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(54) **Title**: AC FAULT HANDLING ARRANGEMENT

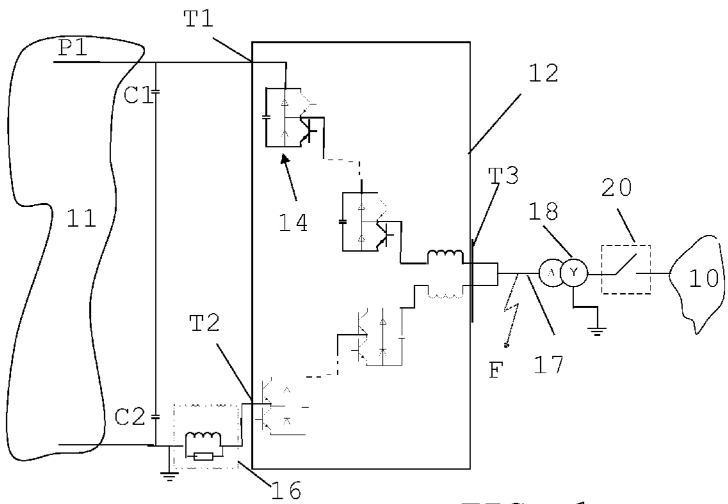

FIG. 1

(57) **Abstract**: The present invention relates to an AC fault handling arrangement for handling an AC fault (F) on the AC side of a converter converting between AC and DC, the arrangement comprising a voltage source converter (12) for performing the conversion between AC and DC, the converter having a DC side with a first and a second terminal (T1, T2) for coupling to pole (P1) and ground of a DC system (11) and an AC side with a group of terminals (T3) for being coupled to an AC system (10), a circuit breaker (20) serially connected between the AC side of the converter and the AC system (10) and a parallel circuit (16) with one end connected to the second terminal (T2) and the other coupled to ground potential, where the parallel circuit consists of a resistor in parallel with an inductor.

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AC FAULT HANDLING ARRANGEMENT

FIELD OF THE INVENTION

The present invention generally relates to power transmission systems. More particularly the present invention relates to an AC fault handling arrangement for handling an AC fault on the AC side of a converter converting between AC and DC.

BACKGROUND

Voltage source converters are known to be connected between an Alternating Current (AC) system, often denoted AC grid, and a Direct Current (DC) system, like a High Voltage Direct Current (HVDC) system. The converter may in this case be a modular multilevel converter that employs cells, each providing a voltage that may be used for contributing to the forming of an AC waveform as well as for providing a required DC voltage.

This converter is in many instances connected to a local AC bus, for instance a bus within a converter station, which in turn is connected to the AC system via a transformer. There is thus a transformer having a primary side coupled to the AC system and a secondary side coupled to the converter.

There is also an AC breaker serially connected between the primary windings of the transformer and the AC system in order to protect the AC system from faults on the AC bus or in the DC system. As an alternative it is possible that the circuit breaker is serially connected between the secondary side of the transformer and the converter.

In relation to the converter, there may occur a number of faults that need to be taken care of.

There may for instance occur faults on the DC side such a single pole-to-ground faults and pole-to-pole faults.

One way of handling faults in a load connected to a voltage source converter converting from AC to DC is shown in KR 10-20004-0035526. In this document a parallel circuit is connected between the converter and load, which parallel circuit comprises a first branch with an inductor and a second branch with a diode and a resistor.

There may also occur faults on the AC side such as over-voltages and phase-to-ground faults.

Multi-level converter built up with small cells has become the state of art for HVDC converter. Asymmetrical monopole or bipole configurations are common choices for DC transmission systems. One critical design issue is that isolating the converter station from the AC grid by opening the AC breaker may sometimes fail due to that the AC current may contain too high a DC component and therefore there is no zero-crossing in the current.

One of the faults that this isolation is necessary for is the AC bus fault. This is because any bus-to-ground fault located between the converter and the transformer can cause very high voltages and high currents. Once the AC breaker is open, the AC source voltage is isolated from the converter, thereby the eventual source for the high voltage and high current is disconnected. Unfortunately, the AC circuit breaker takes about 20~30 ms to open if there is a condition for opening, e-g- a current zero-crossing. If there is no condition for opening, it may take a much longer time than 30 ms.

Examples of ways in which the problem has been addressed is through an additional shunt-connected 3-phase high voltage AC breaker, either at the primary side or the secondary side of the transformer. There may also be an impedance connected in series with the additional circuit breaker between the AC line and ground.

The problem of having this additional circuit breaker on the secondary side of the transformer is that when it is closed, the additional circuit breaker will create a series 3-phase AC fault seen from the viewpoint of the AC system. The reason for this is that the impedance may have to be designed to be very low in order to guarantee the zero-crossing in the AC breaker current.

The problem of having the additional circuit breaker on the primary side of the transformer is that when the additional By-pass HV AC breaker is closed, it will create a serious 3-phase fault current in the transformer because the impedance may have to be designed to be very low in order to guarantee the zero-crossing in the AC breaker current. This may reduce the life time of transformer.

There is therefore a need for an improvement in handling the above mentioned type of AC fault.

SUMMARY OF THE INVENTION

The present invention addresses this situation. The invention is thus directed towards improving fault handling.

This is according to one aspect of the invention achieved through an AC fault handling arrangement for handling an AC fault on the AC side of a converter converting between AC and DC, where the arrangement comprises:

a voltage source converter for performing the conversion between AC and DC, the converter having a DC side with a first and a second terminal for coupling to pole and ground of a DC system and an AC side with a group of terminals for being coupled to an AC system,

a circuit breaker serially connected between the AC side of the converter and the AC system, and

a parallel circuit with one end connected to the second terminal and the other coupled to ground potential, the parallel circuit consisting of a resistor in parallel with an inductor.

The expression “coupled” used is intended to cover the possibility of an indirect electrical connection between two elements. There may thus be one or more elements placed between two elements defined as being coupled to each other. The expression “connected” is on the other hand intended to mean a direct electrical connection of two entities to each other without any entity between them.

The invention has a number of advantages. It provides a zero-crossing in the current running through an AC breaker in case of an internal AC fault in the arrangement. This is done with no or limited additional losses during normal operation. This creation is also done independently of in which phase the fault occurs. Furthermore, since only passive elements are involved in the creation of a zero-crossing, there is no need for any control logic to activate such a creation, which simplifies fault handling in the converter.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention will in the following be described with reference being made to the accompanying drawings, where

fig. 1 schematically shows a variation of AC fault handling arrangement between an AC system and an asymmetric monopole DC system,
fig. 2 schematically shows currents through the converter when there is an AC bus voltage fault, and
fig. 3 shows a circuit diagram of a parallel circuit used in the AC fault handling arrangement.

DETAILED DESCRIPTION OF THE INVENTION

In the following, embodiments of the invention will be described.

The present invention is directed towards providing an arrangement for handling Alternating Current (AC) faults on an AC side of a converter concerting between AC and Direct Current (DC) and being provided between a DC system and an AC system, which systems may both be power transmission systems. The arrangement may for this reason be provided in a converter station. The DC system can for instance be a High Voltage Direct Current (HVDC) power transmission system and the AC system may be a Flexible Alternating Current Transmission System (FACTS). However these types of systems are mere examples of such systems and the invention is in no way limited to these systems. The invention can also be applied in for instance power distribution systems.

Fig. 1 schematically shows a single line diagram of an arrangement for handling AC faults according to a first embodiment of the invention, which arrangement is provided for being connected between an AC system 10 and a DC system 11. The AC system 10 may be a three-phase AC system. The DC system 11 in turn includes a pole P1 coupled to the AC system 10 via the arrangement. In this embodiment the DC system 11 is an asymmetric monopole system. Therefore there is also a ground potential which may or may not be provided as a neutral conductor in the DC system 11.

In order to enable the DC system 11 to be connected to the AC system 10, the arrangement includes a converter 12 for conversion between AC and DC. The converter 12 may function as a rectifier and/or inverter. The converter 12 may be a voltage source converter and in this embodiment it is a cell-based multilevel voltage source converter or a modular multilevel converter. Such a converter is typically made up of a number of cells 14 provided in phase arms of phase legs, where there is one phase leg per AC phase provided in parallel between the DC pole P1 and ground, where the connection point between such a phase leg and the pole P1 of the DC system provides a first DC terminal T1 and the connection point between the phase leg and ground provides a second DC terminal T2 or neutral connection terminal. Each phase leg comprises two phase arms. There is, in a phase leg, an upper phase arm leading from the first pole P1 to an AC terminal or third terminal T3 of the converter 12 and a lower phase arm leading from ground to the AC terminal T3. The cells 14 in the phase leg may be placed symmetrically around the AC terminal T3. The cells 14 may with advantage be connected in cascade in the cell arms. There are typically three phase legs in the converter 12. However, since fig. 1 is a single line diagram there is only one phase leg shown. It is furthermore only shown in a general fashion. For the same reason fig. 1 only shows one AC terminal T3. However, the AC terminal T3 is provided in a group of terminals typically comprising three AC terminals, one for each phase leg.

The arrangement also comprises a pair of optional capacitors C1 and C2 connected between the first and second DC terminals T1 and T2.

Furthermore, it can be seen that there is parallel circuit 16 coupled between the second DC terminal T2 and ground, which parallel circuit 16 comprises and in this case consists of two parallel branches, where a first branch comprises and in this case consists of an inductor and a second branch comprises and in this case consists of a resistor. The parallel circuit thus consists of a resistor in parallel with an inductor. The parallel circuit is thus at one end connected to the second terminal T2 and at the other coupled to a ground potential. The parallel circuit may also be termed an auxiliary parallel circuit or auxiliary neutral equipment.

Each cell 14 may be a half-bridge cell, made up of two series connected switching elements having a capacitor connected in parallel with both these elements. The switching elements are typically provided in the form of a semiconductor device of turn off-type, like an Insulated Gate Bipolar Transistor (IGBT), with anti-parallel diode. In this example the midpoint between two switching elements of a cell is connected to one end of the capacitor of a following cell. In this way the cells are connected in cascade in the two phase arms between the pole P1 and ground. In this type of converter each cell provides a zero or a small voltage contribution that are combined for forming an AC voltage.

In this first embodiment there is provided first and second phase reactors between the cells of the upper phase arm and the lower phase arm, where a first end of the first reactor is connected to the upper arm and a first end of the second reactor is connected to the lower arm and the second ends of these two reactors are interconnected and also connected to an AC bus 17.

The converter 12 thus has a DC side for connection to the DC system 11 and more particularly to at least one pole P1 of the DC system and an AC side for being coupled to the AC system 10.

The arrangement may also include a transformer 18 having a primary side with a first set of primary windings for being coupled to the AC system 10 and a secondary side with a second set of secondary windings coupled to the AC side of the converter 12. In this first embodiment the secondary windings are more particularly connected to the phase reactors via the AC bus 17.

In the present example the bus 17 and AC system 10 are provided for transmission of three phase AC power. For this reason the primary side of the transformer 18 includes three primary windings (not shown), which in this first embodiment are connected in a wye configuration. It should however be realized that it is also possible with a delta configuration. The primary side here furthermore has a neutral point, which is coupled to ground. The neutral point may be directly connected to ground, as shown in fig. 1. The primary side is furthermore connected to the AC system 10 via a circuit breaker 20. As the AC system 10 is a three-phase system the circuit breaker 20 typically comprises three circuit breaking elements, one for each phase. The circuit breaker 20 is more particularly serially connected between the primary side of the transformer 18 and the AC system 10. As an alternative it is possible that the circuit breaker 20 is serially connected between the secondary side of the transformer 18 and the AC side of the converter.

The secondary side of the transformer 18 also comprises three secondary windings (not shown) connected in a delta configuration. It should however be realized that it is also possible with a wye configuration. The second set of secondary windings may thus be connected either in delta or in wye configuration.

The arrangement may also comprise a fault handling unit, which blocks the switching elements of the cells if a fault is detected, such as an AC bus fault. Such a fault handling unit may also be set to instruct the circuit breaker 20 to open based on the detection of a fault. Such a fault handling unit may be implemented through a computer or a processor with computer program instructions providing the fault handling functionality that acts on current and voltage measurements made in the system.

As mentioned earlier the arrangement may be provided in a converter station. Therefore the parallel circuit 16, converter 12, capacitors C1 and C2, transformer 18 and possibly also the circuit breaker 20 may be provided in such a converter station.

The present invention is provided for handling faults in the arrangement like an AC bus fault, where at least one of the phases of the AC bus gets grounded.

Fig. 2 shows fault currents of such a fault F in the converter 12 connected to the transformer 18, where two phase legs are shown. There is also a surge arrester between the pole P1 and ground. In the drawing only one cell is shown in each phase arm. The situation depicted in fig. 2 is furthermore the situation without the parallel circuit.

In operation the cells of the converter are controlled, for instance using pulse width modulation (PWM), for obtaining an AC voltage at the AC bus 17. It is then possible that a fault F on one of the AC bus phases occur.

In this case the cells are blocked, which is done through the transistors of the cells being turned off, for instance through the control performed by a fault handling unit.

It can be seen that this situation causes the first current I1 to flow from the pole P1 through the cells of the upper phase arm. In these cells the current I1 flows through an anti-parallel diode of a switching element when it is forward-biased, through the cell capacitor and then to the AC bus via the upper phase reactor. The situation also causes the second current I2 to flow from ground and through the cells of the lower phase arm. In these cells the current I2 flows through an anti-parallel diode of a switching element when it is forward-biased and then to the AC bus via the lower phase reactor and the secondary winding of the transformer 18. The second current I2 does thus not pass through any cell capacitor. Here the first current I1 is a current that overcharges the cell capacitors and the second current I2 is a diode surge current.

More importantly though, because of these two currents, if there is no parallel-circuit connected to the second terminal T2, there may be no zero-crossing in the AC bus for at least some of the phases and more-importantly also no zero-crossing in the current on the primary side of the transformer 18 within an allowed arcing time of the breaker. There may therefore be no zero-crossing in the current passing through the AC breaker 20 and therefore it cannot break the current within a maximum allowed time.

The problem of non-zero crossing current in the AC breaker 20 is caused by constant uncontrolled coupling of the DC side to the AC side via free-wheeling diodes of the lower phase arms. The current I2 has both AC and DC components. The current through the AC breaker 20 is affected by this DC component and is therefore also a combination of AC and DC components. If the magnitude of the DC component is higher than the amplitude of the corresponding AC component, the current through the breaker 20 will not cross zero.

This is solved through the use of the parallel circuit 16.

Fig. 3 shows the parallel circuit 16 with resistor R and inductor L. The resistor R is selected to have a value that damps the DC component of the AC current through the circuit breaker to a level where zero crossings are present despite the fact that there is an AC fault. The resistor value may depend on the damping capability of the circuit formed from the grounding point up to the fault e.g. losses in this circuit. The resistor value may then depend on the number of diodes connected in series between the second terminal T and the AC side of the converter, which may be the same as the number of cells in a lower phase arm. It may also depend on grounding resistance, electrode line impedance, equipment at neutral bus, converter reactor resistance, transformer impedance, etc. The value may also be set based on the driving voltage and currents rating. After a suitable resistor value has been chosen, the inductance value may be chosen as low as possible that is capable to drive a current through the resistor R when there is an AC bus fault. The resistor R may therefore have a value in the range between 0.1 Ω and 10 Ω and preferably between 0.5 and 1 Ω, while the inductor may have a value in the range between 5 mH and 500 mH and preferably between 10 and 150 mH.

The inductance L makes it possible to not affect losses in the main circuit during normal operation when there is only DC current in the neutral bus. This means that in normal operation all the current will run through the inductor L essentially without losses. During the fault condition when the current in the neutral bus is a combination of AC and DC components, the inductor L creates an impedance against the AC component that leads to at least part of the current being driven into the resistor R. Thereby the resistor R damps the DC-offset during AC bus faults so that the zero-crossing current in the AC breaker is created without any or with only limited delay.

The parallel-circuit is thus placed in the neutral connection of the converter. This placing has another advantage and that is that it will assist in creating a zero-crossing independently of in which phase the fault occurs. Furthermore, since only passive elements are involved in the creation of a zero-crossing, there is no need for any control logic to activate such a creation. This simplifies the fault handling in the converter.

In the embodiment described above, the DC system was an asymmetric monopole system. It should be realized that the invention may just as well be implemented in a bipole system or multi-terminal system. The DC system may essentially be any system where asymmetric monopole may be a building block.

Although the main advantages of the invention are to be found in handling faults for cell based converters, it should be realized that the inventive concept can also be used with other types, such as two- or three-level voltage source converters. The cells are furthermore not limited to half-bridge cells, but may as an alternative be full-bridge cells.

From the foregoing description of different variations of the present invention, it should be realized that it is only to be limited by the following claims.

CLAIMS

1. An AC fault handling arrangement for handling an AC fault (F) on the AC side of a converter converting between AC and DC and comprising

a voltage source converter (12) for performing the conversion between AC and DC, said converter having a DC side with a first and a second terminal (T1, T2) for coupling to pole (P1) and ground of a DC system (11) and an AC side with a group of terminals (T3) for being coupled to an AC system (10),

a circuit breaker (20) serially connected between the AC side of the converter and the AC system, and

a parallel circuit (16) with one end connected to the second terminal (T2) and the other coupled to ground potential, the parallel circuit consisting of a resistor (R) in parallel with an inductor (L).

2. The arrangement according to claim 1, wherein the resistor (R) has a value that damps a DC component of the AC current due to the AC fault through the circuit breaker (20) to a level where zero-crossings are present.

3. The arrangement according to claim 2, wherein the resistor value depends on the number of diodes connected in series between the second terminal and the AC side.

4. The arrangement according to any previous claim, wherein the resistor has a value in the range

between 0.1 Ω and 10 Ω and preferably between 0.5 and 1 Ω.

5. The arrangement according to claim 3 or 4, wherein the inductor value is chosen as low as possible capable of driving at least a part of the current through the resistor (R) when there is an AC bus fault.

6. The arrangement according to claim5 when depending on claim 4, inductor is set in the range 5 mH - 500 mH and preferably 10 - 150 mH.

7. The arrangement according to any previous claim, further comprising a transformer (18) having a primary side with a first set of primary windings for being coupled to said AC system and a secondary side with a second set of secondary windings coupled to said converter.

8. The arrangement according to claim 7, wherein the circuit breaker is connected between the primary side of the transformer and the AC system.

9. The arrangement according to claim 7, wherein the circuit breaker is connected between the secondary side of the transformer and the AC side of the converter.

10. Arrangement according to any previous claim, wherein the DC system is an asymmetric monopole system.

11. The arrangement according to any of claims 1 – 9, wherein the DC system is a bipole system.

12. The arrangement according to any previous claim, wherein the DC system is a multi-terminal system.

13. The arrangement according to any previous claim, wherein the converter is a modular multilevel converter.

14. The arrangement according to any previous claim, further comprising a fault handling unit configured to block the switching elements of the cells if a fault is detected.

15. The arrangement according to claim 14, wherein the fault handling unit is configured to instruct the circuit breaker (20) to open based on the detection of the AC fault.

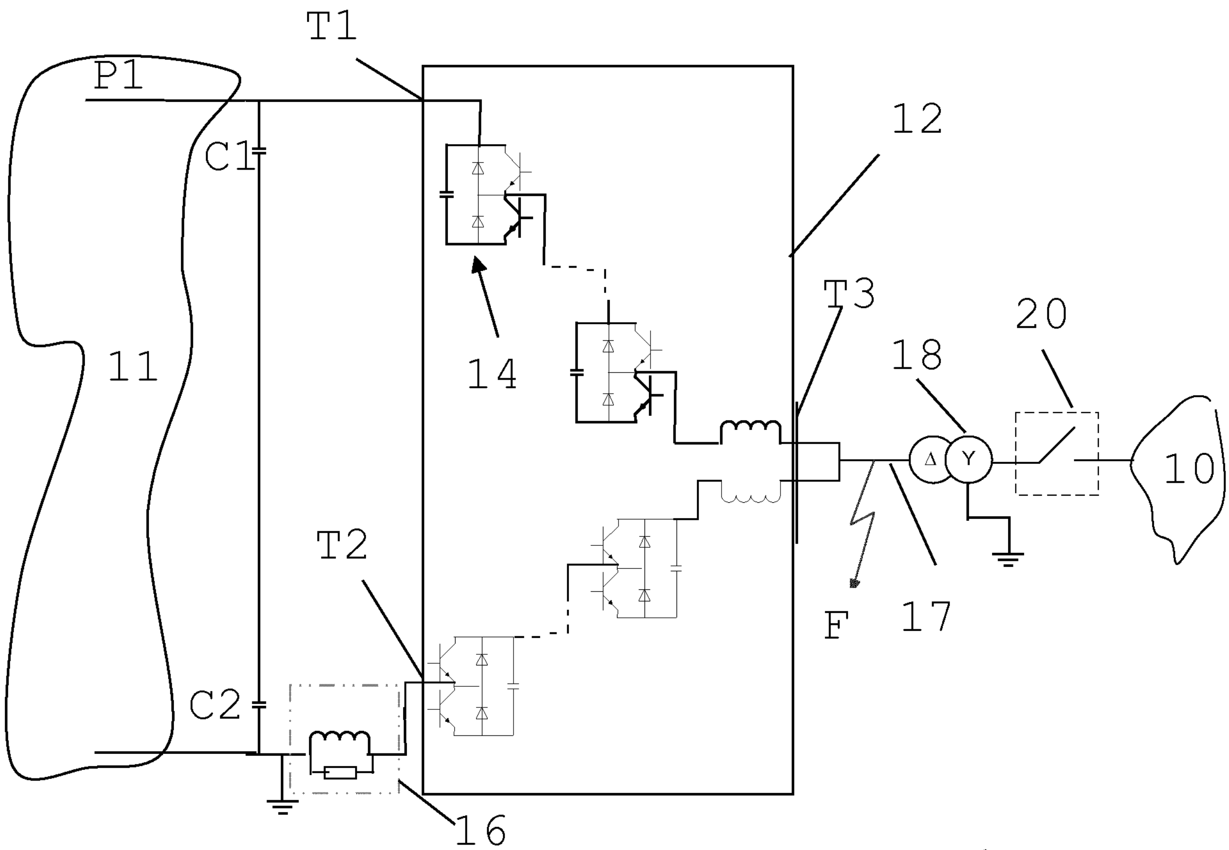

FIG. 1

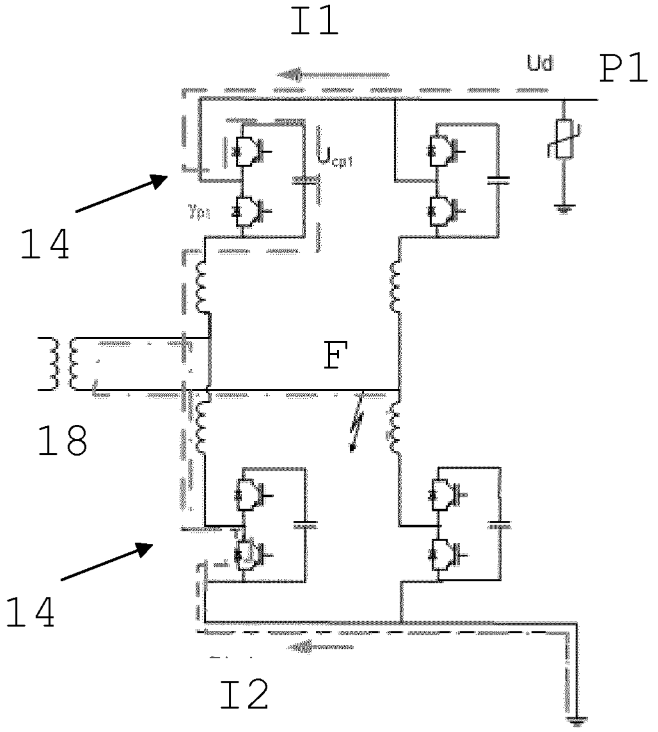

FIG. 2

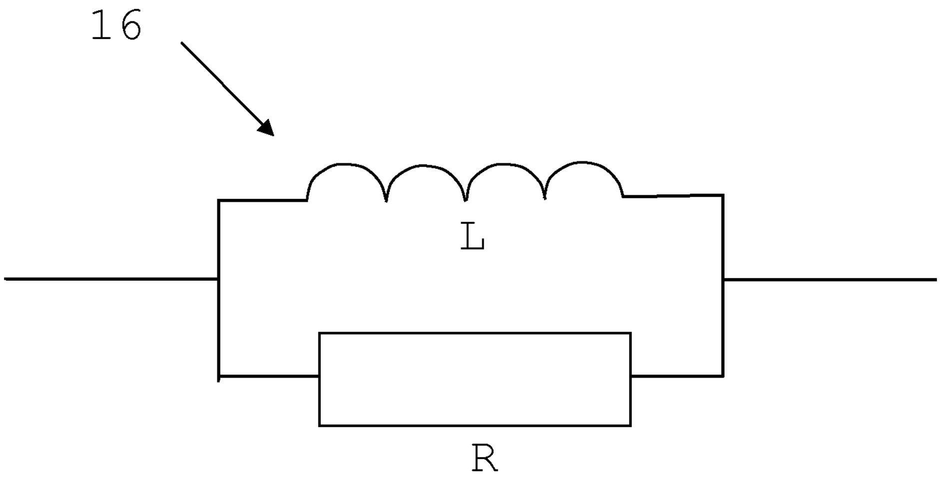

FIG. 3

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2014/059862

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)
H02M H02J

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 A	GB 2 459 764 A (SIEMENS AG [DE]) 11 November 2009 (2009-11-11) figure 5 page 3, line 35 - page 4, line 2 page 7, lines 27-32 -----	1,2,7-15 3-6
T	BUCHER MATTHIAS K ET AL: "Comparison of fault currents in multiterminal HVDC grids with different grounding schemes", 2014 IEEE PES GENERAL MEETING ¦ CONFERENCE & EXPOSITION, IEEE, 27 July 2014 (2014-07-27), pages 1-5, XP032670771, DOI: 10.1109/PESGM.2014.6938990 [retrieved on 2014-10-29] paragraphs [00II], [0III] figure 1 ----- -/--	1

[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

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"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"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

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Date of the actual completion of the international search	Date of mailing of the international search report
5 February 2015	17/02/2015

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	Gotzig, Bernhard

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

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	STEVEN DE BOECK ET AL: "Configurations and earthing of HVDC grids", 2013 IEEE POWER & ENERGY SOCIETY GENERAL MEETING, 1 January 2013 (2013-01-01), pages 1-5, XP055167145, DOI: 10.1109/PESMG.2013.6672808 ISBN: 978-1-47-991303-9 figure 1 paragraphs [00II], [0III] -----	1-15
A	GB 2 397 445 A (ALSTOM [FR]) 21 July 2004 (2004-07-21) figures 2,5 -----	1-15
A	XIAOFANG CHEN ET AL: "Research on the fault characteristics of HVDC based on modular multilevel converter", ELECTRICAL POWER AND ENERGY CONFERENCE (EPEC), 2011 IEEE, IEEE, 3 October 2011 (2011-10-03), pages 91-96, XP031974626, DOI: 10.1109/EPEC.2011.6070260 ISBN: 978-1-4577-0405-5 paragraph [0III] figure 3 -----	1-15
A	US 2011/080758 A1 (ASPLUND GUNNAR [SE]) 7 April 2011 (2011-04-07) figure 2 paragraph [0005] - paragraph [0012] -----	1-15

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/EP2014/059862

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
GB 2459764 A	11-11-2009	CN 101577501 A	11-11-2009
		GB 2459764 A	11-11-2009
		JP 2009273355 A	19-11-2009
GB 2397445 A	21-07-2004	NONE	
US 2011080758 A1	07-04-2011	AR 072026 A1	28-07-2010
		CA 2727367 A1	17-12-2009
		EP 2289156 A1	02-03-2011
		US 2011080758 A1	07-04-2011
		WO 2009149750 A1	17-12-2009