Power One Aurora HF-isolated stringinverter:
Isolation control and grounding method description

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SCOPE

Scope of the document is to provide a description of the DC-side (PV generator) isolation control and grounding method implemented in high-frequency isolated (HF-iso) Power-One Aurora string inverters.

APPLICATION AREA

The next table contains the inverters which the document refers to:

Inverter type	Inverter model	Nominal AC power
Single Phase HF-iso inverter	UNO-2.0-I-OUTD UNO-2.0-I-OUTD-S	2.0kW
	UNO-2.5-I-OUTD UNO-2.5-I-OUTD-S	2.5kW
	PVI-3.8-I-OUTD PVI-3.8-I-OUTD-S	3.8kW
	PVI-4.6-I-OUTD PVI-4.6-I-OUTD-S	4.6kW
Three Phase HF-iso inverter	PVI-10.0-I-OUTD-400 PVI-10.0-I-OUTD-400-S	10.0kW
	PVI-12.0-I-OUTD-400 PVI-12.0-I-OUTD-400-S	12.0kW

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

INVERTER BLOCK DIAGRAM AND GROUNDING METHOD

The following picture shows the block diagram of HF-iso dual MPPT single-phase inverter (PVI-3.8/4.6-I-OUTD). For the three-phase inverters (PVI-10.0/12.0-I-OUTD) the block diagram is the same, with exception of DC/AC converter which is a three-legs converter. For the single-phase single-MPPT inverters (UNO-2.0/2.5-I-OUTD) the block diagram is the same, with exception one DC//DC input converter is missing.

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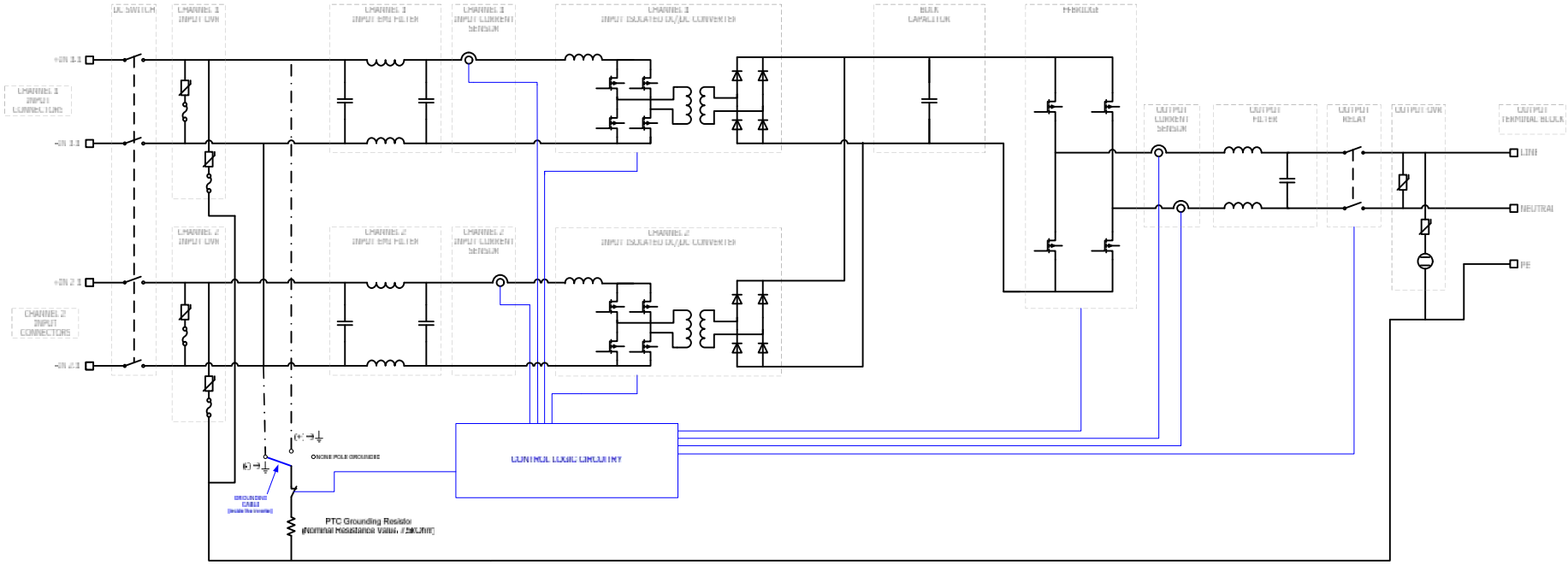

Picture no.1: Power-One Aurora HF-iso single-phase inverter block diagram.

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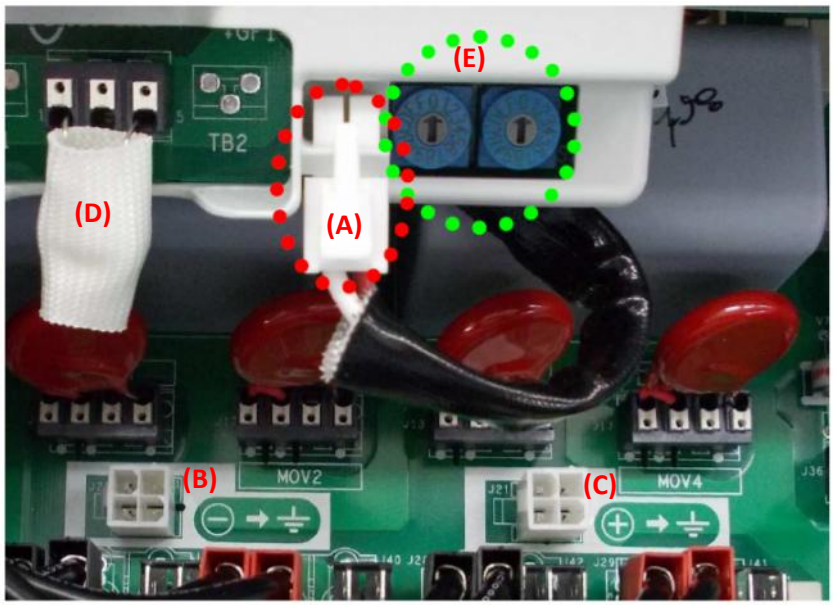
The HF-iso inverters can work with floating arrays or with grounded arrays; the grounding can be on the positive pole or on negative pole. Inside the inverter it's possible to select the positive grounding, the negative grounding or no pole grounded (floating arrays) using a dedicated cable as shown in the below picture.



Picture no.2: grounding connection possibilities inside the inverter.

(A): grounding cable: in the picture is locked in the ungrounding position.
(B): negative grounding connector: the grounding cable (A) shall be connected here in case negative grounding shall be done.
(C): positive grounding connector: the grounding cable (A) shall be connected here in case positive grounding shall be done.
(D): grounding PTC
(E): grid standard rotary switches selection.

Dependently by the grounding configuration, the input channel configuration possibilities may be limited. Particularly:

Grounding	Input channels allowed configuration
Positive (+ → ⊥)	Parallel ONLY
Negative (- → ⊥)	Independent or Parallel
None	Parallel ONLY

Table no.2: grounding possibilities Vs input channels configuration.

Note: the independent configuration of input channels is allowed **ONLY** in case of negative grounding. In case of positive grounding or floating arrays, the only possibility for the input channel configuration is the parallel configuration. The default (factory) configuration of the inverter is the negative grounding.

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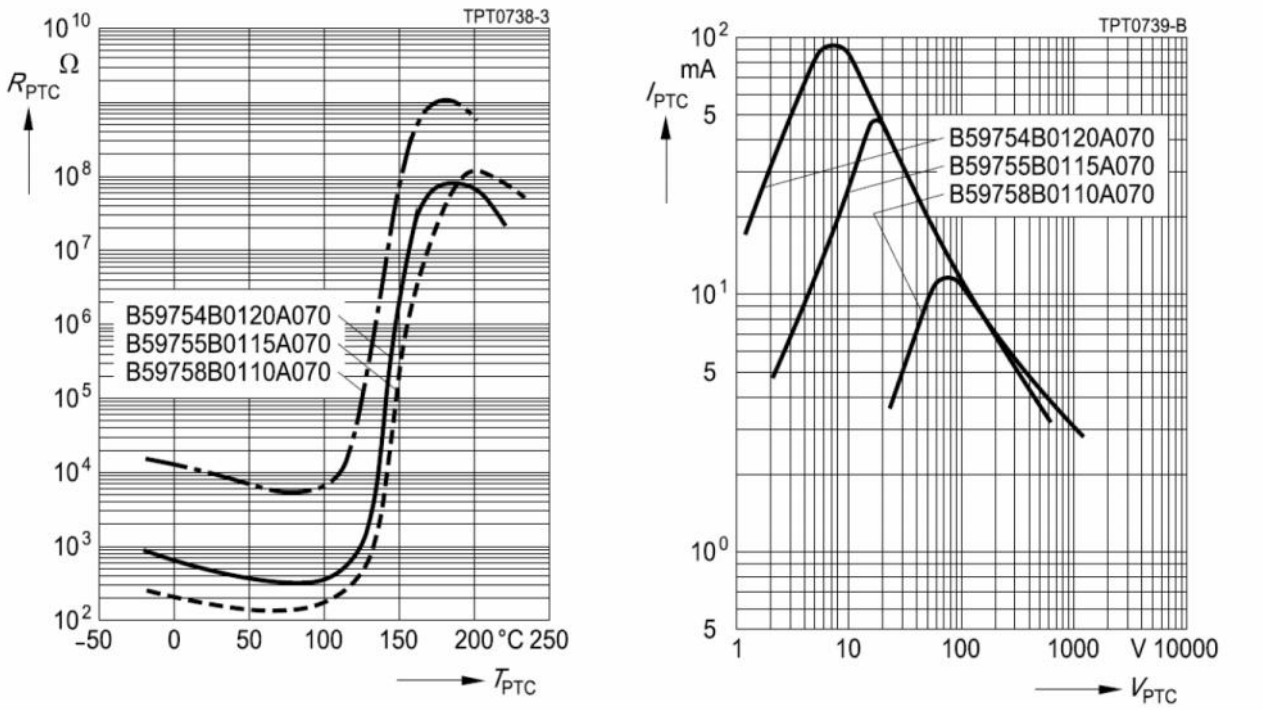
When one of the two grounding possibilities is selected, the connection to ground is made through a **PTC Resistor**. PTC is the acronym of Positive Thermal Coefficient: the component shows a direct proportionality of its own resistance value respect its own temperature. The following pictures (derived directly from the data sheet of the component) report the resistance as function of the temperature and the current as function of the voltage across the component. Please refer to the B59758B0110A070 curve.



Picture no.3: typical curves of PTC component used for grounding in Power-One Aurora HF-iso inverters.

The isolation control mechanism is varies, depending on the grounding status of the arrays, grounded or floating.

FLOATING ARRAYS

In case no grounding is selected, the inverter continuously check DC-side isolation impedance: the measured isolation impedance is compared with an adjustable threshold (default value: 200kOhm) to detect a DC-side ground fault condition. In particular:

- Before each connection to the grid, the inverter performs the isolation impedance measurement. In case the measured value is lower than the set threshold (default: 200kOhm), the inverter doesn't connect to the grid. The threshold is adjustable using the inverter configuration SW. The measured isolation impedance (R-iso) is available at the display after the connection to the grid.
- During the grid parallel operation, the inverter performs the isolation impedance measurement. In case the measured value is lower than the set threshold (default: 200kOhm), the inverter disconnect to the grid. The threshold is adjustable using the inverter configuration SW.

The following picture shows the R-iso measurement block diagram.

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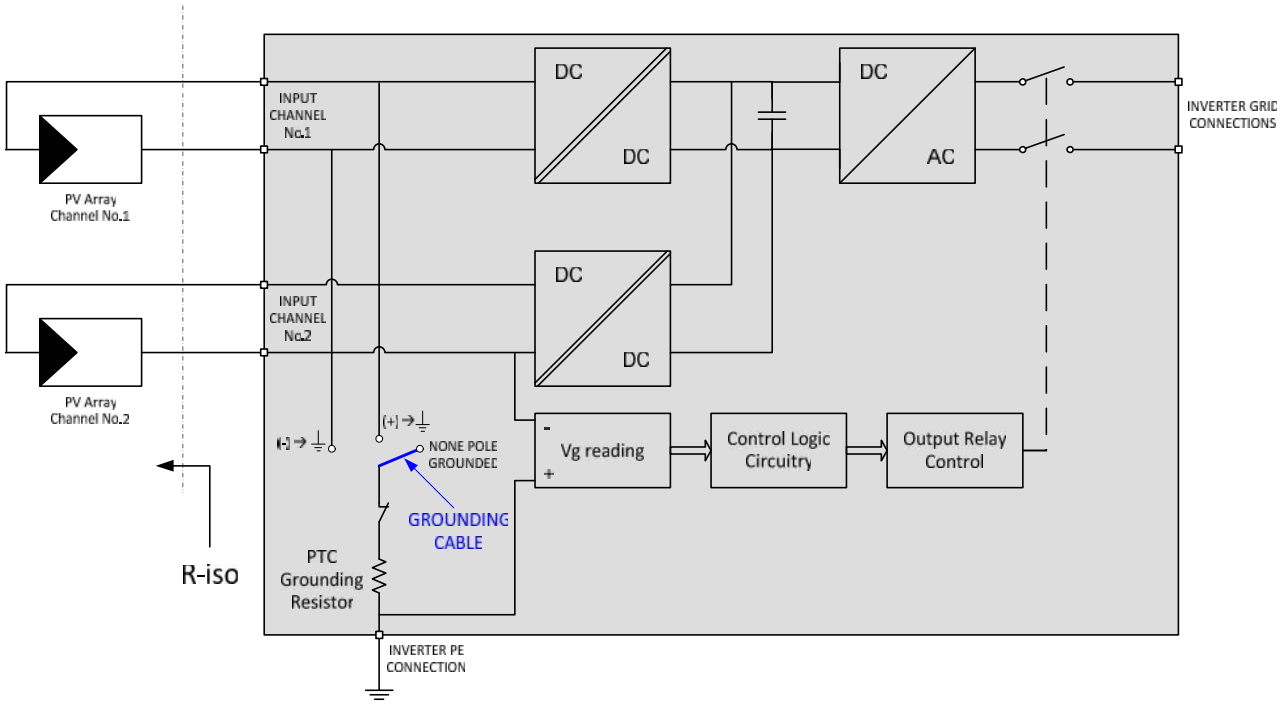
Note: in case of floating arrays the only allowed configuration for the input channels is the parallel one.



Picture no.4: floating arrays R-iso measurement block diagram.

GROUNDED ARRAYS

In case of grounding, the grounded pole is referred to PE inverter terminal using a PTC resistor. Depending by the status of the connection to the grid, the inverter checks the isolation of the DC Side in two different ways; these checks are made in the same way for positive or negative grounding.

Preliminary checks: Isolation Quality Factor (Iso QF) definition

Before each connection to the grid, the inverter performs the isolation impedance measurement by removing the grounding connection opening the contactor in series with PTC grounding resistor. This control allows the inverter to check the status of the PV generator with respect to ground, testing if additional grounding connections or leakages are present in the DC side of the plant.

Removing the grounding connection (opening the contactor), if no additional grounding connections or leakages are present, the grounded pole shall increase (negative grounding) or decrease (positive grounding) its voltage respect to ground. Refer to the following table for the various possible scenarios. The inverters read the voltage of the ground-selected pole respect to the negative input during the contactor open state and compare this value with an internal threshold which is dependent by the input voltage and R-iso threshold for the connection. The R-iso threshold is adjustable and is set by default at 200kOhm.

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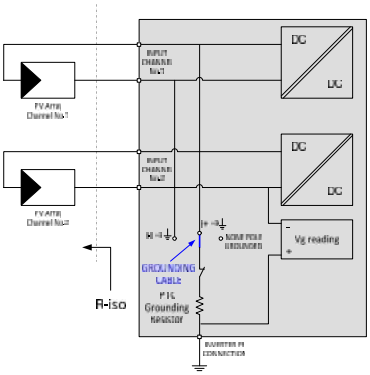
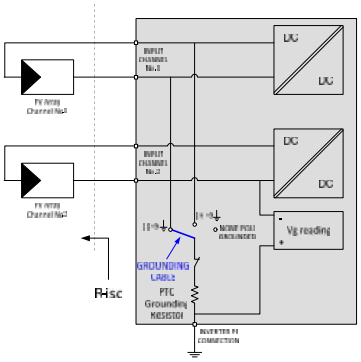
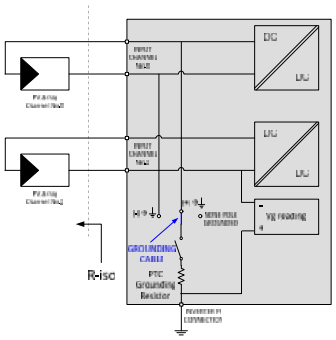
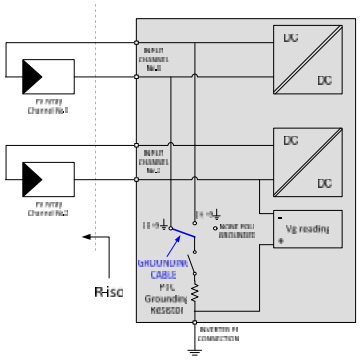
CONTACTOR STATE	POSITIVE GROUNDING	NEGATIVE GROUNDING
CLOSE	 Vg=Vin	 Vg=0
OPEN	 Vg=Vin/2	 Vg=Vin/2

Note: in case of positive grounding the only allowed configuration for the input channels is the parallel one. In case of negative grounding the input channels configuration can be selected.

The comparison between the read voltage and the internal threshold allows define a quality factor for the DC-side isolation: **Iso QF**. This parameter represents a measurement of isolation quality: higher Iso QF values mean higher isolation impedance. The threshold for the grid connection is Iso QF=1: in case Iso QF=1 the isolation impedance is equal to the R-iso selected threshold.

Grid parallel operation protections

The nominal value of the PTC resistance is 7.5kOhm. This value increases (and reach values of some MOhm, in accordance to the diagram in picture no.2) when a current flows through the component and causes the component heating. Due to the fact is a grounding resistor, the current could flow through the resistor is a leakage current. The voltage across the grounding PTC resistor is sensed by the logic circuitry and basing on

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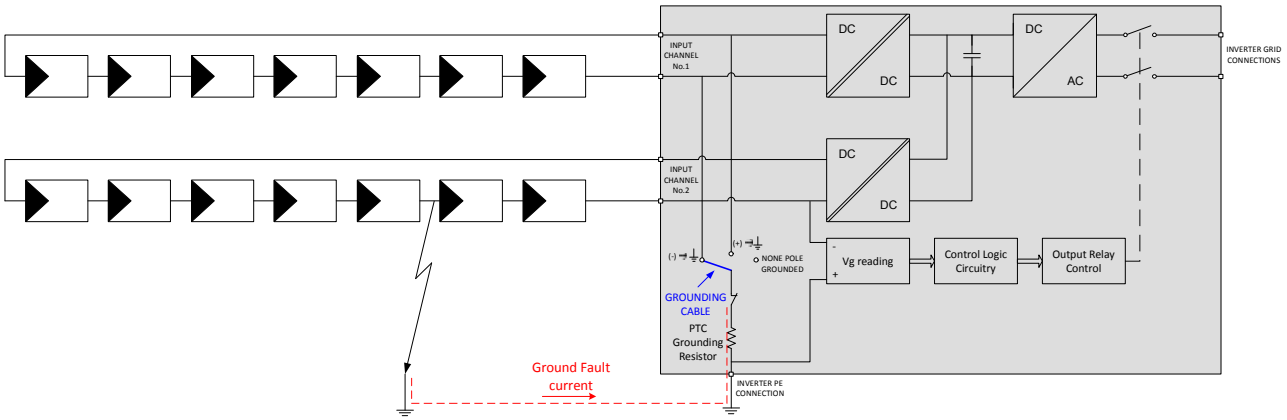
the voltage measurement the logic circuitry drives the grid parallel relays to disconnect the inverter from the grid.



Picture no.5: ground fault scenario with negative grounding selected.

There are two protection levels related to the Vg (voltage across the grounding PTC resistor) value:

- 30V for more than 2 seconds
- 60V for more than 500msec

The threshold overcoming, will cause the inverter disconnect from the grid.

The main advantage of PTC solution for the grounding is the possibility to detect a leakage current in the DC side of the plant and to remove the fault condition thanks to the high resistance value the component can reach. In addition the PTC allows a self-restore of inverter functioning as soon as the leakage current stops to flow.

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