ORIGINAL

ABSTRACT

"INVERTER CIRCUITS FOR PHOTOVOLTAIC ARRAYS"

An inverter circuit receives DC power supplies from first and second photovoltaic arrays connected in series and converts the DC input into an AC power supply suitable for provision to an electricity grid. In the event that a ground fault is detected, the inverter is isolated from the AC grid and a switch provided across at least one of the first and second photovoltaic arrays is closed in order to keep PV panel voltages within acceptable limits.

Figure for publication with the Abstract: Fig. 1

We Claim:

1. A circuit comprising:

a first input connector for connecting to a first photovoltaic array, the first input connector having a lower potential terminal and a higher potential terminal;

a second input connector for connecting to a second photovoltaic array, the second input connector having a lower potential terminal and a higher potential terminal, wherein the higher potential terminal of the second input connector is coupled to the lower potential terminal of the first input connector;

an output connector for connecting to an electricity supply network;

a conversion circuit arranged to convert direct current power supplies obtained via the first and second input connectors to an alternating current power supply, and to output the alternating current power supply via the output connector;

a fault detector arranged to isolate the circuit from the output connector on detection of a fault; and

a switch across the terminals of at least one of the first and second input connectors, wherein the switch is closed in response to the detection of the said fault by the fault detector.

2. A circuit as claimed in claim 1, wherein the higher potential terminal of the first input connector at above ground potential and the lower potential terminal of the second input connector is below ground potential.

3. A circuit as claimed in claim 1 or claim 2, wherein the fault is a ground fault.

4. A circuit as claimed in any one of claims 1 to 3, wherein the fault detector is a residual current monitoring unit.

5. A circuit as claimed in any one of claims 1 to 4, further comprising a booster circuit arranged to selectively boost the voltage level of the direct current power supplies obtained via the first and second input connectors to a level suitable for the inverter.

6. A circuit as claimed in any one of claims 1 to 4, wherein the inverter is a boosterless inverter.

7. A method of providing an alternating current power supply, comprising the steps of:

receiving direct current power supplies from first and second photovoltaic arrays, wherein the first and second photovoltaic arrays are connected in series;

converting the direct current power supplies to an alternating current power supply using an inverter circuit;

outputting the alternating current power supply; and

using a fault detector to detect a fault,

wherein, in the event of the detection of the fault, the method further comprising isolating the inverter circuit from the alternating current power supply output and closing a switch that is provided across at least one of the first and second photovoltaic arrays.

8. A method as claimed in claim 7, wherein the fault is a ground fault.

9. A method as claimed in claim 7 or claim 8, wherein the fault detector is a residual current monitoring unit.

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2204DEL12

DANFOSS POWER ELECTRONICS A/S
No. /DEL/2012

2-SHEETS
SHEET-1

07 JUL 2012

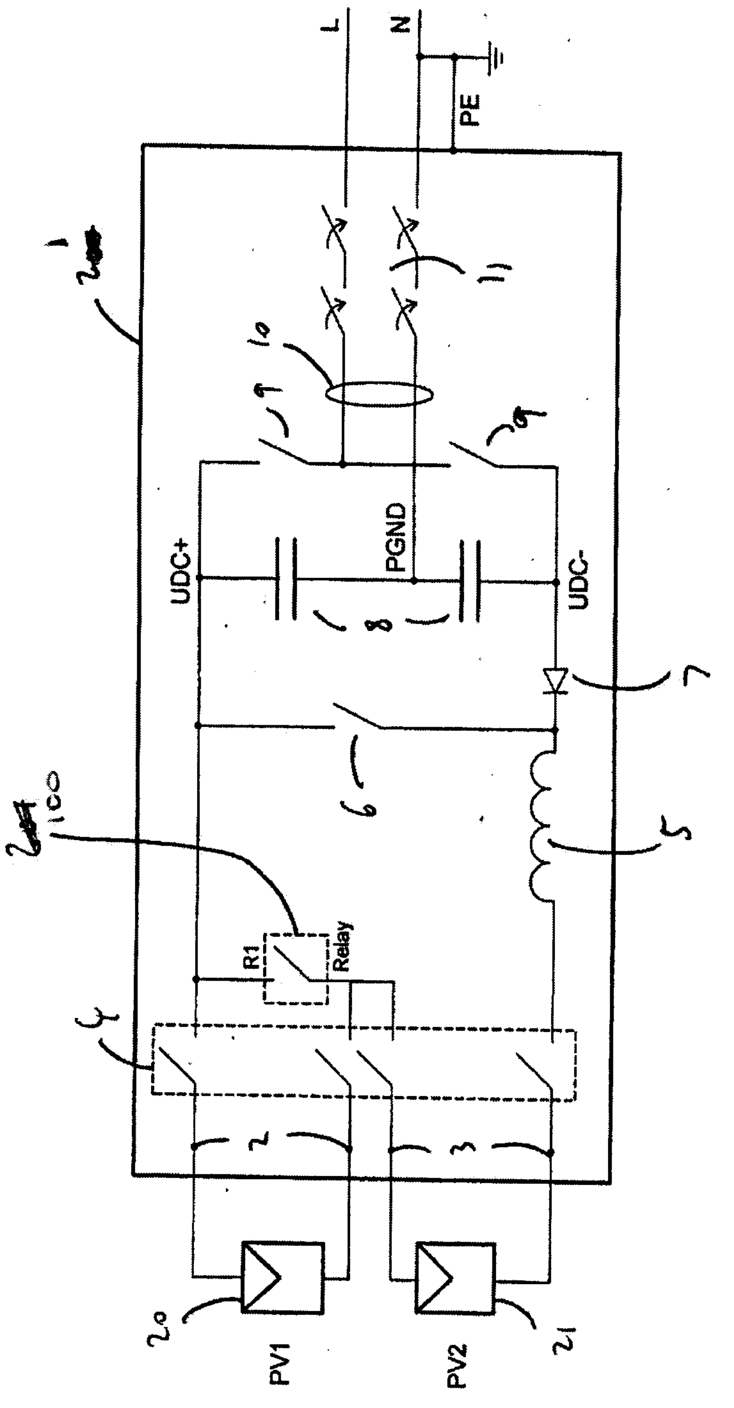

Fig. 1

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2204DEL12

DANFOSS POWER ELECTRONICS A/S
No. /DEL/2012

2-SHEETS
SHEET-2

17 JUL 2012

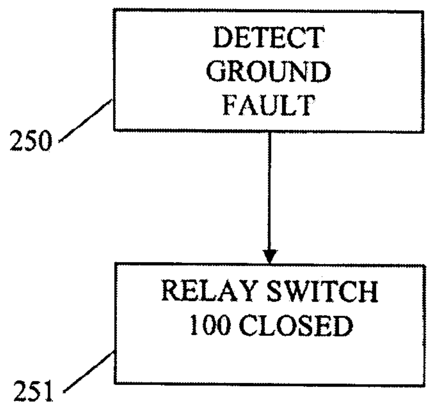

Fig. 2

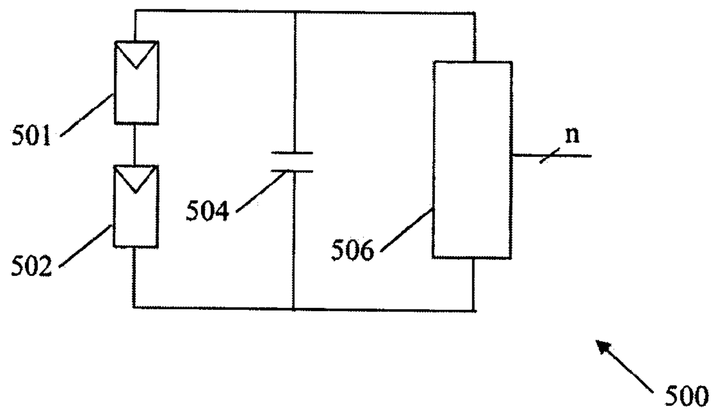

Fig. 3

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FIELD OF THE INVENTION

The present invention concerns an inverter circuit. More particularly, but not exclusively, the invention concerns inverter circuits for converting direct current power supplies from photovoltaic arrays into alternating current power supplies.

BACKGROUND OF THE INVENTION

The use of inverter circuits for converting direct current (DC) power supplies from photovoltaic (PV) arrays into alternating current (AC) power supplies is well established.

In one known configuration, a PV array provides a DC voltage of the order of 1000V for conversion, by an inverter, into an AC voltage suitable for provision to an electricity grid. By way of example, Figure 3 shows a known inverter circuit 500 comprising a first photovoltaic array 501 connected in series with a second photovoltaic array 502. The inverter circuit 500 further comprises a DC link capacitor 504 and an inverter 506.

The first photovoltaic array 501 and the second photovoltaic array 502 together provide a direct current supply that charges the DC link capacitor 504. In one exemplary implementation, the two photovoltaic arrays together provide a voltage of around 1000V to the DC link capacitor 504. The voltage across the DC link capacitor 504 is used as an input to the inverter 506. The inverter provides an AC output that can be provided to an electricity grid. The AC output shown in Figure 3 is an n-phase output. That output may be a 1-phase output, or may be multi-phase (3-phase supplies are well known).

In some countries (notably the USA), there is a restriction on the DC voltage that is allowed to be drawn from photovoltaic arrays, particularly in domestic settings. A known solution to this problem is to connect two PV arrays in series, with one PV array providing a DC voltage between 0V and 500V and the other PV array providing a DC voltage between -500V and 0V. When connected in series, the PV arrays still provide a voltage difference of 1000V. If the series connection is broken, the voltages across each PV array can be kept within limits that are deemed safe.

By way of example, WO 2009/020917 A2 (Advanced Energy Industries, Inc.) published 12 February 2009, discloses a circuit for converting a power supply from first and second photovoltaic arrays. The first and second photovoltaic arrays are coupled together via a photovoltaic tie, which allows the arrays to be uncoupled when not providing power.

The provision of photovoltaic ties and other solutions for disconnecting two PV arrays connected in series can be expensive to implement, not least because they require additional circuitry to be provided at the PV array installation site.

The present invention seeks to mitigate at least some of the above-mentioned problems. Alternatively or additionally, the present invention seeks to provide an improved inverter circuit.

SUMMARY OF THE INVENTION

The present invention provides a circuit comprising: a first input connector for connecting to a first photovoltaic array, the first input connector having a lower potential terminal and a higher potential terminal; a second input connector for connecting to a second photovoltaic array, the second input connector having a lower potential terminal and a higher potential terminal, wherein the higher potential terminal of the second input connector is coupled to the lower potential terminal of the first input connector (such that the first and second photovoltaic arrays are connected in series); an output connector for connecting to an electricity supply network; a conversion circuit arranged to convert direct current power supplies obtained via the first and second input connectors to an alternating current power supply, and to output the alternating current power supply via the output connector; a fault detector arranged to isolate the circuit from the output connector on detection of a fault (such as a ground fault); and a switch across the terminals of at least one of the first and second input connectors, wherein the switch is closed in response to the detection of the said fault by the fault detector. The switch is typically open during normal operation of the inverter circuit. The switch may be an electronic switch. The switch may be a mechanical relay.

The present invention also provides a method of providing an alternating current power supply, comprising the steps of: receiving direct current power supplies from first and second photovoltaic arrays, wherein the first and second photovoltaic arrays are connected in series; converting the direct current power supplies to an alternating current power supply using an inverter circuit; outputting the alternating current power supply; and using a fault detector to detect a fault (such as a ground fault), wherein, in the event of the detection of the fault, the method further comprising isolating the inverter circuit from the alternating current power supply output and closing a switch that is provided across at least one of the first and second photovoltaic arrays.

Thus, in one embodiment of the invention, an inverter circuit receives DC power supplies from first and second photovoltaic arrays connected in series and converts the DC input into an AC power supply suitable for provision to an electricity grid. In the event that a ground fault is detected, the inverter is isolated from the AC grid and a switch provided across at least one of the first and second photovoltaic arrays is closed in order to keep PV panel voltages within acceptable limits.

In the use of the invention, the higher potential terminal of the first input connector may be above ground potential and the lower potential terminal of the second input connector may be below ground potential. Moreover, the lower potential terminal of the first input connector and the upper potential terminal of the second input connector (which are coupled together) may be at around ground potential.

In many forms of the invention, the fault detector is a residual current monitoring unit.

In some forms of the invention, a booster circuit is provided to selectively boost the voltage level of the direct current power supplies obtained via the first and second input connectors to a level suitable for the inverter. In alternative forms of the invention, the inverter is a boosterless inverter.

BRIEF DESCRIPTION OF THE DRAWINGS

Embodiments of the present invention will now be described by way of example only with reference to the accompanying schematic drawings of which:

Figure 1 is a circuit diagram of an inverter circuit in accordance with an embodiment of the invention; and

Figure 2 is a flow chart showing the operation of the inverter circuit of Figure 1 when a fault occurs; and

Figure 3 is a circuit diagram of a known inverter circuit.

DESCRIPTION OF THE INVENTION

Figure 1 shows an inverter circuit 1 in accordance with an embodiment of the present invention. The inverter circuit 1 comprises a first input connector 2 which connects the inverter circuit 1 to a first photovoltaic array 20, and a second input connector 3 which connects the inverter circuit 1 to a second photovoltaic array 21. The connectors 2 and 3 are connected to the rest of the circuit by a single-use switch 4. During installation of the inverter circuit 1, following correct connection of the photovoltaic arrays 20 and 21 the single-use switch 4 is closed, and remains closed as long as the inverter circuit 1 is in use.

Both the first photovoltaic array 20 and the second photovoltaic array 21 provide an open-circuit direct current supply of approximately 500V (although, of course, different voltages could be provided in alternative forms of the invention). In an open circuit configuration, the first photovoltaic array 20 has a lower potential terminal at approximately ground potential and a higher potential terminal at approximately +500V, while the second photovoltaic array 21 has a lower potential terminal at approximately -500V and a higher potential terminal at approximately ground potential. The first photovoltaic array 20 and second photovoltaic array 21 are connected to the inverter circuit 1 in series, with their terminals at ground potential being connected together. This allows the first photovoltaic array 20 and second photovoltaic array 21 to provide a supply to the inverter circuit 1 with a potential of 1000V, which is advantageous for conversion to an alternating current supply, without either array exceeding a potential of 500V away from ground allowing them to meet safety guidelines.

The inverter circuit 1 further comprises a booster circuit comprising an inductor 5 and a relay switch 6 (typically implemented using an electronic switch, such as a transistor). The switch 6 when closed connects the inductor 5 across the photovoltaic arrays 20 and 21. By opening and closing the switch 6, the inductor 5 of the booster circuit is alternately charged and discharged. The booster circuit shown in Figure 1 is provided by way of example only.

Alternative booster circuits could be used. Moreover, the inverter 1 could be implemented without a booster, thereby providing a boosterless inverter as is known in the art.

The inverter circuit 1 further comprises a diode 7, a pair of capacitors 8 and a pair of switches 9 (typically implemented using electronic switches). The pair of capacitors 8 are connected in series across the photovoltaic arrays 20 and 21, with a first output line (which is typically grounded) at their midpoint. Similarly, the pair of switches 9 are connected in series across the photovoltaic arrays 20 and 21, with a second output line at their midpoint. The inverter circuit 1 comprises control circuitry (not shown) that controls the operation of the switch 6 and pair of switches 9. The control circuitry opens and closes the switch 6, and at the same time alternates between one of the pair of switches 9 being open while the other is closed. In this way, an alternating current supply is created between the first and second output lines. Note that although the inverter circuit 1 provides a single-phase output, a multi-phase output (such as a three-phase output) could be provided as is well known in the art.

The inverter circuit 1 further comprises a residual current monitoring unit 10 and isolation switches 11, through which the inverter circuit 1 is connected to the electrical grid (the commercial electricity network). The residual current monitor unit 10 and the isolation switches 11 are, of course, shown in highly schematic form in Figure 1.

The residual current monitoring unit 10 measures the difference between currents provided on one or more live output lines and a neutral output. In normal use, the sum of these current should be zero. The presence of a current difference is indicative of a ground fault in one of the photovoltaic arrays. In response to the detection of a ground fault (e.g. in the presence of a current difference above a threshold current, such as 300mA), the residual current monitoring unit 10 disconnects the inverter output from the electricity grid by opening the isolation switches 11.

The inverter circuit 1 further comprises a relay switch 100 connected between the terminals of the first photovoltaic array 20. In normal operation of the inverter circuit 1, the switch 100 is open and so the inverter circuit 1 operates as described above.

As shown in Figure 2, in a first step 250 a ground fault is detected (for example in one of the photovoltaic arrays 20 and 21). In response to the detection of the ground fault, in a second step 251 the control circuitry of the inverter circuit closes the switch 100, isolating the first photovoltaic array 20 from the inverter circuit 1 by creating a short-circuit across its terminals. At the same time, the residual current monitoring unit 10 opens the isolation switches 11 to disconnect the circuit 1 from the grid. The second photovoltaic array 21 continues to be connected to the inverter circuit 1. In this configuration, the second photovoltaic array 21 (which has not been short-circuited) can continue to provide a supply of direct current power to the inverter circuit 1 (and can therefore provide power for operating the circuit 1).

In alternative embodiments a relay switch is provided connected between the terminals of the second photovoltaic array 21, in addition to, or instead of, the switch 100.

Whilst the present invention has been described and illustrated with reference to particular embodiments, it will be appreciated by those of ordinary skill in the art that the invention lends itself to many different variations not specifically illustrated herein.