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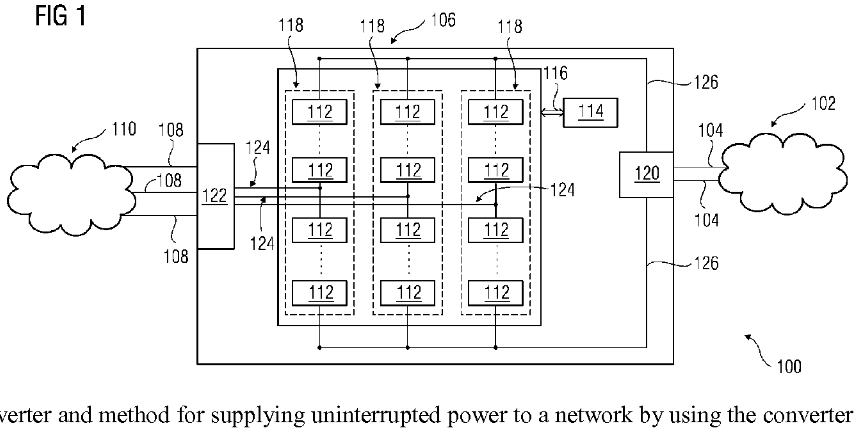
(54) Title: CONVERTER AND METHOD FOR SUPPLYING UNINTERRUPTED POWER TO A NETWORK

FIG 1



(57) Abstract: A converter and method for supplying uninterrupted power to a network by using the converter is disclosed. The converter comprises one or more converter submodules for supplying uninterrupted power to a first network. The one or more converter submodules of the converter comprises at least one power semiconductor circuit for converting power received from a second network and one or more additional energy store for supplying power to the at least one power semiconductor circuit during a fault mode.

WO 2015/113604 A1

Description

Converter and method for supplying uninterrupted power to a network

The present invention relates to a method and system for uninterrupted current transfer in a high voltage direct current transmission system and more particularly, to a method and system for uninterrupted current transfer from a current converter of a high voltage direct current transmission system.

From last few decades there is a continuously increasing demand of electrical power for various residential and industrial applications. An electrical power generation and distribution system has various functional stages and challenges associated with each functional stage. In general, the electrical power generation and distribution system includes a power generation station, a power transmission system and a power distribution network. The power generation station generates electrical power and transmits it to the power distribution network through the power transmission system. The power distribution network includes power sub-stations which receive power from the power generation station through the power transmission system. The power sub-stations further distribute power to end consumers.

It is well known in the state of the art that transmission of electrical power using a direct current (DC) system can be advantageous as compared to an alternative current (AC) system. A commonly known electrical power transmission system is the high voltage direct current (HVDC) electrical transmission system which transmits DC power from a rectifier station, which is, for example, connected to a power generation station to inverter station which is, for example connected to a power distribution network. The two converter stations are connected by a dc link, e.g. by using overhead DC lines. Classical current converters are especially used for bulk power point to point transmission.

The overhead DC lines are directly exposed to the influences of environment which implies a risk of faults like short circuits in the overhead DC lines. In addition to this, there is always a risk of faults in various modules of the power generation station of the HVDC system. When a fault occurs in the overhead DC lines and/or the power generation station, the supply of power from the current converters to the power distribution network interrupts. The interruption in power supply continues till the fault identified and rectified. Due to interruption in power supply, the end consumer suffers from loss of power.

Voltage-source converters (VSC) are suitable for multi-terminal applications. Multi-terminal HVDC systems comprises several converters which are connected by a dc grid. For on-shore applications overhead dc lines can be cost efficiently used. The overhead DC lines are directly exposed to the influences of environment which implies a risk of short lasting faults due to ionization of the air by a lightning. When a short lasting fault occurs in the overhead DC lines, the supply of power from the current converters to the power distribution network interrupts. The interruption in power supply continues till the fault is rectified. Due to interruption in power supply, the end consumer suffers from loss of power.

From the above description it is evident that there is a strong need of a method and system for supplying uninterrupted power to the power distribution network in case of a fault at the overhead DC lines.

It is therefore an object of the present invention to provide a system and a method for supplying uninterrupted current to the power distribution network.

The object is achieved by providing a converter according to claim 1, and a method for supplying uninterrupted power to a first network by means of a converter according to claim 5.

Further embodiments of the present invention are addressed in the dependent claims.

In a first aspect of the present invention, a converter is disclosed. The converter comprises one or more converter submodules for supplying uninterrupted power to a first network. The one or more converter submodules of the converter comprises at least one power semiconductor circuit and one or more additional energy store for storing and supplying power to the AC connection of the converter during a fault mode. The fault mode is at least one mode from a plurality of modes of operation. The converter also comprises a controller for selecting a mode from the plurality of modes of operation for the submodules.

In accordance with the first aspect of the present invention, the converter submodules of the converter further comprises at least one capacitor unit that is connected across the at least one power semiconductor circuit. The at least one capacitor unit facilitates in identifying the voltage across the at least one power semiconductor circuit.

Further, in accordance with the first aspect of the present invention, the controller is in contact with the at least one capacitor unit for sensing voltage across the at least one power semiconductor circuit of the one or more converter submodules.

Furthermore, in accordance with the first aspect of the present invention, the one or more converter submodules also comprises at least one chopper unit for controlling the one or more additional energy store of the one or more converter submodules.

In a second aspect of the present invention, a method for supplying uninterrupted power to a first network by means of a converter is disclosed. A first step of the disclosed method is to select at least one mode from a plurality of modes of operation for one or more converter submodules of the converter by a controller. At next step of the method disclosed, power is supplied from one or more additional energy store to at least one power semiconductor circuit of the one or more converter submodules under a fault mode when the fault mode is the at least one mode is selected by the controller from the plurality of modes of operation. At the last step of the method, the power is converted by the one or more converter submodules and fed to the first network.

In accordance to the second aspect of the present invention, the method further comprises a step of sensing voltage across the at least one power semiconductor circuit by the controller before the step of selecting the at least one mode from the plurality of modes of operation for the one or more converter submodules.

Further, in accordance to the second aspect of the present invention, the method further comprises a step of receiving power by the converter from a second network before the step of sensing voltage across the at least one power semiconductor circuit.

Furthermore, in accordance to the second aspect of the present invention, the method further comprises a step of supplying power to the at least one power semiconductor circuit from a second network under a normal mode wherein the normal mode is the at least one mode selected by the controller from the plurality of modes of operation.

Accordingly, the present invention provides a converter and a method for supplying uninterrupted power to a network by means of a converter.

The present invention is further described hereinafter with reference to illustrated embodiments shown in the accompanying drawings, in which:

FIG 1 illustrates an overview of an electrical power transmission and distribution system in accordance with an embodiment of the present invention,

FIG 2 illustrates a circuit diagram of converter submodule shown in FIG 1.

Various embodiments are described with reference to the drawings, wherein like reference numerals are used to refer to like elements throughout. In the following description, for purpose of explanation, numerous specific details are set forth in order to provide a thorough understanding of one or more embodiments. It may be evident that such embodiments may be practiced without these specific details.

FIG 1 illustrates an overview of an electrical power transmission and distribution system 100 in accordance with an embodiment of the present invention.

The electrical power transmission and distribution system 100 shown in FIG 1 includes a DC network 102 having overhead DC lines 104, a converter station 106 and AC lines 108 as a part of an AC network 110. The converter station 106 includes a controller 114 and several identical converter submodules 112 connected serially in three phase modules 118 as shown in FIG 1. The number of converter submodules in the converter station 106 depends on the voltage of the DC network 102. The greater the DC voltage across a dc input 120 of the converter station 106, the greater is the number of the converter submodules 112, as well. This variable number is intended to be represented by the dashed connecting line between the lower submodules 112. A controller 114 of the converter station 106 is in contact with the converter submodules 112 through a bus 116 as shown in FIG 1. The controller 114 controls mode of operation of the converter submodules 112 by sending control and various other signals on the bus 116.

The converter station 106 also includes a DC connector 120 and an AC connector 122. The DC connector 120 is connected to the overhead DC lines 104. A positive clamp of the DC connector 120 is connected with the positive dc connection clamps of each phase module 118 via connection 126 as shown in FIG 1. The negative clamp of each phase module is connected to the negative clamp of the DC connection 120. Each phase module 118 is further equipped with an AC connection clamp 124. In other words each phase module is three pole. The connection clamps 124 are forming the AC connection 122 of the converter station 106. The AC connector 122 connects the converter station 106 to the AC network 110 via AC lines 108. In other words, the DC connector 120 and the AC connector 122 are interface modules that facilitate connection of the converter station 106 to the DC and AC network 110, respectively.

Under normal mode i.e. no fault condition, the controller 114 controls the operation of the converter station 106 in a way that the converter station 106 transmits power received from the DC network 102 via overhead DC lines 104 through the DC connector 120 to the AC network 110 via AC lines 108 through the AC connector 122.

Under fault mode i.e. in case of a fault occurred in the DC network 102 and/or overhead DC lines 104, the supply of DC power to the converter station 106 interrupts. In other words, the DC network 102 fails to supply power to the converter station 106 when one or more faults occurred within the DC network 102 and/or the overhead DC lines 104. During the fault condition, the controller 114 controls the operation of the converter station 106 in a way that the converter submodules 112 start supplying power to the AC network 110 through the AC connector 122. The detail functionality of a converter submodule 112 of the converter station 106 is described in FIG 2. In an embodiment of the present invention the converter station 106 is a current converter station.

In a preferred embodiment of the present invention the DC network 102 of FIG 1 is a power transmission network of an electrical power generation and distribution system. In another embodiment of the present invention the AC network 110 shown in FIG 1 is a power distribution system of the electrical power generation and distribution system.

For clarity reasons FIG 2 illustrates a circuit diagram of the converter submodule 112 of FIG 1. The other converter submodules 112 shown in FIG 1 are, however, of identical design.

The converter submodule 112 has a capacitor unit 202 and a power semiconductor circuit 204 which, in the illustrated embodiment, is arranged in parallel with the capacitor unit 202. The power semiconductor circuit 204 comprises four power semiconductor switches 206 which can be turned on and off. Together with the capacitor unit a so-called full bridge is formed. A freewheeling diode 208 is connected back-to-back in parallel with each power semiconductor switch 206 and which, in the chosen embodiment, is in the form of an IGBT. The four IGBTs 206 can be switched to an on position, in which current can flow via the IGBTs 206, from an off position, in which current is prevented from flowing via the IGBTs 206, by means of the controller 114 shown in FIG 1. Furthermore, it is also possible to switch from the on position to the off position that is to say to turn off, by means of control signals received from the controller 114. For drive purposes, the power semiconductor switches 206 which can be turned off are connected to the controller 114 via bus 116 as shown in FIG 1. The voltage U_c which is dropped across the capacitor unit 202, a zero voltage or else the inverse voltage of the capacitor unit $-U_c$ can therefore be produced at the output terminals 210 and 212, depending on the signals received from the controller 114. The submodules are two poles. They have a first and a second submodule clamp. The submodules of one phase modules a switched in series to one another. Thus, a modular multi level converter is provided. Because of the cascaded design of a converter, a plurality of voltage steps can be produced at the AC connection 122 of the converter station 106 shown in FIG 1, thus making it possible, for example, to simulate the profile of an AC voltage, in steps.

In order to allow AC power to be fed in the AC network 110 of FIG 1 when required i.e. under fault condition, an additional energy store 214 is provided, and is connected to the capacitor unit 202 via a chopper unit 216 as shown in FIG 2. By way of example, the additional energy store 214 is a battery, a supercapacitor or an electrolytic capacitor. In the shown embodiment the voltage across the additional energy store is smaller than the voltage across the capacitor.

The chopper unit 216 has an inductive unit 218 and an electronic switch 220 in series with the inductive unit 218. This makes it possible to prevent high current peaks when the electronic switch 220 is switched on. The electronic switch 220 in the embodiment shown in FIG 2 is formed by a power semiconductor switch 222 which can be turned on and off, in this case, an IGBT, as well as a freewheeling diode 224 connected back-to-back in parallel with the power semiconductor 222. The IGBT 222 is once again connected via bus 116 to the controller 114 of FIG 1 which is capable of detecting the voltage which drops across the additional energy store 214 and across the capacitor unit 202. If the IGBT 222 is switched on, current flows from the capacitor 202 to the additional energy storage 214. If the IGBT 222 is switched off the current driven by the inductive element 218, e.g. a coil, commutates to the diode 228 until the inductive element 218 is deenergised. Another electronic switch 226 in antiparallel orientation with the diode 228 can be used if the voltage of the additional energy storage is higher than the voltage across the capacitor 202. If the IGBT 230 is switched off, the current driven by the inductive component 218 commutates to diode 224. The electronic switch 226 is also controlled by the controller 114, shown in FIG 1. The controller is provided with one or more voltage sensors which measures and determines the voltage across the capacitor 202, the additional energy storage 214 and/or across the dc connection 120.

Under normal mode i.e. no fault condition, in other words when there is no fault occurred on the dc side of the converter station 106 , the voltage drop across the dc connection or across the capacitor unit 202 are detected within predefined voltage ranges by the controller 114. The predefined voltage ranges are values of voltages across the dc connection 120 and/or across the capacitor unit 202 which indicates the DC power received from the overhead DC lines 104 are within permissible limit of operation for the converter station 106 of FIG 1. When the controller 114 detects the voltage across the additional energy store 214 and/or across the capacitor unit 202 and/or across the dc connection is/are within the predefined voltage ranges, the converter station 106 continues receiving DC power from the DC network 102 and transmitting the converted AC power to the AC network 110 as shown in FIG 1.

When one or more faults occurred at the dc side, the DC power received by the converter station 106 interrupts. The controller 114 detects the change in voltage across the monitored component and switches the mode of operation of the converter submodule 112 from normal mode to fault mode. Under fault mode, the additional energy storages of the submodules provide for the active power which is used on the AC side of the converter. Due to the limited charging capacities the additional energy storages the time period of the fault mode operation is limited to some seconds or minutes.

In other words, when one or more faults occurred at the overhead DC lines 104 and/or the DC network 102, the converter station 106 does not receive any power from the overhead DC lines 104. During this condition, the power semiconductor circuit 204 of each converter submodule 112 start drawing power from the additional energy store 214 installed within the each converter submodule 112 as shown in FIG 2. The power semiconductor circuit 204 start drawing power from the additional energy store 214 after receiving control signals from the controller 114 via bus 116 as shown in FIG 1. As an effect of receiving power from the additional energy store 214, the supply of AC power from the converter station 106 to the AC network 110 continues even during the fault occurred at the overhead DC lines 104 and/or the DC network 102.

However the scope of the invention is not limited to the converter station 106 described in preceding figures. The invention is also applicable for one or more converter stations used for converting a received AC power from an AC network and supplying the converted DC power to a DC network.

It is evident from the foregoing description of the present invention that the invention provides a system and a method for supplying uninterrupted current to the power distribution network.

The converter station disclosed in the invention is capable of supplying power uninterruptedly to an AC network even in case of fault occurred at a DC supply network. In addition to this, capability of the disclosed converter station to supply uninterrupted power to the AC network is independent of the technical nature of the fault occurred at the DC network.

While the present invention has been described in detail with reference to certain embodiments, it should be appreciated that the present invention is not limited to those embodiments. In view of the present disclosure, many modifications and variations would present themselves, to those of skill in the art without departing from the scope of various embodiments of the present invention, as described herein. The scope of the present invention is, therefore, indicated by the following claims rather than by the foregoing description. All changes, modifications, and variations coming within the meaning and range of equivalency of the claims are to be considered within their scope.

LIST OF REFERENCES

100 TRANSMISSION AND DISTRIBUTION SYSTEM
102 DC NETWORK
104 OVERHEAD DC Lines
106 CONVERTER STATION
108 AC LINES
110 AC NETWROK
112 CONVERTER SUBMODULE
114 CONTROLLER
116 BUS
118 THREE PHASE MODULES
120 DC CONNECTOR
122 AC CONNECTOR
124 AC CONNECTION CLAMP
126 CONNECTION

202 CAPACITOR UNIT
204 POWER SEMICONDUCTOR CIRCUIT
206 POWER SEMICONDUCTOR SWITCHES
208 FREEWHEELING DIODE
210 OUTPUT TERMINAL
212 OUTPUT TERMINAL
214 ADDITIONAL ENERGY STORE
216 CHOPPER UNIT
218 INDUCTIVE UNIT
220 ELECTRONIC SWITCH
222 POWER SEMICONDUCTOR SWITCH
224 FREEWHEELING DIODE
226 ELECTRONIC SWITCH
228 DIODE
230 IGBT

Claims

1. A converter (106) comprising:
   - -a DC connector (120) in connection with a first network (102);
   - -an AC connector (122) in connection with a second network (110);
   - -a plurality of converter submodules (112) for supplying uninterrupted power to the second network (110) wherein each converter submodules (112) of the a plurality of converter submodules (112) comprising:
     - -at least one power semiconductor circuit (204);
     - -an additional energy store (214) for supplying power to the AC connector (122) during a fault mode wherein the fault mode is at least one mode from a plurality of modes of operation; and
   - -a controller (114) for selecting a mode from the plurality of modes of operation for the plurality of converter submodules (112).

2. The converter according to claim 1, wherein the plurality of converter submodules (112) further comprises at least one capacitor unit (202) connected across the at least one power semiconductor circuit (204).

3. The converter according to claim 2, wherein the controller (114) is in contact with the at least one capacitor unit (202) for sensing voltage across the at least one power semiconductor circuit (204).

4. The converter according to claim 1, wherein the plurality of converter submodules (112) further comprises at least one chopper unit (216) for controlling the one or more additional energy store (214) of the plurality of converter submodules (112).

5. The converter according to claim 1, wherein each converter submodule (112) of the plurality of converter submodules (112) is a two pole converter submodules.

6. The converter according to claim 1 further comprising a plurality of phase modules (118).

7. The converter according to claim 6, wherein each phase module (118) of the plurality of phase modules (118) is a three pole phase module.

8. A method for supplying uninterrupted power to a first network (110) by means of a converter (106), the method comprising:
- selecting at least one mode from a plurality of modes of operation for a plurality of converter submodules (112) of the converter (106) by a controller (114);
- supplying power from one or more additional energy store (214) to an AC connector (122) of the converter (106) under a fault mode wherein the fault mode is the at least one mode from the plurality of modes of operation; and
- converting the power for the first network (110) by the plurality of converter submodules (112).

9. The method according to claim 8 further comprises a step of determining power delivered from the AC connector (122) of the plurality of converter submodules (112) by the controller (114) before the step of selecting the at least one mode from the plurality of modes of operation for the plurality of converter submodules (112).

10. The method according to claim 9 further comprises a step of receiving power by a DC connector (120) of the converter (106) from a second network (102) before the step of determining power delivered from the AC connector (122) of the plurality of converter submodules (112).

11. The method according to claim 8 further comprises a step of supplying power to the at least one power semiconductor circuit (204) from a second network (102) under a normal mode wherein the normal mode is the at least one mode from the plurality of modes of operation.

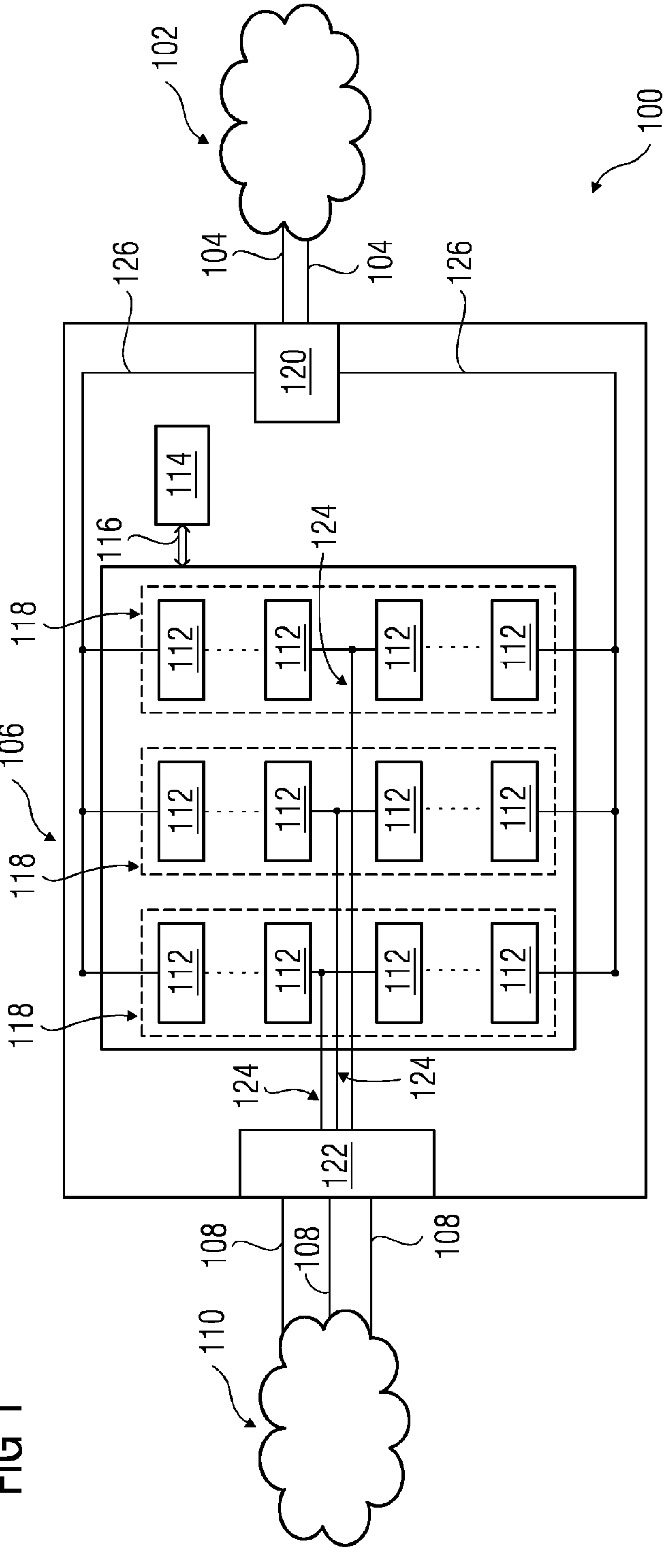

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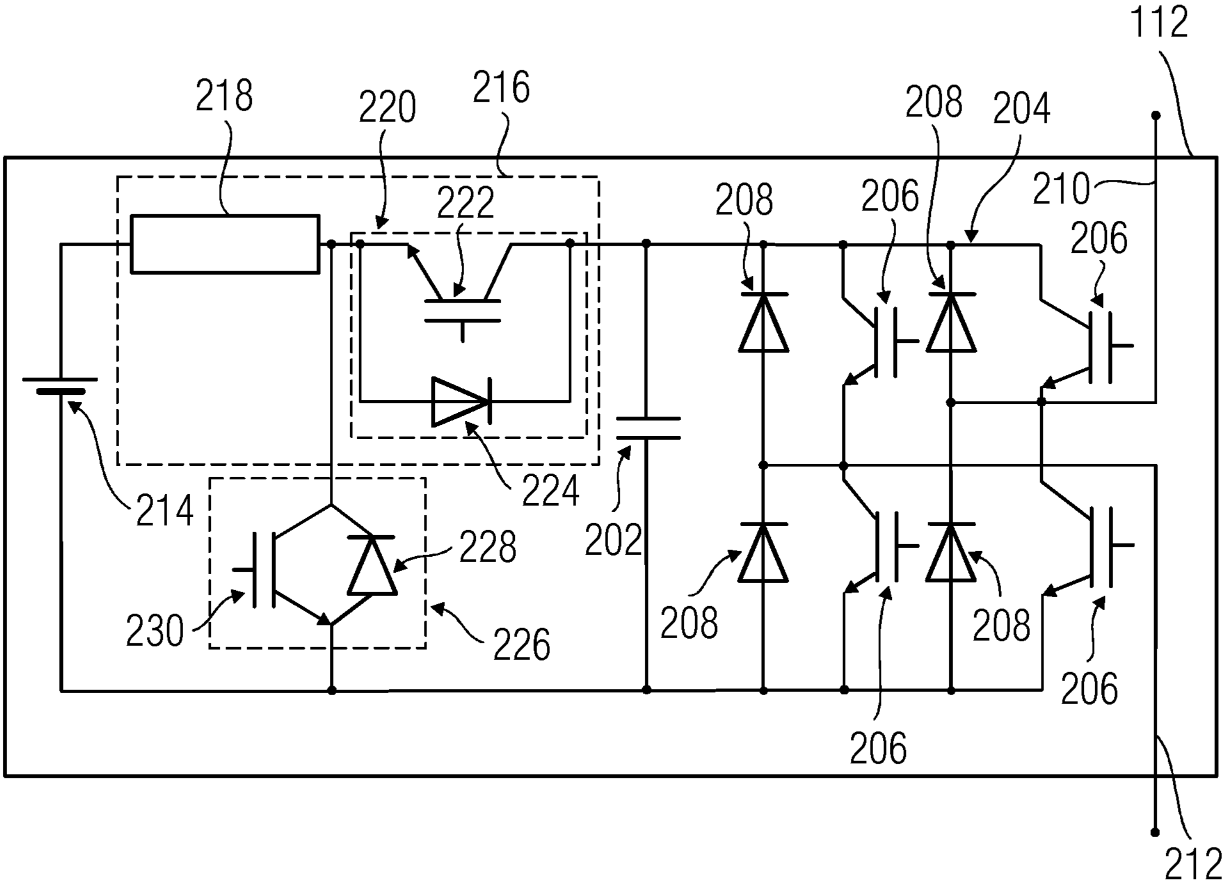
FIG 1

FIG 2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INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2014/051807

A. CLASSIFICATION OF SUBJECT MATTER
INV. H02J3/36 H02M7/483
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)
H02J H02M

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	WO 2012/013248 A1 (AREVA T & D UK LTD [GB]; TRAINER DAVID REGINALD [GB]; CROOKES WILLIAM) 2 February 2012 (2012-02-02) page 24, line 19 figure 7 claim 7 -----	1-11
X	WO 2010/124706 A1 (SIEMENS AG [DE]; PEREIRA MARCOS [DE]) 4 November 2010 (2010-11-04) the whole document -----	1-11
A	WO 2012/136252 A1 (ABB RESEARCH LTD [CH]; DEMETRIADES GEORGIOS [SE]) 11 October 2012 (2012-10-11) 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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"P" document published prior to the international filing date but later than the priority date claimed

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"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
17 September 2014	25/09/2014

Name and mailing address of the ISA/	Authorized officer
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INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2014/051807

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	WO 2010/102667 A1 (ABB TECHNOLOGY AG [CH]; HOSINI FALAH [SE]; SVENSSON JAN R [SE]; HASLER) 16 September 2010 (2010-09-16) the whole document -----	1-11

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

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