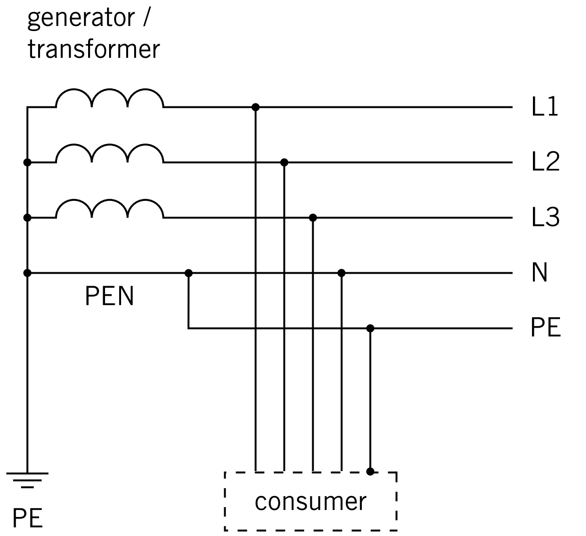

Figure 3: Circuit diagram of a TN-C-S grid.

A TN-C-S grid (Fig. 3) is a hybrid of the TN-C and TN-S grids. This is the form most commonly employed in low voltage German grids. It is important to note that in this grid, part of the system uses a combined PEN conductor (TN-C), which at some point is divided into PE and N lines (TN-S), usually at the building entry point (service box). This type of grid is used in Italy, for example, primarily for industrial applications.

3.4 TT GRID (FRENCH: TERRE TERRE)

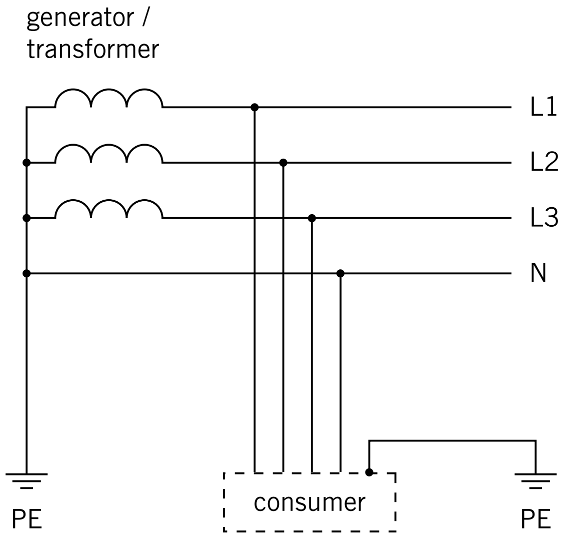

Figure 4: Circuit diagram of a TT grid.

In TT grids (Fig. 4) the transformer star point is functionally grounded. Functional ground is connected electrically to the protective earths in the system only over ground, however not by a continuous conductor. In such systems the protective earth does not present a problem, because here the effectiveness of the protective measure depends on the ground resistance. In circuits with higher current, use of a ground fault detection device is required.

Typical applications for TT grid.
- Germany in rural areas
- Italy in private households
- Spain in installations supplied by the public low voltage grid.

Grounding in TN and TT systems.
Since PE and PEN can assume a voltage relative to ground potential exceeding the permissible contact voltage, in all TN systems as well as TT systems in the event of a ground fault in one of the external conductors, excessive voltages are prevented by use of a number of functional and system grounds. This reduces the overall resistance to ground. All grounds in the system form a parallel circuit.

Decisive for operation of PV systems is that all grids used in public AC power supplies in Europe have functional as well as protective earths, thus allowing ground currents in the event of a fault.

3.5 IT GRID (FRENCH: ISOLÉ TERRE)

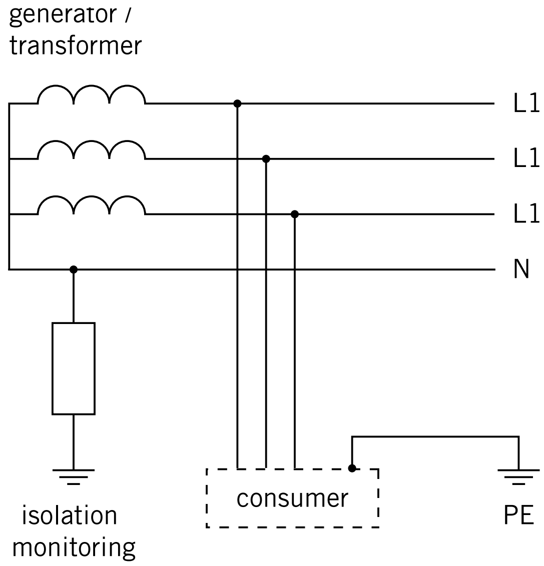

Figure 5: Circuit diagram of an IT grid.

IT grids (Fig. 5) do not have any functional ground. The grid is completely isolated respective to ground and the insulation value to ground is monitored. (i.e. the grid is not connected to protective earth). Such grids consist of 3 or 4 conductors with a transformer star point as ungrounded conductor, all routed together. Such grids are extremely fail-safe, because a double short-circuit to ground is required to produce a ground fault. Here the only protective measure against a short-circuit to ground is the conductor insulation. However, since the individual conductors have a capacitive effect in relation to ground, ground fault currents can flow to ground when the capacity is high enough (i.e. long conductor cables). For this reason, the length of the conductors in IT grids is limited in practice.

In special cases, such grids are used for industrial applications or in mining operations.
For this consideration, the grid topology is relevant primarily in systems operated with one central inverter connected to a medium voltage transformer.
If, in such cases, the connection between the inverter and the low voltage side of the transformer is laid out as an IT grid, electrical isolation is also ensured between the inverter and the medium voltage grid. An inverter operated in this manner can be treated as a transformer inverter in terms of grounding, regardless of its topology.

4 GROUNDING SYSTEM RECOMMENDATIONS: INVERTER TOPOLOGIES AND POSSIBLE CIRCUITS

Recent advancements in inverter technologies have led to new topologies on the market which can limit the potential difference between the protective earth (mounting system) and the negative pole of the PV generator. Inverters with quiet rail topology may be used in all regions with Q.SMART modules when it is ensured that the potential difference between the protective earth (PE) and the negative pole of the PV generator is not less than 0 V. It is in general not permissible for the negative pole of the generator to have a negative potential in relation to the mounting system. It is essential to measure this during operation of the system.
This chapter introduces seven different inverter topologies, including special safety precautions for their respective uses.

4.1 INVERTERS WITH TRANSFORMERS AND UNGROUNDED PV GENERATOR

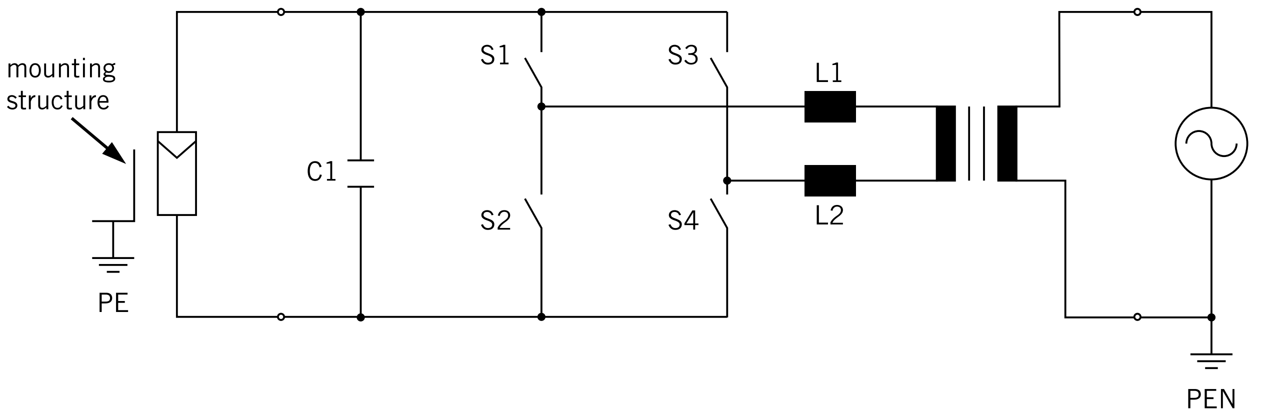

Figure 6: Circuit diagram of inverter with transformer

It is unimportant whether or not the inverter is equipped with a 50 Hz or high frequency transformer. Critical is whether the PV generator DC connections can assume any desired value in relation to ground potential as a result of electrical isolation from the grid. Only a slight voltage ripple is superimposed on the DC voltage. This residual ripple results from the alternating switching states of the inverter‘s bridge circuitry.

Requirements for Safe Operation

With this topology (Fig. 6) additional safety devices are not required, because here the PV generator is electrically isolated from the grid via the transformer, and thus from all functional and protective earths present in the grid. Only a double short-circuit to ground can lead to a ground fault current. It is absolutely necessary to monitor the PV generator for ground faults or to perform an insulation monitor test prior to the system being put into operation.

4.2 INVERTERS WITH TRANSFORMERS AND GROUNDED PV GENERATOR

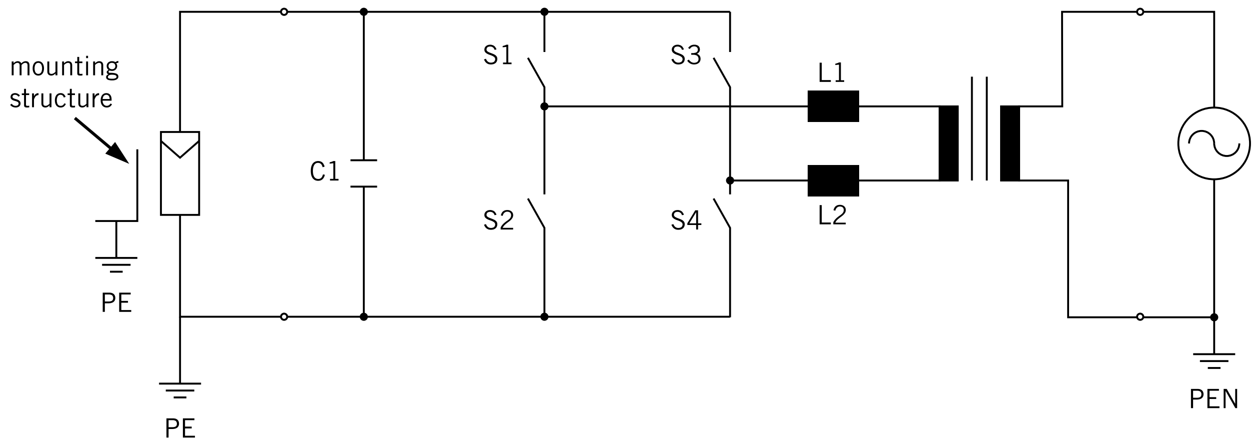

Figure 7: Circuit diagram of an inverter with transformer and grounded PV generator.

This concept (Fig. 7) is used primarily in smaller systems in regions where grounding is required. Use of an inverter with transformer is mandatory for this grounding concept. The potential of the PV generator is limited to a fixed value by this arrangement. The disadvantage is that in such systems, it is not easily possible to measure the insulation resistance in the inverter. Since a short-circuit to ground[3] already exists in the form of the functional ground, it is necessary to shut off the insulation monitoring feature integrated into the inverter to ensure proper operation.

Requirements for Safe Operation

High ground fault currents are possible with this topology in case of glass breakage in the presence of moisture (i.e. rain, condensation).
The ground fault current continues to flow even when the inverter is disconnected from the grid, since the short-circuit to ground is not eliminated. Reliable separation of the ground fault circuit is possible only after the ground fault detection interrupter (GFDI) trips (typically 1-6 A). However even at smaller values, ground fault currents may still pose a hazard (300 mA - fire hazard, 30 mA hazard for humans and animals).

We recommend:
- Connect the ground over a resistor to limit the maximum current to 50 mA at the system voltage present (open circuit voltage). Various inverter manufacturers offer appropriate grounding kits. However grounding over a resistor results in a decrease in the rms value of the residual voltage ripple across the resistor and thus a DC offset. Therefore it is still possible to observe a potential difference of a few volts between the mounting system and the grounded generator pole. This value depends on the inverter and resistor used. For this reason, on request, we offer testing and, when successful, approval of the combination of certain transformer inverters in combination with resistance grounding kits.

Approved inverters for such applications include:
- Fronius IG Plus Series with resistive grounding kit
- Danfoss Unilynx grounded over 100 kΩ resistor
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Other possibilities:
- An all-phase residual current monitoring unit (RCMU) can be installed on the system side of the inverter such that a ground fault can be interrupted when a pre-set current level is detected..
- Grounding kits with ground fault detection interrupters can be used when fire or safety hazards are excluded by other safety measures (e.g. fencing, non-combustible surroundings).

Note for future development:
- Current technical developments are in progress to achieve reliable protection by reducing the size of ground fault detection interrupters. However this poses the danger of an interrupter tripping as a result of leakage currents, eliminating the ground. For this reason PV systems with a grounded conductor can be operated safely only using automatic monitoring devices or via limitation of ground fault currents.

4.3 TRANSFORMERLESS CENTRAL INVERTERS, ELECTRICALLY ISOLATED FROM THE GRID BY MEDIUM VOLTAGE TRANSFORMERS

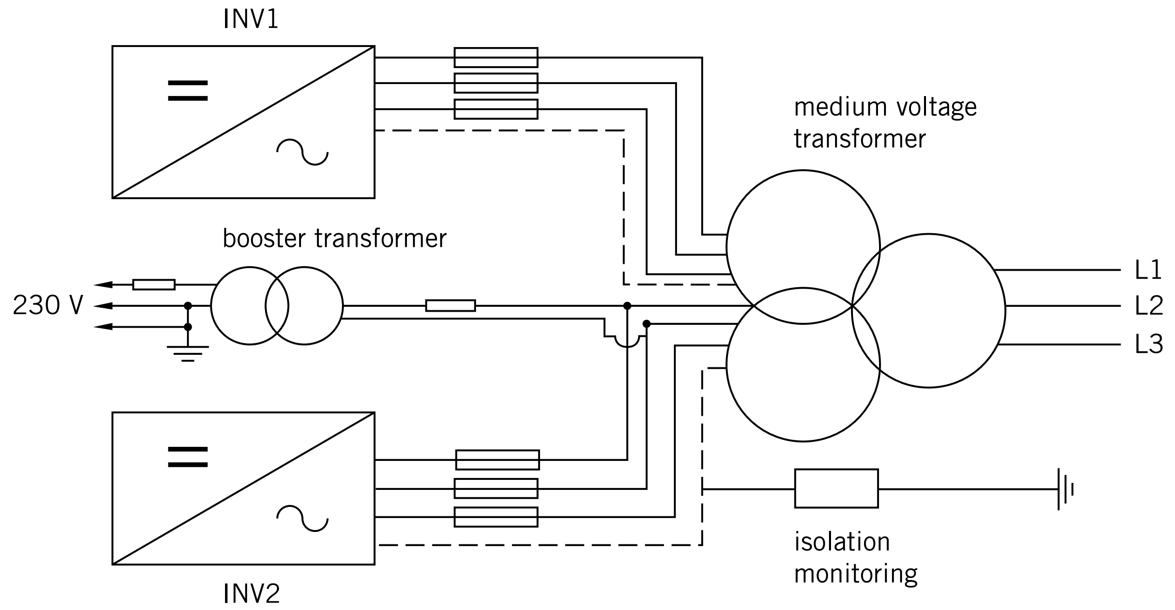

Figure 8: Circuit diagram with transformerless central inverter and electrical isolation from grid with medium voltage transformer

Since with this inverter topology (Fig. 8) the system is separated from the grid by a medium voltage transformer, this circuit can always be considered to be a transformer inverter regardless of the type of inverter used. Critically, the star point of the medium voltage transformer is not grounded on the low voltage side. The relative short section of the low voltage grid between the inverter(s) and medium voltage transformer is laid out as an IT grid.

Requirements for Safe Operation

The PV generator pole can also be grounded directly in such systems. We recommend this concept particularly for fenced-in systems (protection for humans and animals) in outdoor areas, which require grounding and use one central inverter.

It is necessary to observe the following when such inverters are used:
- All circumstances specified in Chapter 4.2 apply.
- When a 230 V auxiliary voltage grid is used (control voltages) it is also necessary to ensure that this grid is either separated by an auxiliary transformer or is operated without grounding.. The conductor lengths in the ungrounded grid must be limited to prevent voltage drops to ground greater than 50 V that may arise due to capacitive reactive effects (requirements for IT grids).
- When grounded over a resistor and more than 50 parallel strings are connected to an inverter, the voltage drop across the resistor should be measured. This value should not exceed 20 V.

Alternates:
- **Separation of ground connection without resistor** (Figure 9): As an alternative, a ground connection without resistor can be used, however, a residual current monitoring unit (RCMU Type B) must be installed on the DC side. Such devices are capable of detecting currents of up to 30 mA within 0.4 s and are typically programmable. This allows equalizing current peaks to be bridged reliably. At high currents flowing for longer periods of time, the ground should be disconnected and an alarm triggered.

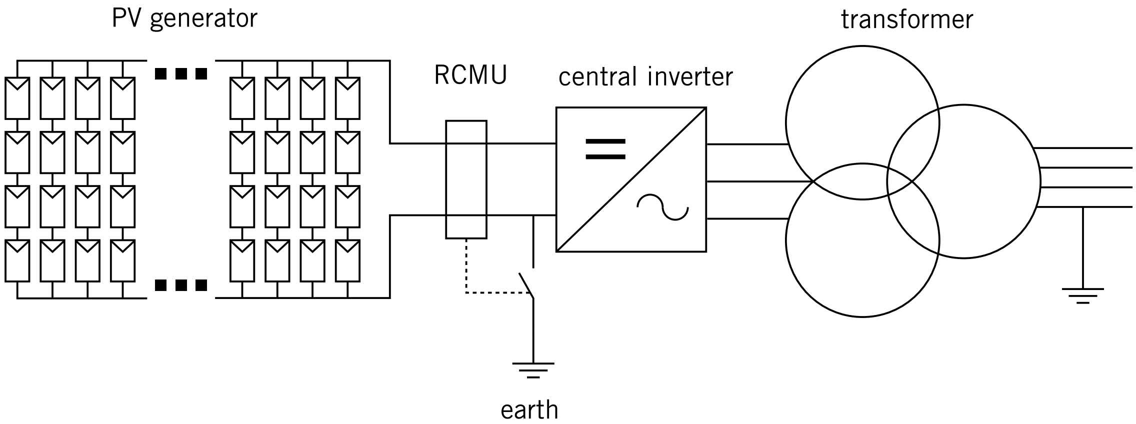

Fig. 9: Separation of ground connection without resistor

- **Separation of generator poles (Fig. 10):** If the ground connection is located inside the inverter (grounding kit), it is necessary to separate the generator connections with the aid of DC contactors. This form of ground fault monitoring can be used generally for all electrically separated systems, however, it is economically practical only when central inverters are used. Good grounding is also possible here when the equalizing currents to ground are monitored by a suitable circuit and the leakage current are limited (less than 30 mA). In some countries it is necessary to separate the inverter from the grid on the AC side in the event of a short-circuit to ground. This can also be realized with an RCMU.

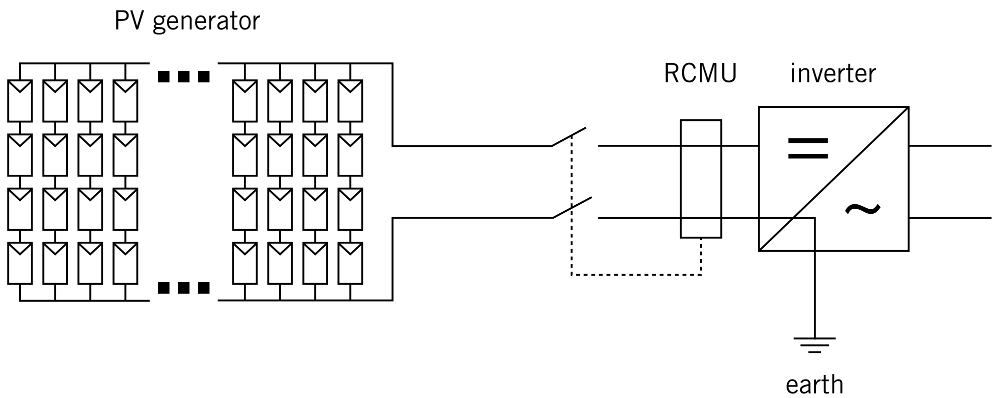

Figure 10: Separation of generator poles.

Recommended residual current monitoring devices (RCMU):
- DOLD IP 5883
- Bender RCMA420

It is important always to observe local regulations.

4.4 CLASSIC TRANSFORMERLESS INVERTERS

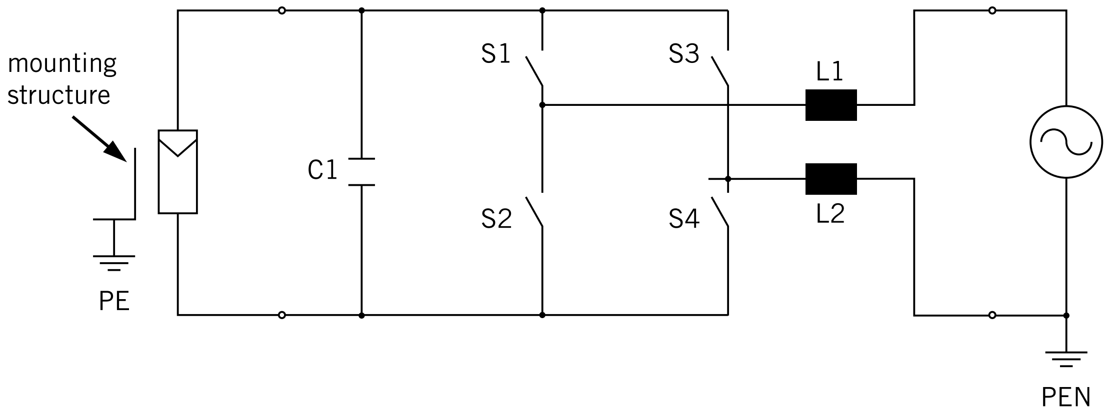

Figure 11: Circuit diagram with classic transformerless inverter

Standard transformerless inverters provide no electrical isolation from the grid (Fig. 11). Therefore it is not possible to ground the PV generator, because otherwise the PV generator would be short-circuited over the inverter in the corresponding switching state (S2, S3 closed). The lack of electrical isolation would also make it impossible to measure the insulation resistance during operation. For this reason it is necessary to measure the insulation resistance (Riso test) on such devices before connecting to the grid. According to valid regulations the insulation resistance should not exceed 1 kΩ/V, or at least 500 kΩ. During operation, AC fault currents on the grid side as well as DC fault currents on the generator side should be detectable by an all-phase residual current monitoring unit (RCMU) followed by inverter disconnection from the grid at a fault current surge ≥ 30 mA. Reliable operation on the grid is guaranteed only by a combination of both monitoring mechanisms. Any electrically conductive mounting system must be included in the potential compensation (protective earth) due to the expected capacitive ground fault currents.

Requirements for Safe Operation

With classic transformerless inverters, during operation a conductive connection exists from one PV generator pole over the neutral conductor to the grid‘s combined operating / protective earth and therefore to protective earth of the mounting system. This can lead to ground fault currents in the event of a short-circuit to ground. The all-phase residual current monitoring unit (RCMU) prescribed for such equipment in VDE 0100 Part 530 normally separates the inverter from the grid at fault currents greater than 30 mA within 0.4 s. As shown in the circuit topology, external conductors as well as neutral conductors are disconnected from the grid. This reliably interrupts the short-circuit to ground.

It is necessary to observe the following when such inverters are used:
- The integrated RCMU must disconnect reliably at an amperage of up to 30mA within 0.4 s.
- It is not permissible to use inverters with RCMU‘s with higher values (permissible up to 300 mA according to VDE 0100 Part 530) with Q.SMART modules in the regions where functional grounding is required.
- An RCMU (RCD type B) can be retrofitted to the entire system. This device must be connected on the AC side.

4.5 TRANSFORMERLESS INVERTERS WITH STEP-UP CONVERTERS AND DIVIDED INDIRECT VOLTAGE LINK AC CONVERTERS (QUIET RAIL TOPOLOGY)

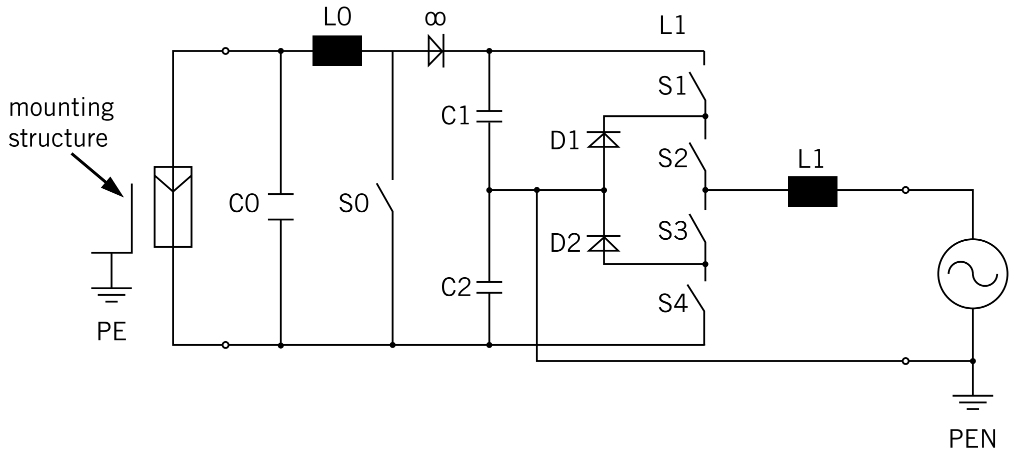

Figure 12: Circuit diagram of quiet rail topology

The quiet rail switching concept (Fig. 12) uses two intermediate circuit capacitors (C1, C2) with the AC grid neutral conductor at their center point. The capacitors are high performance so that the voltage over these power sinks is virtually constant. This means that the poles of the solar generator are at a virtual static potential in reference to ground which is not equal to zero (quiet rail concept). Although with this concept the capacitive fault currents are lower due to the static potential, it is not possible to ground the PV generator on the DC side for the same reasons as with classic transformerless inverters. With the classic devices in this category the potential differences with respect to ground are usually so unfavorable, that they should never be used in regions where grounding is recommended under any circumstances.
The latest developments of this technology have produced devices suitable for use in such regions under certain circumstances. These are described in detail in Chapter 4.6.

Requirements for Safe Operation

The position and ripple in the generator potentials relative to ground effect the protection concept. When an intermediate circuit is used, the problems with capacitive fault currents are only reduced. The circuit diagram shows that these inverters are separated from the direct current capacitively at least over the intermediate circuit even in the most unfavorable case of circuit design.

It is necessary to observe the following when such inverters are used:
- A DC fault current over the protective / operating grounds to the mounting system is not possible after disconnection of the grid by the RCMU.
- The requirements specified in Chapter 4.4 apply for the RCMU. In the regions where functional grounding is required it is not permissible to use Q.SMART modules and an RCMU with higher potential settings.

4.6 TRANSFORMERLESS INVERTERS WITH ASYMMETRIC STEP-UP CONVERTERS AND DIVIDED INDIRECT VOLTAGE LINK AC CONVERTERS

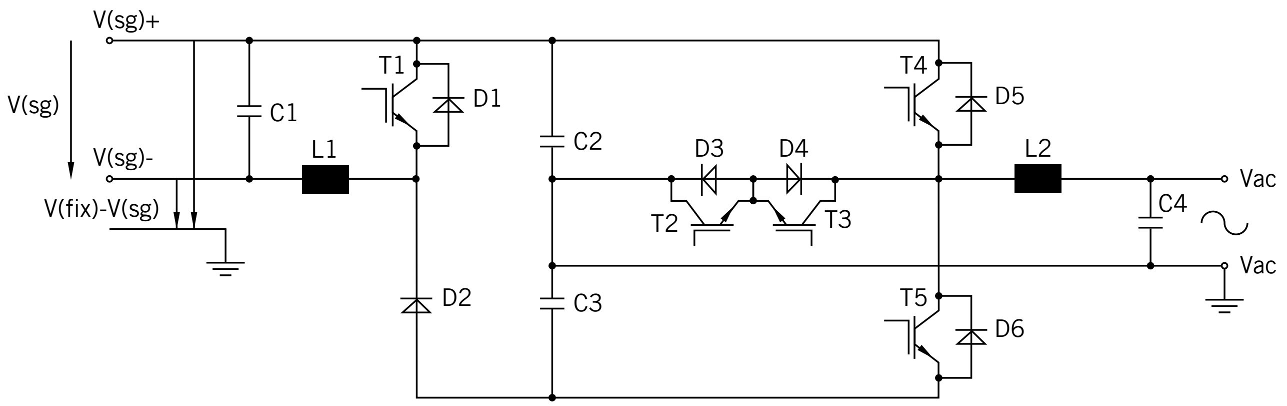

Figure 13: Circuit diagram with transformerless inverter with asymmetric step-up converter and divided indirect voltage link AC converter

This topology (Fig. 13) represents a special form of quiet rail topology. By shifting the diode D2 into the low current path, the step-up converter (C1, L1, T1) operates quasi asymmetrically in relation to the indirect voltage link AC converter. With this circuit the positive potential of the solar generator U(fix) is set to a fixed value relative to the mounting system potential (PE) within the operating limits of the step-up converter. This is usually one-half of the operating voltage of the step-up converter (approx. 350 V - 400 V). The potentials are divided symmetrically in relation to the ground potential only when the operating range of the step-up converter is exceeded by the string voltage. The potential of the negative generator pole in relation to ground can then be influenced directly by the string voltage. The voltage drop between the negative generator pole and mounting system results from the difference between the fixed value and the string voltage U(fix)-U(sg). If the number of modules in the string is selected so that the Mpp voltage is less than the value U(fix), it is possible to ensure that the potential difference between the mounting system and the negative generator pole is not negative during feed-in. In this case it is necessary to ensure that the inverter still operates in the Mpp range at the selected string voltage.

Requirements for Safe Operation

It is necessary to observe the following when such inverters are used:

- Such inverters can be used with Q.SMART modules in all countries when the string voltage is selected correctly.
- The requirements specified in Chapter 4.4 apply for the integrated safety circuits (RCMU, ENS).
- It is also necessary to ensure that the Mpp string voltage does not exceed the fixed value U(fix).
- The potential of the negative generator pole relative to the mounting system (PE) must be measured at the time the system is put into operation and should not be negative. In contrast, positive values are permissible.

Possible inverters:

- Voltwerk VS Series with 6 modules per string

4.7 TRANSFORMERLESS INVERTERS WITH SINGLE POLE GROUNDED PV GENERATOR

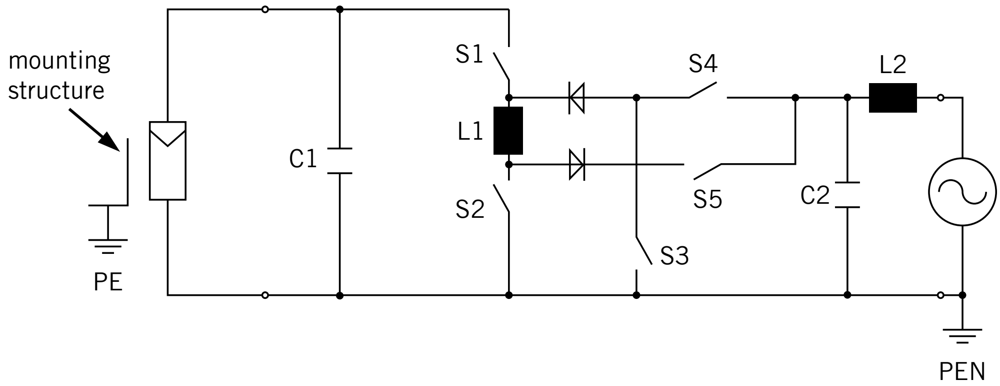

Figure 14: Circuit diagram with flying inductor technology.

On these devices (flying inductor technology) one pole of the PV generator is permanently connected to the neutral conductor in the AC grid (Fig. 14.) This means that the potential of the PV generator relative to ground remains constant during inverter operation. During operation a conductive connection exists between the grounded generator pole and all protective and operating grounds in the grid.

Requirements for Safe Operation

Transformerless inverter with single pole grounded negative pole can be used with Q.SMART modules everywhere.

For safety reasons the following points should be observed:

- The RCMU must disconnect the inverter from the grid in case a fault current of 30 mA for longer than 0.4 s arises.
- The inverter must be separated from the grid by disconnecting all external conductors connected to the inverter as well as the neutral conductor (L1, L2, L3, N).

If the electrical connection over the operating / protective earths in the grid to the mounting system is maintained over a connected neutral conductor, the fault current will continue to flow even when the inverter is shut off.

Approved inverters:

- Sunways AT Series

5 KEY TO TERMS

TERM	DESCRIPTION
Dew point	Temperature at which the relative humidity is 100%
Electrical isolation	Circuits that are electrically isolated allow energy transfer, however charge carriers are not exchanged.
ENS	Device for network monitoring with allocated switching devices (MSD): automatic disconnection for low-power generation plants (up to 30 kW peak power).
External conductor	Conductor which is live in operation and is not the neutral conductor.
Functional ground	Connection between an electrical conductor and ground, required for correct operation of the system. In the case of PV grounding this corresponds to the operating ground.
GFDI	Ground Fault Detection Interupter: monitors short-circuit to ground and cuts connection if necessary.
Ground conductor	Electrical conductor, serving exclusively for safety; does not conduct current in normal cases.
Low voltage grid	AC power supply at less than 1000 V
Medium voltage	AC power supply between 1000 V and 30 kV.
N	See neutral conductor
Neutral conductor	The conductor that connects to the star point in a three-phase system, or that carries the return current in a single-phase system.
Operating ground	Electrical connection between a conductor which conducts current during operation and ground (as a rule neutral conductor)
PE	See protective earth
PEN	Combined protective earth and neutral conductor
Protective earth	Electrically conductive connection of all easily accessible parts of a system with ground potential; serves exclusively for safety.
RCMU	Residual Current Monitoring Unit (fig. 15): monitors differential string current and disconnects the components with which the RCMU is wired when a set voltage is exceeded.
Short-circuit to ground, ground fault	Electrical connection (i.e. short) between a conductor and ground (usually as a result of an insulation fault).

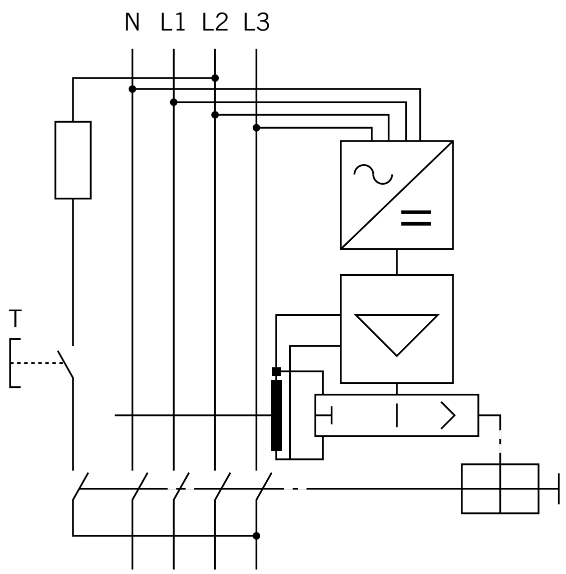

Figure 15: Circuit diagram of an RCMU

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