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(71) Applicant: **ABB SCHWEIZ AG** [CH/CH]; Brown Boveri Strasse 6, 5400 Baden (CH).

(72) Inventors: **REDDY, B. Dastagiri**; c/o ABB Global Industries and Services, 3rd Floor, Jayanth Tech Park, Old no7, New no 41, Mount Poonamalle High Rd, 600098 Chennai, Tamil Nadu (IN). **NOISETTE, Philippe**; c/o ABB Industrie, Chemin Colladon 2, 1209 Geneve (CH). **WU, Tong**; c/o ABB AB, 721 83 Västerås (SE).

(74) Agent: **KOLSTER OY AB**; (Salmisaarenaukio 1), P.O.Box 204, 00181 Helsinki (FI).

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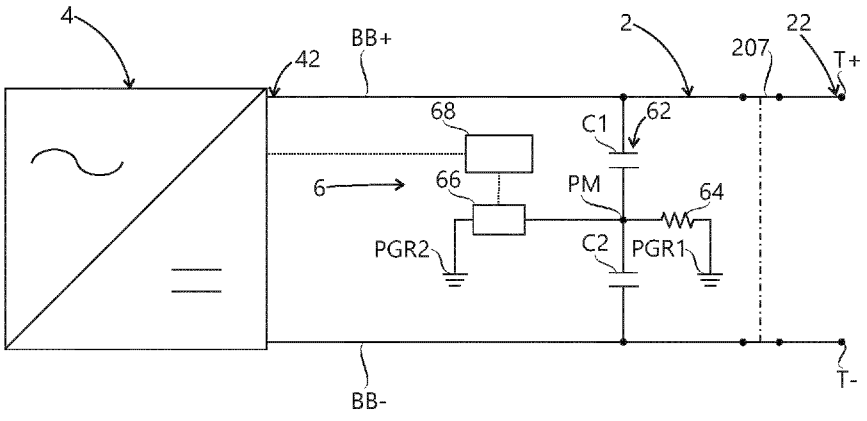
(54) Title: DIRECT CURRENT POWER SUPPLY ASSEMBLY PROVIDED WITH FAULT DETECTION SYSTEM

Fig. 1



(57) Abstract: A direct current power supply assembly comprising a bus bar system (2) and a fault detection system (6) adapted to detect ground faults in the direct current power supply assembly. The bus bar system (2) has a positive bus bar (BB+) and a negative bus bar (BB-). The fault detection system (6) comprises a capacitor arrangement (62) comprising a first capacitor (C1) connected between the positive bus bar (BB+) and a middle point (PM), and a second capacitor (C2) connected between the negative bus bar (BB-) and the middle point (PM), a resistor arrangement (64) providing a high resistance between the middle point (PM) and a ground potential,and a detector arrangement (68) adapted to detect a fault situation if a voltage value of the middle point (PM) is equal to or greater than a first threshold voltage.

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DIRECT CURRENT POWER SUPPLY ASSEMBLY PROVIDED WITH FAULT DETECTION SYSTEM

FIELD OF THE INVENTION

The present invention relates to detection of electrical faults in connection with a direct current power supply assembly.

Direct current power supply assemblies are used for example for charging electric vehicles. In order to avoid personal injuries and material damages, direct current power supply assemblies in many cases require a fault detection system for detecting ground faults.

A known direct current power supply assembly is provided with a fault detection system which is based on an insulation measurement method. This type of fault detection system does detect an insulation fault in the assembly.

One of the problems associated with the above direct current power supply assembly is that a reaction time of the fault detection system thereof is relatively long, about 15 to 30 seconds.

BRIEF DESCRIPTION OF THE INVENTION

An object of the present invention is to provide a direct current power supply assembly so as to solve the above problem. The objects of the invention are achieved by a direct current power supply assembly which is characterized by what is stated in the independent claim. The preferred embodiments of the invention are disclosed in the dependent claims.

The invention is based on the idea of detecting ground faults in a direct current power supply assembly by means of common mode voltage monitoring.

An advantage of the direct current power supply assembly of the invention is that a fault detection system thereof is capable of detecting fast ground faults in the assembly. Further, the direct current power supply assembly of the invention is simple and inexpensive.

BRIEF DESCRIPTION OF THE DRAWINGS

In the following the invention will be described in greater detail by means of preferred embodiments with reference to the attached Figure 1 which shows a direct current power supply assembly according to an embodiment of the invention.

DETAILED DESCRIPTION OF THE INVENTION

Figure 1 shows a direct current power supply assembly comprising a bus bar system 2, a direct current power supply system 4, and a fault detection system 6. The assembly is adapted for charging electric vehicles.

The bus bar system 2 has a positive bus bar BB+, a negative bus bar BB-, an output 22 adapted to be connected to a load of the assembly, and a bus bar switch 207. The output 22 of the bus bar system 2 comprises a plug contact having a positive load terminal T+ connected to the positive bus bar BB+, and a negative load terminal T- connected to the negative bus bar BB-. In an alternative embodiment, the output of the bus bar system comprises another type of a temporary coupling device.

The direct current power supply system 4 is adapted to supply direct current power to an output 42 thereof. The output 42 of the direct current power supply system 4 is connected to the bus bar system 2 for supplying direct current power from the direct current power supply system 4 to the bus bar system 2. The bus bar switch 207 is adapted to selectively connect the output 42 of the direct current power supply system 4 to the output 22 of the bus bar system 2, and to disconnect the output 42 of the direct current power supply system 4 from the output 22 of the bus bar system 2.

A nominal voltage of the output 42 of the direct current power supply system 4 is 400 V. In alternative embodiments, a nominal voltage of the output of the direct current power supply system is equal to or greater than 40 V.

A nominal power of the direct current power supply system 4 is 50 kVA. In alternative embodiments, a nominal power of the direct current power supply system is equal to or greater than 500 VA.

The direct current power supply system 4 comprises a rectifier having a plurality of controllable semiconductor switches. In alternative embodiments the direct current power supply system is another type of system such as a direct-current converter.

The fault detection system 6 is adapted to detect ground faults in the direct current power supply assembly. The fault detection system 6 is also adapted to detect electric arcs in the direct current power supply assembly.

The fault detection system 6 is connected between the positive bus bar BB+ and the negative bus bar BB-, and comprises a capacitor arrangement 62, a resistor arrangement 64, a voltage measuring arrangement 66, and a detector arrangement 68.

The capacitor arrangement 62 comprises a first capacitor C1 connected between the positive bus bar BB+ and a middle point PM, and a second capacitor C2 connected between the negative bus bar BB- and the middle point PM. The first capacitor C1 and the second capacitor C2 are designed the same way as capacitors of a known output filter for the rectifier of the direct current power supply system 4. The first capacitor C1 and the second capacitor C2 are identical with each other.

In an embodiment, capacitances of the first capacitor and the second capacitor are identical and in a range of $0.4 \cdot C_{vl12}$ to $2 \cdot C_{vl12}$, in which C_{vl12} is calculated with an equation

$$C_{vl12} = \frac{I_{dc\_max}}{f_{rpl} \Delta V_{dc\_rpl}} \quad ,$$

where I_{dc_max} is the maximum output current of the direct current power supply system, f_{rpl} is the ripple frequency at the output of the direct current power supply system, and ΔV_{dc_rpl} is the maximum allowable ripple in an output voltage at the output of the direct current power supply system. The resistor arrangement 64 provides a high resistance between the middle point PM and a ground potential. Resistance of the resistor arrangement 64 is 2 MΩ. In an alternative embodiment, resistance provided by the resistor arrangement between the middle point and the ground potential is equal to or greater than 1 MΩ. In a further alternative embodiment, resistance R_{mg} provided by the resistor arrangement between the middle point and the ground potential is selected based on an inequality

$$R_{mg} \geq \frac{U_{dc\_nom}}{0.001\ V/\Omega},$$

where U_{dc_nom} is a nominal value of an output voltage at the output of the direct current power supply system. Using the above inequality, the resistor arrangement 64 in the embodiment of Figure 1 should have a resistance greater than or equal to 400 kΩ, and thereby the value 2 MΩ satisfies the inequality.

The fault detection system 6 is adapted to serve as a DC voltage filter to filter out any ripple in the output 42 of the direct current power supply system 4.

The voltage measuring arrangement 66 is adapted for measuring a voltage of the middle point PM relative to the ground potential. The voltage measuring arrangement 66 comprises a voltage sensor.

In Figure 1, the resistor arrangement 64 is connected between the mid-

dle point PM and a first ground potential point PGR1 which is in the ground potential, and the voltage measuring arrangement 66 is adapted for measuring a voltage of the middle point PM relative to the ground potential by measuring a voltage between the middle point PM and a second ground potential point PGR2 which is in the ground potential. In an alternative embodiment, the resistor arrangement is connected between the middle point and a common ground potential point which is in the ground potential, and the voltage measuring arrangement is adapted for measuring a voltage of the middle point relative to the ground potential by measuring a voltage between the middle point and the common ground potential point.

In an alternative embodiment, the resistor arrangement is integrated in the voltage measuring arrangement.

The detector arrangement 68 is communicatively connected to the voltage measuring arrangement 66 and the direct current power supply system 4. The detector arrangement 68 is adapted to monitor a voltage value of the middle point PM, and to detect a fault situation if predetermined fault conditions relating to the voltage value of the middle point PM are fulfilled, the predetermined fault conditions including an absolute value of the voltage value of the middle point PM being equal to or greater than a first threshold voltage. The predetermined fault conditions further include a requirement that the absolute value of the voltage value of the middle point PM has to remain equal to or greater than the first threshold voltage for a predetermined first minimum duration.

In the assembly of Figure 1, the predetermined first minimum duration is 5 ms. In alternative embodiments, the predetermined first minimum duration is less than or equal to 5 s. In many embodiments, the predetermined first minimum duration is less than or equal to 5 ms, a typical range being from 1 ms to 5 ms. However, it is possible to use values less than 1 ms, or values in a range of 5 ms to 5 s. In still further alternative embodiments, the predetermined fault conditions include a plurality of threshold voltages, and a predetermined minimum duration for each of the plurality of threshold voltages such that the higher the threshold voltage, the shorter the corresponding predetermined minimum duration.

As a response to the detected fault situation, the detector arrangement 68 is adapted to stop supplying direct current power from the direct current power supply system 4 to the bus bar system 2.

The detector arrangement 68 is adapted to generate the voltage value of the middle point PM from an output signal of the voltage measuring arrangement 66 through signal processing, wherein the signal processing is adapted to improve

quality of the fault detection by filtering the output signal of the voltage measuring arrangement 66. In an alternative embodiment, the signal processing step is carried out by the voltage measuring arrangement. In a further alternative embodiment, the voltage measuring arrangement is integrated in the detector arrangement.

In an alternative embodiment, the detector arrangement is adapted to respond to a detected fault situation by reducing supply of direct current power out of the bus bar system through controlling the direct current power supply system. In a further alternative embodiment, the detector arrangement is adapted to respond to a detected fault situation by disconnecting the direct current power supply system from the output of the bus bar system. In the embodiment of Figure 1, such disconnection could be done by opening the bus bar switch 207.

In the embodiment of Figure 1 the first threshold voltage is 20 V. Therefore, the predetermined fault conditions relating to the voltage value of the middle point PM can be fulfilled only if the voltage value of the middle point PM is +20 V or higher, or -20 V or less.

In an alternative embodiment, a ratio between the first threshold voltage and a nominal voltage of the output of the direct current power supply system is in a range of 1 – 10 %. In a further alternative embodiment, a ratio between the first threshold voltage and a nominal voltage of the output of the direct current power supply system is in a range of 4 – 6 %.

It will be obvious to a person skilled in the art that the inventive concept can be implemented in various ways. The invention and its embodiments are not limited to the examples described above but may vary within the scope of the claims.

CLAIMS

1. A direct current power supply assembly comprising:

a bus bar system (2) having a positive bus bar (BB+) and a negative bus bar (BB-), the bus bar system (2) comprising an output (22) adapted to be connected to a load of the assembly;

a direct current power supply system (4) having an output (42) connected to the bus bar system (2);

a fault detection system (6) adapted to detect ground faults in the direct current power supply assembly,

characterized in that the fault detection system (6) comprises:

a capacitor arrangement (62) comprising a first capacitor (C1) connected between the positive bus bar (BB+) and a middle point (PM), and a second capacitor (C2) connected between the negative bus bar (BB-) and the middle point (PM);

a resistor arrangement (64) providing a high resistance between the middle point (PM) and a ground potential;

a voltage measuring arrangement (66) for measuring a voltage of the middle point (PM) relative to the ground potential; and

a detector arrangement (68) adapted to monitor a voltage value of the middle point (PM), and to detect a fault situation if predetermined fault conditions relating to the voltage value of the middle point (PM) are fulfilled, the predetermined fault conditions including the voltage value of the middle point (PM) being equal to or greater than a first threshold voltage.

2. A direct current power supply assembly according to claim 1, **characterized** in that as a response to a detected fault situation, the detector arrangement (68) is adapted to at least reduce supply of direct current power out of the bus bar system (2).

3. A direct current power supply assembly according to claim 2, **characterized** in that as a response to the detected fault situation, the detector arrangement (68) is adapted to stop supplying direct current power from the direct current power supply system (4) to the bus bar system (2).

4. A direct current power supply assembly according to claim 2 or 3, **characterized** in that as a response to the detected fault situation, the detector arrangement (68) is adapted to disconnect the direct current power supply system (4) from the output (22) of the bus bar system (2).

5. A direct current power supply assembly according to any one of preceding claims, **characterized** in that a ratio between the first threshold voltage and a nominal voltage of the output (42) of the direct current power supply system (4) is in a range of 1 – 10 %.

6. A direct current power supply assembly according to any one of preceding claims, **characterized** in that a nominal voltage of the output (42) of the direct current power supply system (4) is equal to or greater than 40 V.

7. A direct current power supply assembly any one of preceding claims, **characterized** in that the first threshold voltage is in a range of 4 – 50 V.

8. A direct current power supply assembly according to any one of preceding claims, **characterized** in that the voltage value of the middle point (PM) is generated from an output signal of the voltage measuring arrangement (66) through signal processing by the detector arrangement (68), wherein the signal processing is adapted to improve quality of the fault detection by filtering the output signal of the voltage measuring arrangement (66).

9. A direct current power supply assembly according to any one of preceding claims, **characterized** in that a value of the high resistance provided by the resistor arrangement (64) between the middle point (PM) and the ground potential fulfils an inequality

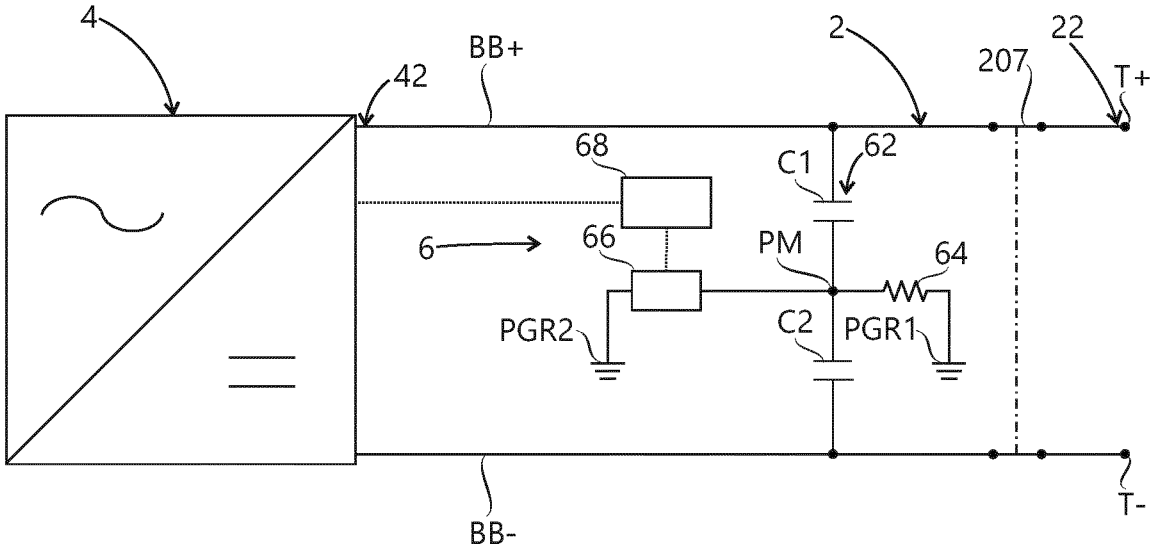
$$R_{mg} \geq \frac{U_{dc\_nom}}{0.001\ V/\Omega},$$

where R_{mg} is the value of the high resistance, and U_{dc_nom} is a nominal value of an output voltage at the output (42) of the direct current power supply system (4).

10. A direct current power supply assembly according to any one of preceding claims, **characterized** in that the assembly is adapted for charging electric vehicles.

11. A direct current power supply assembly according to any one of preceding claims, **characterized** in that the output (22) of the bus bar system (2) comprises a temporary coupling device such as a plug contact.

Fig. 1



INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2019/071826

A. CLASSIFICATION OF SUBJECT MATTER
INV. H02H3/16 B60L3/00 G01R27/18 G01R31/52
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
G01R H02H B60L

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	LEE SANG HYUK ET AL: "Proposal of DC Ground Fault Detection and Interruption Method in the Ungrounded Photovoltaic Array", 2019 IEEE 46TH PHOTOVOLTAIC SPECIALISTS CONFERENCE (PVSC), IEEE, 16 June 2019 (2019-06-16), pages 1357-1362, XP033702922, DOI: 10.1109/PVSC40753.2019.8980529 [retrieved on 2020-02-03] the whole document -----	1-11
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[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

* Special categories of cited documents :

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
19 March 2020	26/03/2020

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Trifonov, Antoniy

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Form PCT/ISA/210 (second sheet) (April 2005)

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

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INTERNATIONAL SEARCH REPORT

Information on patent family members

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