Power-One Aurora Inverter:

anti-islanding protection description

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SCOPE

Scope of the document is to provide a brief description of the islanding condition and of the requirements about the protection against the islanding condition (anti-islanding protection). Finally a description of the anti-islanding protection implemented in Power-One Aurora central inverters will be presented.

APPLICATION AREA

The document refers to the inverter listed in the below table.

HF-isolated and Transformerless String Inverter	55kW module-based modular central inverters (PLUS series)	Monolithic central inverter (LITE series)	350kW module-based modular central inverters (ULTRA series)
PVI-10.0-TL-OUTD	PVI-55.0 / PVI-55.0-TL	PVI-250.0-TL	ULTRA-700.0-TL
PVI-12.5-TL-OUTD	PVI-110.0 / PVI-110.0-TL	PVI-500.0-TL	ULTRA-1050.0-TL
PVI-10.0-I-OUTD	PVI-165.0 / PVI-165.0-TL		ULTRA-1400.0-TL
PVI-12.0-I-OUTD	PVI-220.0 / PVI-220.0-TL		
TRIO-20.0-TL-OUTD	PVI-275.0 / PVI-275.0-TL		
TRIO-27.6-TL-OUTD	PVI-330.0 / PVI-330.0-TL		

Table no.1: inverters the present document refers to.

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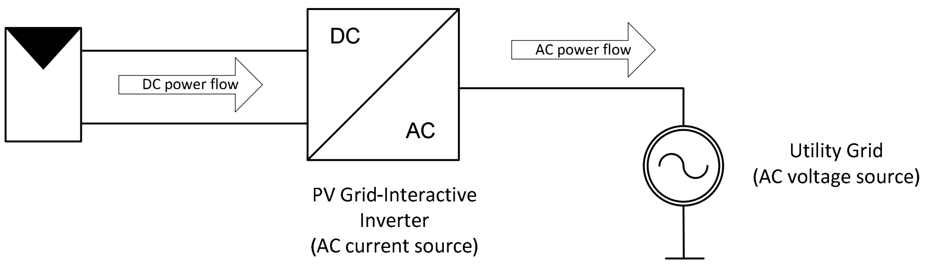
THE “ISLAND” CONDITION

The inverters for grid-parallel operation (grid-interactive inverters) work as current sources which feed power into the utility grid. This kind of inverters is typically unable to supply the utility grid because doesn’t work as voltage source. The grid-tied inverters feed power into the grid as AC current with the same frequency of the grid voltage.



Picture no.1: grid-tied inverter normal operation.

The “island” condition is a grid-parallel situation in which the inverter still continues to power the network even if voltage from the electric utility is no longer present. In the IEEE Std. 1547.1-2005, the definition of “island” is the following:

Island: *a condition in which a portion of an area electric power system (EPS) is energized solely by one or more local EPSs through the associated points of common coupling (PCCs) while that portion of the area EPS is electrically separated from the rest of the area EPS.*

In the IEC62116 Edition 1.0 2008-09, the “island” is defined as following:

Island: *a state in which a portion of the electric utility grid, containing load and generation, continues to operate isolated from the rest of the grid. The generation and loads may be any combination of customer-owned and utility-owned.*

The “island” condition is present when, due to a fault condition in the grid or due to a particular load condition on the grid, the grid shows a resonant-load behavior. In such conditions even if the voltage from the network is no longer present, the resonance between the L-C component still maintain the voltage at the inverter’s output terminal and so the inverter could not be able to detect the grid voltage absence. In this case if the resistive load matches the power produced by the inverter, the parallel operation is still possible and creates the “island condition”.

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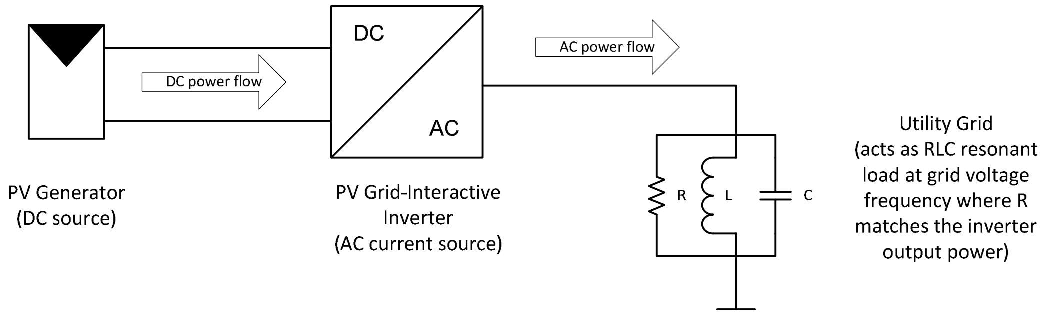

Picture no.2: circuital representation of island condition.

Island condition can be dangerous primarily because four reason:

1. Safety concerns: if an island condition is present the utility workers may be faced with unexpected live wires while expect no voltage is present on the line.
2. Equipment damage: customer equipment could theoretically be damaged if operating parameters differ greatly from the norm. In this case, the utility is liable for the damage.
3. Ending the failure: reclosing the circuit onto an active island may cause problems with the utility's equipment, or cause automatic reclosing systems to fail to notice the problem.
4. Inverter damaging: reclosing onto an active island may cause damaging of the inverters.

ANTI-ISLANDING PROTECTION NEEDS AND STANDARD

Due to the above main reasons the inverter shall be equipped with anti-islanding detection and protection mechanism to avoid the island condition. The applicable rules about the detection and interruption of island condition are various from country to country. Here below are listed some standards with reference of the country where is applicable.

Country	Standard which defines Anti-islanding protection requirements
Australia	AS4777.3-2005
Asian countries (ex. Thailand)	IEC62116 Edition 1.0 2008-09
Germany	VDE-AR-N 4105:2011-08 (*)
USA, Canada	IEEE Std. 1547-2003 / IEEE Std. 1547.1-2005 (**)
Notes:	*(*)Anti-islanding requirements applicable only for inverter with nominal power lower than 30kVA.* *(**) As required per UL1741.*

Table no.2: Standard which defines Anti-islanding protection requirements.

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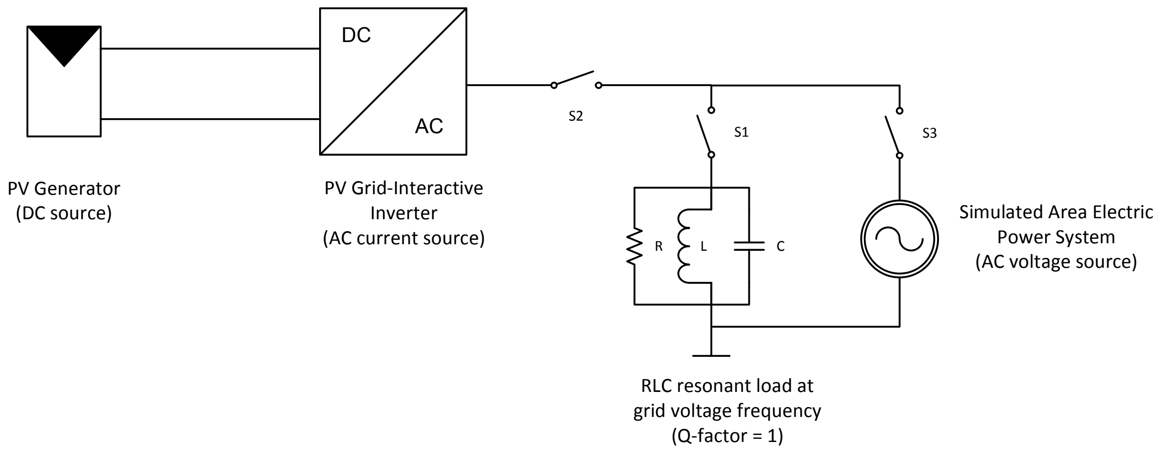
Different standards typically introduce different requirements in terms of island condition detection time and disconnection time as soon as the island condition is detected, as well can define different test set-up and testing procedure: about the test set-up differences, these are represented by the different Q-factor of LC resonant load, while the grid-frequency resonant load usage for testing is common among the standards.

As example of the test set-up, here below is shown the so-called “Unintentional Islanding test set-up” as per IEEE Std. 1547.1-2005 (ref. to paragraph 5.7.1). In the other standards the set-up is similar.



Picture no.3: IEEE Std. 1547.1-2005 test circuit.

The test procedure requires a repetition of the test at different inverter output power levels. For details, please refer to the applicable standard.

POWER-ONE CENTRAL INVERTER ANTI-ISLANDING PROTECTION DESCRIPTION

Independently by the reference standard which defines the anti-islanding protection requirements, the Power-One inverters listed in table no.1 provide the same detection mechanism as described in the following.

Dependently by the reference standard which defines the anti-islanding protection requirements, the Power-One inverter listed in table no.1 provide the protection characteristics (detection time, disconnection time) as required by the standard.

The island condition detection is made observing the grid frequency variation respect the time.

The inverter “induces” the frequency variation by a capacitive reactive power periodically feed into the grid. The period the reactive power is fed into the grid depends by the required detection time (grid standard); the amount of reactive power is typically within the 3-5% of the actual active power the inverter is converting.

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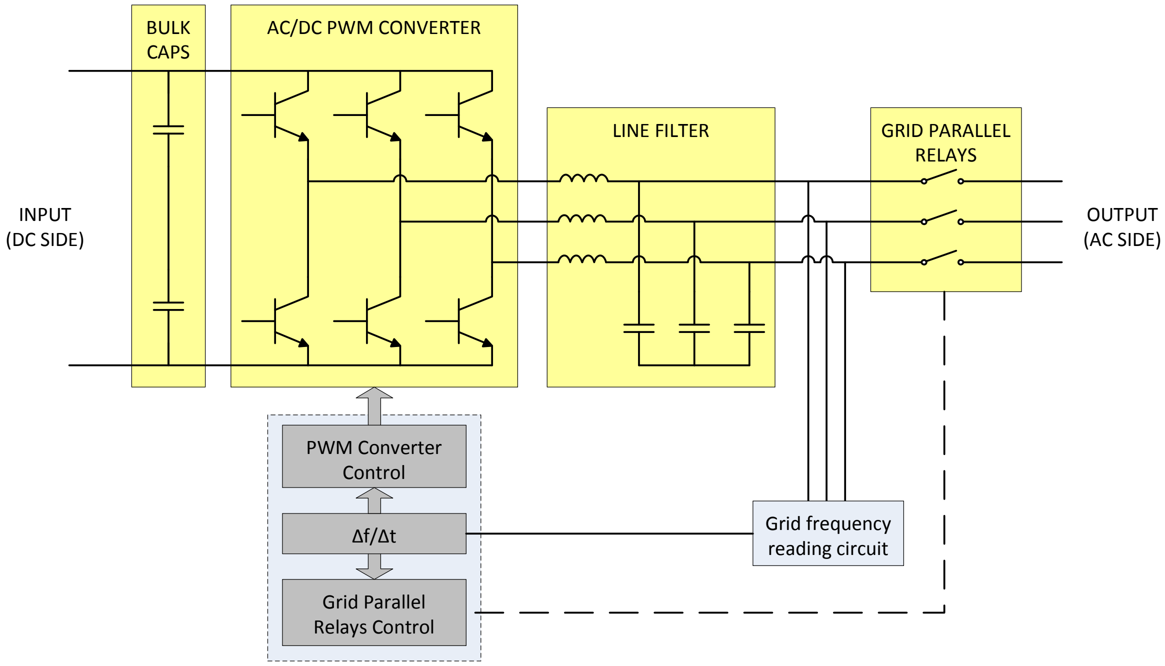

Picture no.4: AC/DC converter and logic circuit block diagram related to anti-islanding protection.

In case the inverter is connected to the grid (no island condition is present) the capacitive reactive power doesn't cause any changes in the grid frequency which is superimposed by the utility grid.

In case the island condition is present, the capacitive reactive power causes the misalignment respect the resonance frequency of the LC load; after the reactive power feeding, the inverter checks the $\Delta f/\Delta t$ (variation of the grid frequency respect the time) and disconnects itself from the island.

The reactive power feeding period, the amount of reactive power feed into the grid and the $\Delta f/\Delta t$ threshold are the three parameters which defines the anti-islanding protection inside the inverter in order to match the requirements from the various grid standards.