(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
26 September 2013 (26.09.2013)

WIPO | PCT

(10) International Publication Number
WO 2013/139392 A1

(51) International Patent Classification: *H02J 3/36* (2006.01)

(21) International Application Number: PCT/EP2012/055023

(22) International Filing Date: 21 March 2012 (21.03.2012)

(25) Filing Language: English

(26) Publication Language: English

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(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU,

[Continued on next page]

(54) Title: SWITCHING SYSTEM FOR A DC GRID

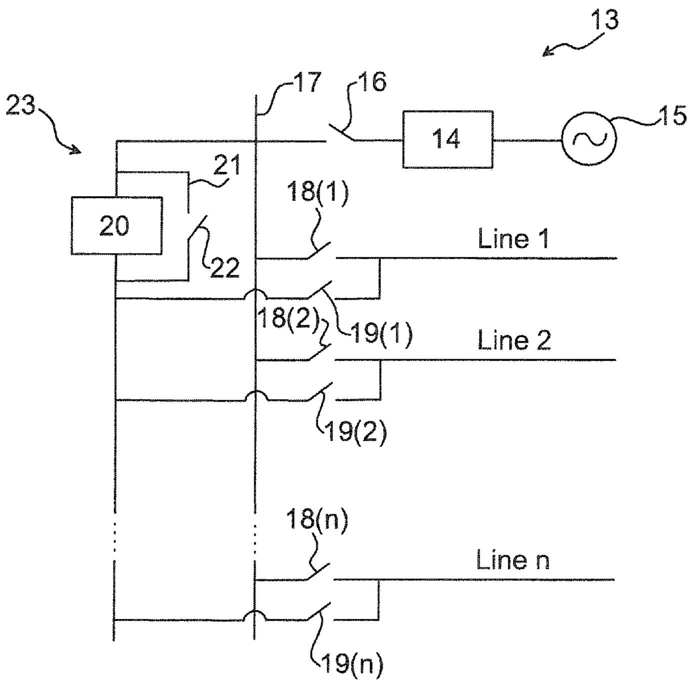

Fig. 2

(57) Abstract: The invention relates to a switching system for connecting a series connectable converter (SC) in a DC grid, comprising: an SC unit (23) configured for being connectable in series with a CD line (1-4) of the DC grid; a DC bus (17) configured for being connectable to a converter station (14) for allowing direct current to flow through said DC bus; and a switching arrangement configured for a) connecting the SC unit in series with the first line for allowing control of direct current flow through the first line via the SC unit, b) disconnecting of the SC unit from the first line such that direct current flow through the first line does not flow via the SC unit, and c) connecting the SC unit in series with the second line for allowing control of direct current flow through the second line via the SC unit.

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TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:

— *with international search report (Art. 21(3))*

Switching system for a DC grid

TECHNICAL FIELD

The present invention relates to a switching system for a direct current (DC) grid comprising a first DC line and a second DC line as well as a converter station for converting alternating current (AC) from an AC source to direct current for feeding the first and second DC lines. The present invention also relates to a method of such a switching system.

BACKGROUND

A HVDC power distribution network or a HVDC power transmission system uses direct current for the transmission of electrical power, in contrast to the more common AC systems. For long-distance transmission or distribution, HVDC systems may be less expensive and may suffer lower electrical losses. In general, a HVDC power transmission system comprises at least one long-distance HVDC link or cable for carrying direct current a long distance, e.g. under sea, and converter stations for converting alternating current to direct current for input to the HVDC power transmission system and converter stations for converting direct current back to alternating current.

US 6,788,033 and US 5,734,258 disclose DC to DC conversion and relate to stationary or portable systems powered by a DC battery, and to electric vehicles. US 6,914,420 describes a power converter for converting power between a first and a second voltage, and relates to electric vehicles.

US 7,518,266 discloses an AC power transmission system, where a DC transmission ring is used, utilizing controllable AC-DC converters in a multi-in-feed/out-feed arrangement.

US 3,694,728 describes a HVDC mesh-operated network comprising several interconnected stations for effecting an exchange of power by means of converters located at the stations and which are connected to AC networks.

DE 2530789 discloses an arrangement for protecting a converter connected to a DC line, the arrangement comprising a surge arrester connected in series with a non-linear resistor.

US 3,694,728 describes a circuit arrangement for altering current distribution in mesh-operated HVDC transmission networks.

JP 2000-175361 discloses an alternating current direct current hybrid power transmission system.

WO 2007/022744 describes a current-limiting switch, which may be connected to a DC network, including a mechanical switching unit, a power-electronic switching unit, a capacitive short-circuit limitation unit and a varistor.

WO 2011/095624 discloses a circuit for connecting and disconnecting an energizable electric system and an electric network of a vehicle, the circuit comprising a mechanical circuit breaker and a semiconductor switch.

WO 2011/124258 describes a power electronic converter for use in HVDC power transmission.

DE 1513827 discloses an apparatus for influencing the current distribution in a HVDC network.

Unless the electric currents/voltages of different DC links are controlled, DC load flow congestion may occur within a DC power distribution network.

SUMMARY

It is an objective of the present invention to provide an improved way of controlling currents of different loops/lines in a DC grid, e.g. to avoid flow congestion.

According to an aspect of the present invention, there is provided a switching system for connecting a series connectable converter, SC, in a direct current, DC, grid, the DC grid comprising a converter station for converting alternating current, AC, from an AC source to direct current for feeding a first and a second DC line which are connectable to the converter station, the system comprising: an SC unit configured for being connectable in series with a DC line of the DC grid and comprising an SC;

a DC bus configured for being connectable to the converter station for allowing direct current to flow through said DC bus; and a switching arrangement configured a) for connecting the SC unit in series with the first line for allowing control of direct current flow through the first line via the SC unit, b) for disconnecting of the SC unit from the first line such that direct current flow through the first line does not flow via the SC unit, and c) for connecting the SC unit in series with the second line for allowing control of direct current flow through the second line via the SC unit.

According to another aspect of the present invention, there is provided a method of switching a series connectable converter (SC) unit from a first DC line to a second DC line in a DC grid, the DC grid comprising a converter station for converting alternating current (AC) from an AC source to direct current for feeding the first and second DC lines, the method comprising the sequential steps of: a) closing a first line bus switch, allowing direct current to bypass the SC unit when flowing through the first line; b) opening a first line SC switch, disconnecting the SC unit from the first line; c) closing a second line SC switch, connecting the SC unit to the second line and controlling direct current flow through the second line via the SC unit; and d) opening a second line bus switch, preventing direct current from bypassing the SC unit when flowing through the second line.

The device aspect of the present invention may be used for performing the method aspect of the present invention.

It is an advantage of the present invention that a series connectable converter may, by means of any of the aspects of the present invention, be switched from one DC line in a DC grid to another DC line of said DC grid. Thus, the same series connectable converter may be used for a plurality of different DC lines associated with the same converter station, obviating the need to provide a series connected converter for each DC line in order to control the electrical currents therein. The installation and maintenance costs may consequently be reduced and the capacity of the converter may be better utilized. The ability of switching a converter from one line to another may also increase the general flexibility of the DC grid.

The discussions above and below in respect of any of the aspects of the invention are also in applicable parts relevant to any other aspect of the present invention.

The switching arrangement may be provided with different means for implementing the system aspect of the present invention, a few examples for which are presented below.

The switching arrangement of the present invention may comprise: a first line SC switch configured for, in a closed position, connecting the first line to the SC unit for allowing direct current to flow through the first line via the SC unit, and for, in an open position, disconnecting the first line from the SC unit; and a second line SC switch configured for, in a closed position, connecting the second line to the SC unit for allowing direct current to flow through the second line via the SC unit, and for, in an open position, disconnecting the second line from the SC unit.

Alternatively or additionally, the switching arrangement of the present invention may comprise: a first line bus switch configured for, in a closed position, connecting the first line to the DC bus for allowing direct current to flow through the first line via the DC bus, and for, in an open position, disconnecting the first line from the DC bus; and a second line bus switch configured for, in a closed position, connecting the second line to the DC bus for allowing direct current to flow through the second line via the DC bus, and for, in an open position, disconnecting the second line from the DC bus.

Alternatively or additionally, the switching arrangement of the present invention may comprise: a first line bus switch configured for, in a closed position, connecting the first line to the DC bus for allowing direct current to flow through the first line via the DC bus, bypassing the SC unit, and for, in an open position, preventing direct current from bypassing the SC unit if flowing through the first line via the DC bus; and a second line bus switch configured for, in a closed position, connecting the second line to the DC bus for allowing direct current to flow through the second line via the DC bus, bypassing the SC unit, and for, in an open position, preventing direct current from bypassing the SC unit if flowing through the second line via the DC bus.

The SC unit may comprise an SC bypass switch configured for, in a closed position, closing an SC bypass loop allowing direct current to flow via said bypass loop instead of through the SC even if the first line SC switch or the second line SC switch is in its closed position. The bypass loop may be used to protect the SC, e.g. from potentially damaging power surges. Consequently, the method of the present invention may comprise: a') prior to step b), closing the bypass switch to allow direct current to flow through the bypass loop instead of through the SC in the SC unit; and d') after step c), opening the bypass switch to prevent direct current from bypassing the SC via the bypass loop. It should be noted that step a') may be performed before, after or simultaneously with step a), and step d' may be performed before, after or simultaneously with step d).

The switching system may comprise a backup DC bus configured for, in cooperation with switches, replacing the (primary) DC bus, for allowing disconnection of the (primary) DC bus from the converter station while still allowing the feeding of the first and second lines with direct current. By means of the backup DC bus, maintenance may be performed e.g. on the primary DC bus and/or on switches or conductors associated with the primary DC bus, without having to cut the power supply/current to DC line(s) of the DC grid.

The SC unit may comprise of a plurality of sub-units, which may independently and/or together be switched between different DC lines, whereby the flexibility in the current control of the DC grid may be additionally improved. Thus, the SC unit may comprise a first SC sub-unit and a second SC sub-unit, wherein the first SC sub-unit is configured for connecting the first SC sub-unit to the first line for controlling direct current flow through the first line via the first SC sub-unit, and wherein the second SC sub-unit is configured for connecting the second SC sub-unit, independently of the connection of the first SC sub-unit, to the second line for controlling direct current flow through the second line via the second SC sub-unit. The first SC sub-unit may be configured for allowing the first SC sub-unit to be connected to the second line for controlling direct current flow through the second line via the first SC sub-unit, and wherein the second SC sub-unit is configured for connecting the second SC sub-unit, independently of the connection of the first SC sub-unit, to the first line for controlling direct current flow through the first line via the second SC sub-unit. The first and second SC sub-units may be configured for connecting said first and second SC sub-units in series with each other to the first line for controlling direct current flow through the first line via both the first and second SC sub-units.

The switching system may be configured to allow the SC unit to be connected to each of a plurality of lines which may be fed by the converter station, sequentially or simultaneously, or the SC unit may be connected to a subgroup of the lines simultaneously while another subgroup is not connected. Thus, when the DC grid comprises n number of lines which the converter station is configured to feed with direct current, the switching arrangement may be configured for allowing the SC unit to be connected to each of the n lines, such that direct current flow through said lines may be controlled, one by one over time and/or simultaneously, and/or a combination thereof.

Generally, all terms used in the claims are to be interpreted according to their ordinary meaning in the technical field, unless explicitly defined otherwise herein. All references to "a/an/the element, apparatus, component, means, step, etc." are to be interpreted openly as referring to at least one instance of the element, apparatus, component, means, step, etc., unless explicitly stated otherwise. The steps of any method disclosed herein do not have to be performed in the exact order disclosed, unless explicitly stated. The use of “first”, “second” etc. for different features/components of the present disclosure are only intended to distinguish the features/components from other similar features/components and not to impart any order or hierarchy to the features/components.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention is now described, by way of example, with reference to the accompanying drawings, in which:

Fig 1 is a schematic diagram of a DC power grid.

Fig 2 is a schematic box diagram of a converter station hub comprising an embodiment of a switching system of the present invention.

Fig 3 is a schematic box diagram of a converter station hub comprising another embodiment of a switching system of the present invention.

Fig 4 is a schematic box diagram of a converter station hub comprising another embodiment of a switching system of the present invention.

Fig 5 is a schematic box diagram of a converter station hub comprising another embodiment of a switching system of the present invention.

Fig 6 is a schematic box diagram of a converter station hub comprising another embodiment of a switching system of the present invention.

Fig 7 is a schematic box diagram of a converter station hub comprising another embodiment of a switching system of the present invention.

Fig 8 is a schematic box diagram of an embodiment of a series connected converter unit of the present invention.

Fig 9 is a schematic flow chart of an embodiment of a method of the present invention.

DETAILED DESCRIPTION

The invention will now be described more fully hereinafter with reference to the accompanying drawings, in which certain embodiments of the invention are shown. This invention may, however, be embodied in many different forms and should not be construed as limited to the embodiments set forth herein; rather, these embodiments are provided by way of example so that this disclosure will be thorough and complete, and will fully convey the scope of the invention to those skilled in the art. Like numbers refer to like elements throughout the description.

A series connected converter (SC), as discussed herein, is an apparatus configured for being connected to a DC line and for controlling the direct current in said DC line by introducing a DC voltage in the DC line in series with said DC line. Sometimes the SC is herein referred to as a series connectable converter in order to stress that the converter need not be series connect, but that the name rather refers to it being configured for being able to be series connected.

The DC grid discussed herein may be a High Voltage Direct Current (HVDC) grid, typically comprising a plurality of loops.

A converter station hub as discussed herein is a converter station arrangement to which more than one line of the DC grid is connected for being fed current by the converter station.

A switch as discussed herein may be any device, such as a switch or circuit breaker, able to connect or disconnect an electrical conductor to/from another electrical conductor. As will be realised from the present disclosure by the person skilled in the art, some switches may require the ability to break a circuit while it is at least to some degree power loaded, whereas some may not require that ability.

With reference to fig 1, an example of a DC grid 10 is schematically illustrated. The grid 10 comprises two loops 11 and 12 of DC lines, both of which are connected to the converter station hub 13(a). Two other converter station hubs 13 are shown, one in each loop 11 and 12. At converter station hubs 13(b) and 13(c), two DC lines meet, whereas four DC lines meet at the converter station hub 13(a). A possible way of controlling/regulating the respective currents of the loops 11 and 12 of the DC grid 10 is to connect a series connected converter 5 or 6 to each of the loops 11 and 12, which may be an alternative or complement to the present invention. By means of the present invention, a single series connected converter may be used for controlling the respective currents of a plurality of DC lines 1-4, one at the time or simultaneously. The present invention may be useful anywhere where at least two DC lines are available, e.g. at or in a converter station hub 13. The present invention may be especially useful where more than two DC lines meet, e.g. where two loops 12, 11 meet such as at/in the converter station hub 13(a) of fig 1 where four lines, two loops, meet. The DC grid may e.g. be an HVDC grid and/or a meshed DC grid.

Fig 2 illustrates an embodiment of a converter station hub 13 of the present invention, connected to an AC source 15.

A converter station 14 is arranged to convert the AC of the AC source 15 to DC for feeding the DC lines 1 to n. The lines 1-n are connected to the converter station 14 via a DC bus 17 for distributing current to the plurality of lines. The bus 17 may take any of many different forms known to the person skilled in the art but may generally be regarded as an electrical conductor or branching point to which the lines as well as the converter station may be connected. A converter station switch or circuit breaker 16 may be used to connect the converter station 14 to the bus 17. Similarly, a bus switch 18 for each of the may be used for connecting each of the lines 1-n to the bus 17. Further, a series connected converter unit 23 is connected to the converter station 14, possibly also via the converter station switch 16. The series connected converter unit 23 comprises a series connected converter (SC) 20 for controlling the respective currents of the DC lines 1-n. The series connected converter unit 23 may further comprise a bypass loop 21, comprising a bypass switch 22, for by allowing current to bypass the SC 20 in the SC unit 23 when the bypass switch 22 is in a closed position, closing the circuit via the bypass loop 21. The series connected converter unit 23 may be connected to each of the lines 1-n via respective SC switches 19 for each of the lines.

As an example for the embodiment of fig 2, for switching the SC 20 to line 1, the SC 20 may be first be blocked. Then, the SC switch 19(1) may be closed as well as the bypass switch 22. . At this time the current is flowing to line 1 through two parallel paths one through the bypass switch 22 of the series converter and the other through the DC bus 17 and bus switch 18(1). When the SC unit 23 is thus connected to line 1, the bus switch 18(1) may need to be opened so that the line 1 is exclusively fed through the SC unit 23. For this, the bus switch 18 may need some or full current breaking capability. After that, the SC 20 is de-blocked and the bypass switch 22 may be opened whereby the series converter 20 is connected to line 1. In order to switch the series converter 20 from line 1, first the bypass switch 22 may be closed and the SC 20 may be blocked. As the current is flowing via the bypass loop 21, the SC may be taken out of service e.g. by means of disconnect switches (not shown) with the bypass switch 22 still closed, to completely disconnect and possibly remove the series converter 20 if desired. Then, the bus switch 18(1) may be closed so that the line 1 may be fed continuously via the bus 17. After, the current flowing through the bypass loop 21 may be fully interrupted by opening the bypass switch 22. At this time, the entire series converter unit 23 does not carry any current. The SC switch 19(1), as well as possibly another switch (not shown) located on the other side of the SC unit 23, disconnecting the SC unit 23 from the converter station 14 and the bus 17 may be opened. This will ensure complete disconnection of the series converter unit 23 from line 1 and may allow removal of the whole SC unit 23 if desired, without interrupting the feeding of any of the lines 1-n. Similarly, for switching the SC 20 to line 2, the bypass switch 22 may be closed, after which the SC switch 19(2) may be closed. At this time, the current is flowing to line 2 through two parallel paths, one through the bypass switch 22 of the series converter and the other through the DC bus 17 and bus switch 18(2). When the SC unit 23 is with line

2, the bus switch 18(2) may be opened so that the line 2 is exclusively fed via the SC unit 23, and the SC 20 may be de-blocked. In this case, the bus switch 18(2) may needs to have some or full load DC current breaking capability. After that, the bypass switch 22 may be opened whereby the series converter 20 is connected to line 2.In this way, the SC 20 may be switched from one line (line 1) to another line (line 2) in accordance with the present invention.

Fig 3 is a schematic diagram of an embodiment of a converter station hub 13 of the present invention, connected to an AC source 15, wherein the hub 13 connects four DC lines 1-4 with the converter station 14.

In fig 3 a more specific example of the more general embodiment of fig 2 is shown. In addition to the parts of a hub 13 shown in fig 2, also a few other parts, which may be convenient, are shown. Between the AC source 15 and the converter station 14, there may be a circuit breaker 32, enabling disconnection of the hub 13 from the AC source if desired, as well as a transformer 31. Also, circuit breakers 33 for each of the lines 1-4 may be used for enabling disconnection of each of the lines 1-4, independently, from the converter station 14 and thus the hub 13. In the embodiment of fig 3, the converter station switch 16 comprises two switches 16a and 16c on either side of a circuit breaker 16b. It should be noted that also other switches discussed herein may comprise a plurality of parts, such as switches and/or circuit breakers, for making the hub 13 more flexible and controllable. By means of this switching arrangement, the SC 20 may be connected to any of the lines 1-4 to control the current of said lines. Typically, only one of the lines 1-4 may be connected to the SC 20 at any one time, but it is also conceivable that a plurality of lines could be controlled together by all being fed current via the SC 20 at the same time (i.e. the SC 20 may be connected to more than one of the lines 1-4 at the same time by more than one of the SC switches 19 being in the closed position).

Below follows an example on how to disconnect the SC 20 from line 1 (disconnection from any other line may be done in analogue way). At the starting point, SC 20 is connected to line 1 with SC switch 19(1) closed and bus switch 18(1) open.

1. Block SC 20
2. Close bypass switch 22 and bus switch 18(1)
3. Open bypass switch 22

4. Open SC switch 19(1)

Below follows an example on how to connect the SC 20 to line 2 (connection to any other line may be done in analogue way). At the starting point, SC 20 is not connected to any line 1-4, with SC switch 19(2) open and bus switch 18(2) closed, and SC 20 blocked.

1. Close SC switch 19(2)
2. Close bypass switch 22
3. Open bus switch 18(2)
4. De-block SC 20 and open bypass switch 22

The above sequences for connecting/disconnecting the SC 20 to/from a line 1-4 is only an example, which may also be relevant for other embodiments shown in the figures below, and the person skilled in the art will realise other possibilities depending on the design of the switching arrangement, the need to protect the SC 20 and/or switches from power surges etc. It is noted that in the embodiment of figure 3, the bus switches 18 need some current breaking ability.

Fig 4 illustrates an embodiment of a switching arrangement which is very similar to that which is shown in fig 3. The difference is that the position of the line circuit breakers 33 is shifted to between the bus switches 18 and the point where the conductor line from the SC unit 23 via the SC switches 19 connect to the lines 1-4, respectively. An advantage with this embodiment is that the bus switches 18 may not need a current breaking ability since the circuit breakers 33 may be used to break the current via the bus when a line 1-4 is fed via the SC unit 23. The embodiment of fig 3 may, however, be preferable to the embodiment of fig 4, depending on the circumstances, since, when the breaker 33 is open, the line is not connected to the SC unit 23 via the breaker anymore, making the SC protected only by its own protection (bypass 21) if there is a fault on the line.

A sequences for connecting the SC 20 to a line 1-4 (in this example line 2) may then in analogy with the above in respect of fig 3 e.g. be:

1. Close SC switch 19(2)

2. Close bypass switch 22
3. Open line circuit breaker 33(2)
4. Open bus switch 18(2) (where there is no longer any current)
5. De-block SC 20 and open bypass switch 22

A potential problem with the embodiments of figures 2 to 4 may be that if any one of the switches e.g. converter station switch 16, a bus switch 18 or an SC switch 19 needs to be serviced, the converter station 14 may need to be shut down. The same may be the case if there is any problem with the DC bus. To overcome this problem the series converter unit 23, the converter station 14 and the DC lines may be connected to two separate buses 17 and 34, through different switches as shown in fig 5, which are here called primary DC bus 17 and backup DC bus 34. As shown in fig 5, the SC unit 23 may thus be connected to the converter station via the backup bus 34 by means of a backup converter station switches 36 and 37, switch 36 connecting the backup bus 34 to the converter station 14 and switch 37 connecting the SC unit 23 to the backup bus 34. By opening the converter station switch 16a in fig 5, the primary bus 17 may be disconnected from the converter station. Similarly, backup bus switches 35 for each of the lines 1-4 may connect each of the lines, independently, to the backup bus 34. By this arrangement, the primary DC bus 17 may be disconnected, whereby e.g. maintenance may be performed on the primary bus 17 and/or any of the bus switches 18, without interrupting the feeding of current to the lines 1-4 from the converter station 14.

Fig 6 illustrates another embodiment of how to implement the switching arrangement of the present invention. In this arrangement the SC unit 23 may be always connected to two dedicated auxiliary buses AUX1 and AUX2. The SC switches 19 as well as part of the converter station switch 16, namely 16a(1-4), may be connected to these two buses to connect SC unit 23 with any one of the lines 1, 2, 3 and 4 respectively. To bypass the SC unit 23, the bus switches 18 may still be required. The total number of bus switches 18 depends on the number of lines to which the SC unit 23 is required to be able to switch to interchangeably. If the SC unit 23 is connected to line 1 and hence the bus switch 18(1) for line 1 is open, all other bus switches 18 for lines 2, 3, 4 respectively, are closed. Further, the SC switch 19(1) as well as the converter station switch 16a(1) are closed, while all other SC switches 19 and converter station switches 16a are open. The switching procedure for the SC unit 23 may be same as before. To disconnect the series converter unit 23 from line 1, first, bus switch 18(1) may be closed to maintain the continuous power flow through the line 1 when the SC unit 23 is blocked. This ensures full line current is flowing through the bus switch 18(1) and line 1. Since SC switch 19(1) and converter station switch 16a(1) do no longer carry line current, they may be opened to isolate the SC unit 23. Similarly, to connect the SC unit 23 to line 2, first SC switch 19(2) and converter station switch 16a(2) (carrying no current) may be closed and with the bypass switch 22 closed. Then, the bus switch 18(2) may be opened whereby the current to line 2 runs via the SC unit 23. In this way, the SC unit 23 may be connected in series with any of the lines 1-4, as also discussed in relation to previous figures.

Fig 7 schematically illustrates an embodiment of a hub 13 and switching arrangement with a ring bus 17 of a switchyard. In this case, a fifth line circuit breaker 33(5) may be used. For the rest, the switching arrangement is essentially the same as in the embodiments of the previous figures. In this embodiment any one of the line circuit breakers 33 forming the ring, except 33(4) and 33(5) (or the parts thereof directly connected to the converter station 14) may be taken out of service e.g. for a regular maintenance purpose while maintaining supply to the lines 1-4. Other than these two switches, the reliability of the supply in this embodiment may thus be improved compared with the previously discussed embodiments.

Fig 8 schematically illustrates an embodiment of an SC unit 23 which comprises a plurality of sub-SCs or SC sub-units 20(1-n), each of which may be independently connected to any of the DC lines e.g. if the SC unit 23 with a plurality of sub-units is used in stead of the SC unit 23 of any previous figure. Any number of sub-SCs 20(1-n) may be comprised in the SC unit 23, each may have its own bypass loop 21(1-n) with a bypass switch 22(1-n), but in fig 8, as an example, only two are shown. The sub-SCs may operate independently of each other (being parallel connected), each functioning as the SC 20 discussed above in relation to any previous figure and being able to be connected to and disconnected from any one of the lines of the hub 13. Additionally, the sub-SCs may be series connected such that all or some of the sub-SCs may operate on the same line or lines. For series connection, a series switch 41 between the sub-SCs may be closed and a parallel switch 42 may be opened, disconnecting a series connected sub-SC from its direct connection to the converter station 14. Additional bypass loops may be formed which jointly bypasses any number of the sub-SCs, e.g. when said sub-

SCs are series connected. To this end bypass switches 43 and 44 may be used. It is also conceivable that a plurality of parallel connected sub-SCs or a mixture of parallel and series connected sub-SCs may be connected to and control the same DC line. In this way, greater flexibility and current control may be achieved since zero, one or several sub-SCs may be connected to any of the lines of a hub 13 as desired, and the currents of a plurality of lines may be independently controlled by a single SC unit 23. The skilled person will, in view of the present disclosure, realise that the switching arrangement may be designed in any of numerous possible ways in order to enable any one of the sub-SCs to be connected to any one of the DC lines of a hub 13, e.g. intermediary switch(es) (not shown) may connect or disconnect a sub-SC from any of the SC switches 19.

Fig 9 is a schematic flow chart of an embodiment of a method of the present invention. The method describes an example of steps for disconnecting the SC 20 from a first DC line 1-4 and then connecting the SC 20 to a second DC line 1-4. It should be noted that not all steps may be necessary and that the order of steps may be different, as is realised by a person skilled in the art.

A first line bus switch 18(1) may be closed (step 102), allowing direct current to bypass the SC unit 23 when flowing between the converter station 14 and the first line. Then, a first line SC switch 19(1) may be opened (step 103), disconnecting the SC unit 23 from the first line. By these steps 102 and 103, the SC 20 has been disconnected from the first line. In the following steps 104 and 105, the SC 20 is connected to the second line. Thus, a second line SC switch 19(2) may be closed (step 104), connecting the SC unit 23 to the second line and allowing direct current to flow between the converter station 14 and the second line via the SC unit 23. Then, a second line bus switch 18(2) may be opened (step 105), preventing direct current from bypassing the SC unit 23 when flowing between the converter station 14 and the second line.

If the SC unit 23 comprises a bypass loop 21 with a bypass switch 22, to protect the SC 20 from current surges etc. during switching (connecting/disconnecting to/from a line 1-4), additional method steps 101 and 106 may be employed. Thus, the bypass switch 22 may be closed (step 101) as a step in disconnecting the SC 20 from the first line, to allow direct current to flow through the bypass loop 21 instead of through the SC 20 in the SC unit 23. This step 101 may be performed before, after or at the same time as the step 102 of closing the first line bus switch 18(1). Similarly, the bypass switch 22 may be opened (step 106) as a step in connecting the SC 20 to the second line, to prevent direct current from bypassing the SC 20 via the bypass loop 21. This step 106 may be performed before, after or simultaneously with the step 105 of opening the second line bus switch 18(2).

In an embodiment of the present invention, there is provided a switching system for connecting a series connected converter (SC) in a DC grid, comprising: a series connected converter unit 23 configured for being connected to a converter station 14 for allowing direct current to flow between the converter station and said series connected converter unit; a DC bus 17 configured for being connected to the converter station for allowing direct current to flow through said DC bus; and a switching arrangement configured for allowing a) the SC unit to be connected to a first line for allowing direct current to flow between the converter station and the first line via the SC unit, b) disconnection of the SC unit from the first line, and c) the SC unit to be connected to a second line for allowing direct current to flow between the converter station and the second line via the SC unit

The invention has mainly been described above with reference to a few embodiments. However, as is readily appreciated by a person skilled in the art, other embodiments than the ones disclosed above are equally possible within the scope of the invention, as defined by the appended patent claims.

claims

1. A switching system for connecting a series connectable converter, SC, (20) in a direct current, DC, grid, the DC grid comprising a converter station (14) for converting alternating current, AC, from an AC source (15) to direct current for feeding a first and a second DC line which are connectable to the converter station (14), the system comprising:

an SC unit (23) configured for being connectable in series with a DC line (1-4) of the DC grid and comprising an SC (20);

a DC bus (17) configured for being connectable to the converter station (14) for allowing a direct current to flow through said DC bus (17); and

a switching arrangement configured a) for connecting the SC unit (23) in series with the first line for allowing control of a direct current through the first line via the SC unit (23), b) for disconnecting of the SC unit (23) from the first line such that direct current through the first line does not flow via the SC unit (23), and c) for connecting the SC unit (23) in series with the second line for allowing control of a direct current through the second line via the SC unit (23).

2. The switching system of claim 1, wherein the switching arrangement comprises:

a first line SC switch (19(1)) configured for, in a closed position, connecting the first line to the SC unit (23) for allowing direct current to flow through the first line via the SC unit (23), and for, in an open position, disconnecting the first line from the SC unit (23); and

a second line SC switch (19(2)) configured for, in a closed position, connecting the second line to the SC unit (23) for allowing direct current to flow through the second line via the SC unit (23), and for, in an open position, disconnecting the second line from the SC unit (23).

3. The switching system of claim 1 or 2, wherein the switching arrangement comprises:

a first line bus switch (18(1)) configured for, in a closed position, connecting the first line to the DC bus (17) for allowing direct current to flow through the first line via the DC bus (17), and for, in an open position, disconnecting the first line from the DC bus (17); and

a second line bus switch (18(2)) configured for, in a closed position, connecting the second line to the DC bus (17) for allowing direct current to flow through the second line via the DC bus (17), and for, in an open position, disconnecting the second line from the DC bus (17).

4. The switching system of claim 1 or 2, wherein the switching arrangement comprises:

a first line bus switch (18(1)) configured for, in a closed position, connecting the first line to the DC bus (17) for allowing direct current to flow through the first line via the DC bus (17), bypassing the SC unit (23), and for, in an open position, preventing direct current from bypassing the SC unit (23) if flowing through the first line via the DC bus (17); and

a second line bus switch (18(2)) configured for, in a closed position, connecting the second line to the DC bus (17) for allowing direct current to flow through the second line via the DC bus (17), bypassing the SC unit (23), and for, in an open position, preventing direct current from bypassing the SC unit (23) if flowing through the second line via the DC bus (17).

5. The switching system of any previous claim, wherein the SC unit (23) further comprises an SC bypass switch (22) configured for, in a closed position, closing an SC bypass loop (21) allowing direct current to flow via said bypass loop (21) instead of through the SC (20) even if the first line SC switch (19(1)) or the second line SC switch (19(2)) is in its closed position.

6. The switching system of any previous claim, further comprising:

a backup DC bus (34) configured for, in cooperation with switches (35, 36, 37), replacing the DC bus (17), for allowing disconnection of the DC bus (17) from the converter station (14) while still allowing the feeding of the first and second lines with direct current.

7. The switching system of any previous claim, wherein the SC unit (23) comprises a first SC sub-unit (20(1)) and a second SC sub-unit (20(n)), wherein the first SC sub-unit (20(1)) is configured for connecting the first SC sub-unit (20(1)) to the first line for controlling the direct current through the first line via the first SC sub-unit (20(1)), and wherein the second SC sub-unit (20(n)) is configured for connecting the second SC sub-unit (20(n)), independently of the connection of the first SC sub-unit (20(1)), to the second line for controlling the direct current through the second line via the second SC sub-unit (20(n)).

8. The switching system of claim 7, wherein the first SC sub-unit (20(1)) is configured for connecting the first SC sub-unit (20(1)) to the second line for controlling the direct current through the second line via the first SC sub-unit (20(1)), and wherein the second SC sub-unit (20(n)) is configured for connecting the second SC sub-unit (20(n)), independently of the connection of the first SC sub-unit (20(1)), to the first line for controlling the direct current through the first line via the second SC sub-unit (20(n)).

9. The switching system of claim 7 or 8, wherein the first and second SC sub-units (20(1), 20(n)) are configured for connecting said first and second SC sub-units (20(1), 20(n)) in series to the first line for controlling the direct current through the first line via both the first and second SC sub-units (20(1), 20(n)).

10. The switching system of any preceding claim, if the DC grid comprises n number of lines (1-4) connectable to the converter station (14) for being fed with direct current, the switching arrangement is configured for connecting the SC unit (23) to each of the n lines, such that the direct current through said lines can be controlled, one by one over time and/or simultaneously, and/or a combination thereof.

11. A method of switching a series connectable converter, SC, unit (23) from a first DC line (1) to a second DC line (2) in a DC grid (10), the DC grid comprising a converter station (14) for converting alternating current, AC, from an AC source (15) to

direct current for feeding the first and second DC lines, the method comprising the sequential steps of:

a) closing (102) a first line bus switch (18(1)), allowing direct current to bypass the SC unit (23) when flowing through the first line;

b) opening (103) a first line SC switch (19(1)), disconnecting the SC unit (23) from the first line;

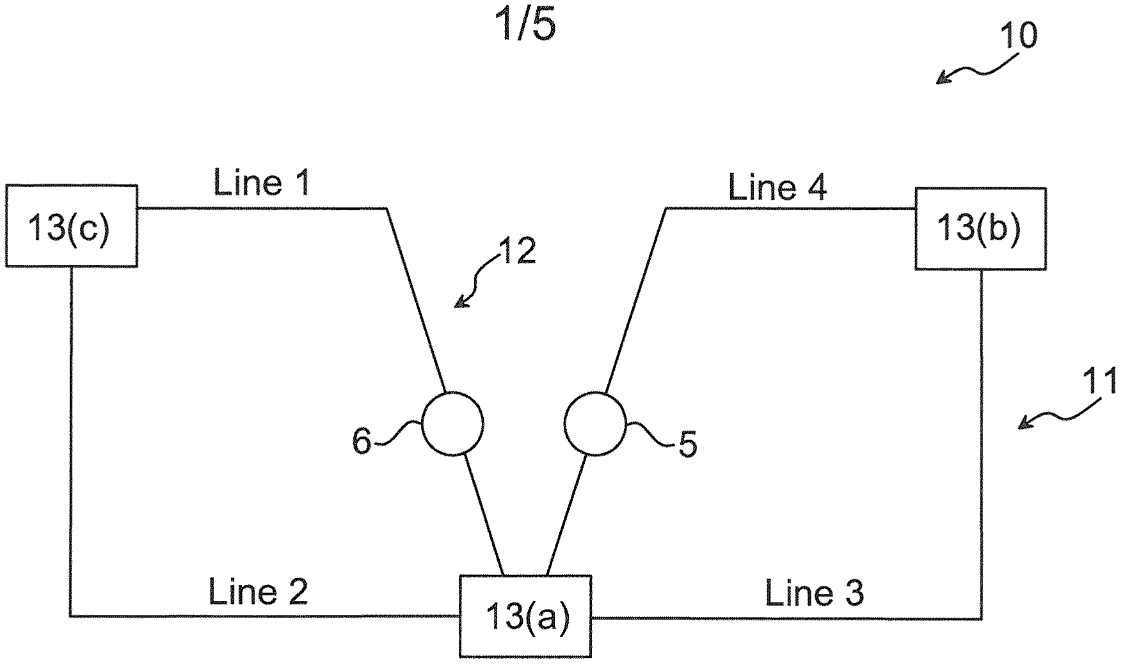
c) closing (104) a second line SC switch (19(2)), connecting the SC unit (23) to the second line and controlling a direct current through the second line via the SC unit (23); and

d) opening (105) a second line bus switch (18(2)), preventing direct current from bypassing the SC unit (23) when flowing through the second line.

12. The method of claim 11, wherein the SC unit (23) comprises an SC (20) and a bypass loop (21) with a bypass switch (22), the method further comprising the steps of:

a') prior to step b), closing (101) the bypass switch (22) to allow direct current to flow through the bypass loop (21) instead of through the SC (20) in the SC unit (23); and

d') after step c), opening (106) the bypass switch (22) to prevent direct current from bypassing the SC (20) via the bypass loop (21).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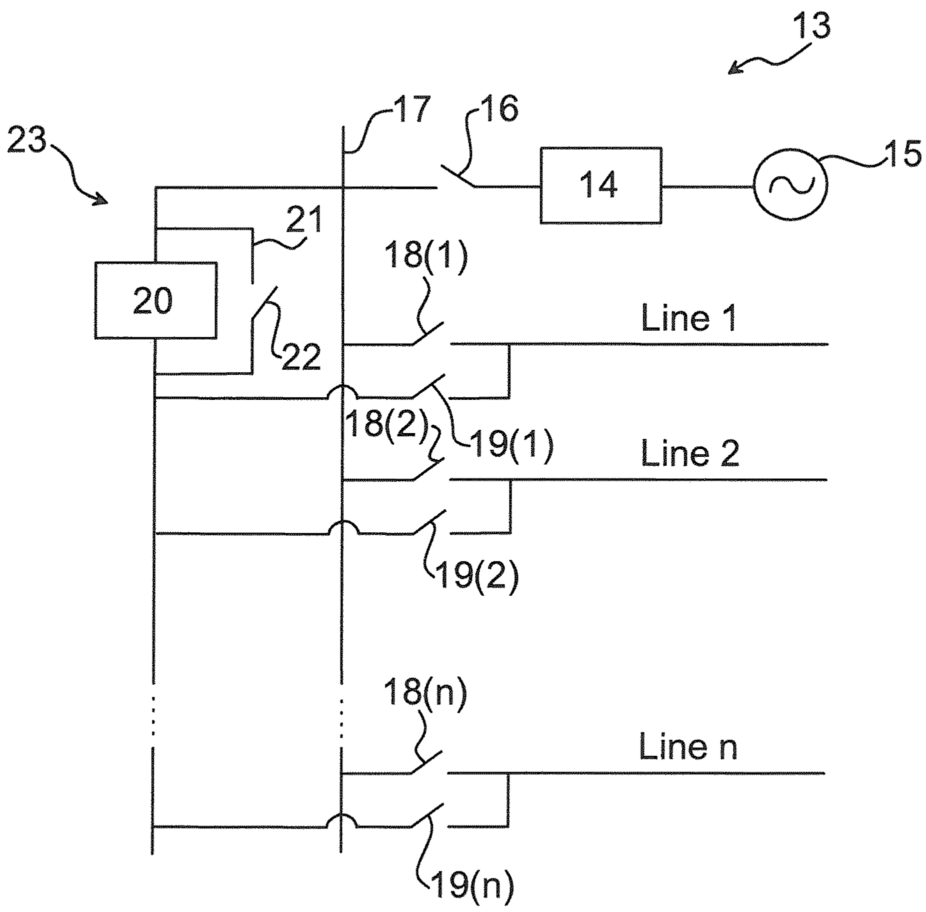
13(c)
Line 1
Line 4
13(b)
12
11
6
5
Line 2
13(a)
Line 3

Fig. 1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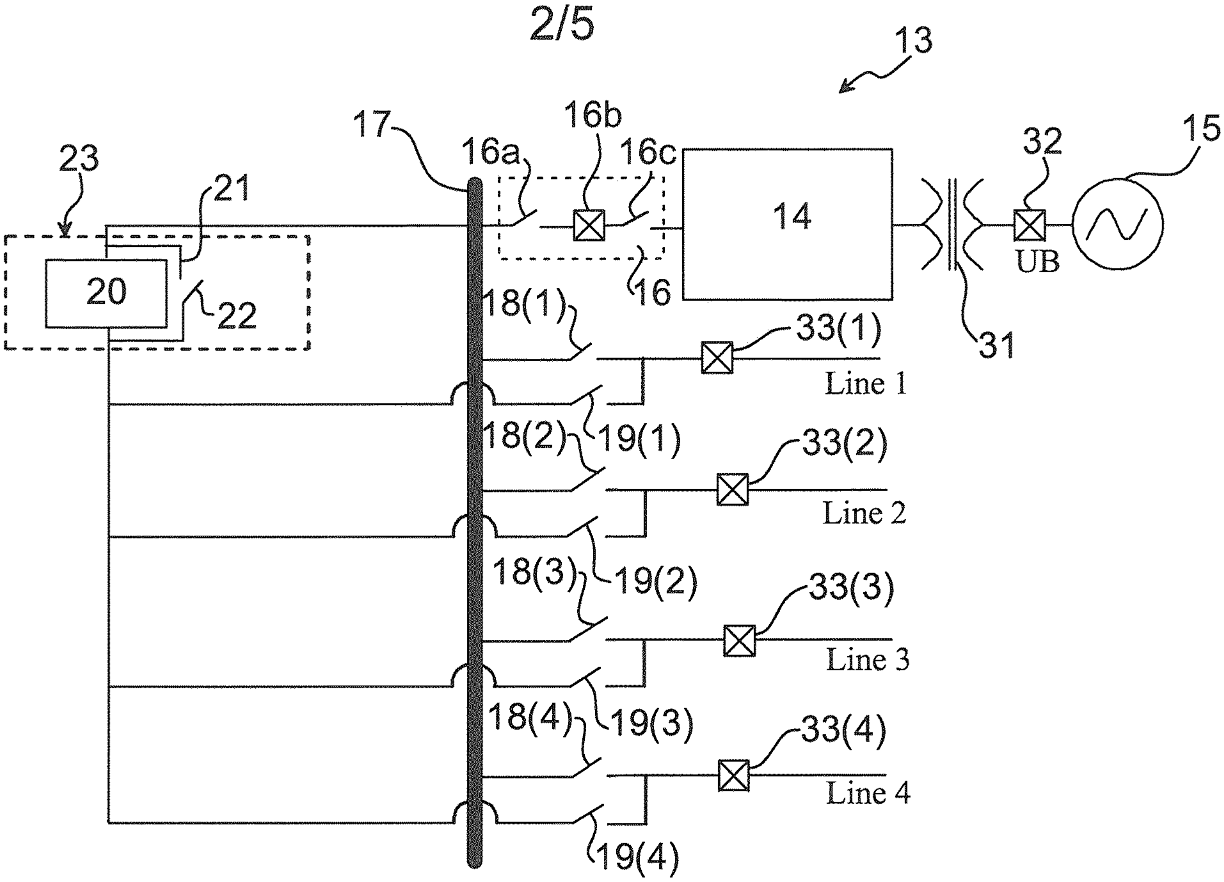
23
17
16
14
15
21
20
22
18(1)
Line 1
18(2)
19(1)
Line 2
19(2)
18(n)
Line n
19(n)

Fig. 2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17
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16c
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18(2)
19(1)
33(2)
Line 2
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Line 3
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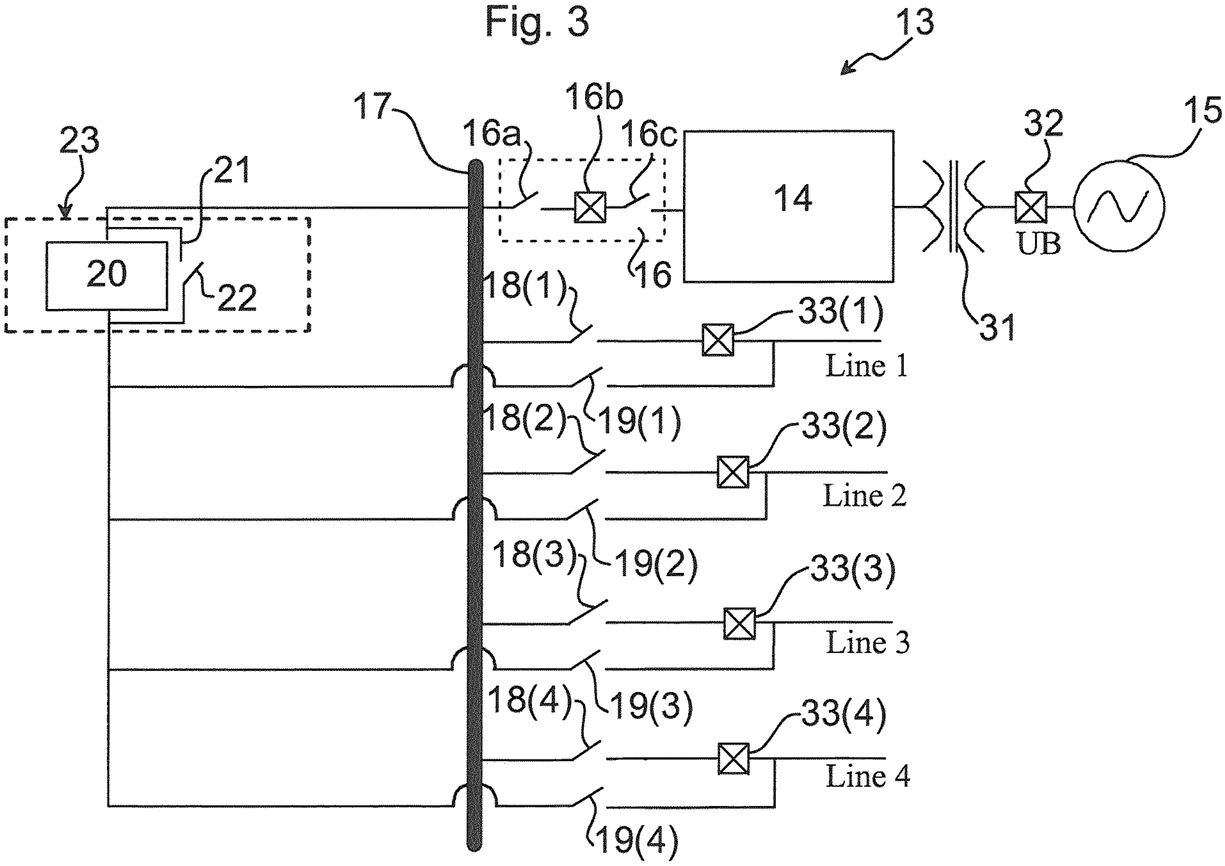
19(3)
33(4)
Line 4
19(4)

Fig. 3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19(1)
33(2)
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Line 3
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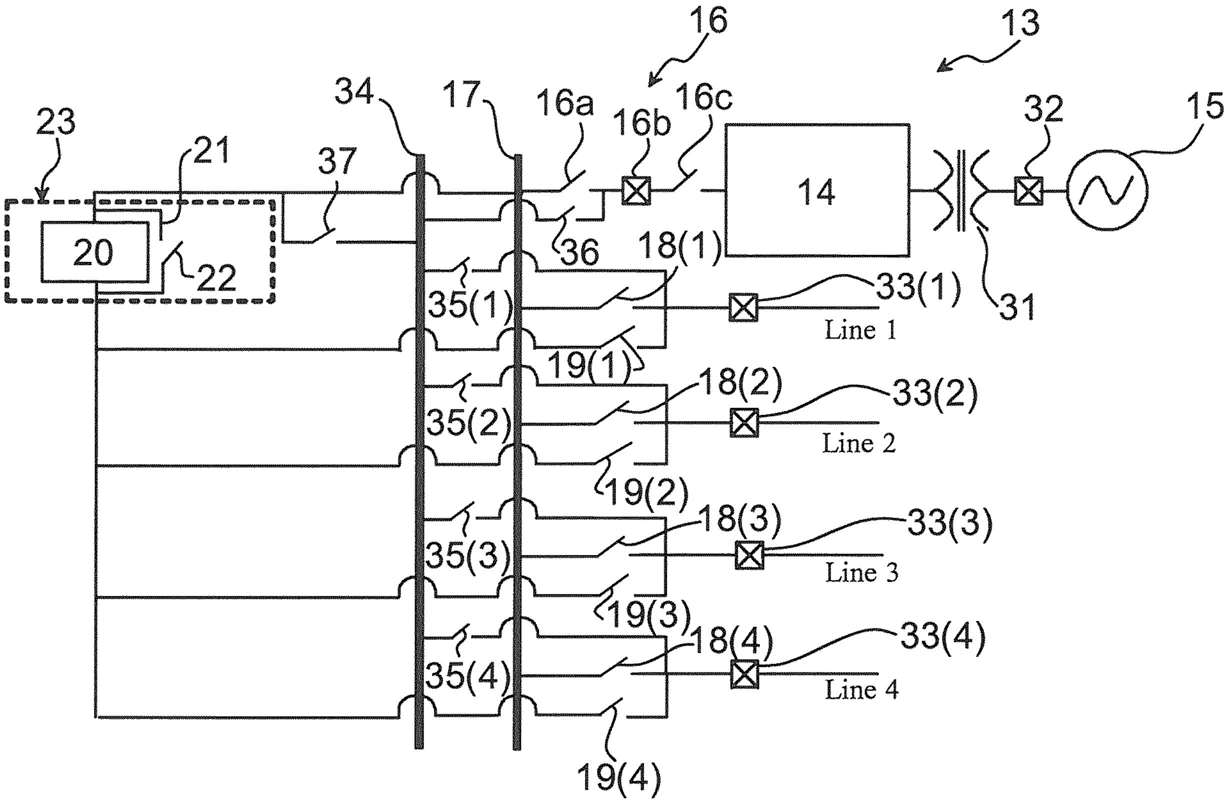
19(3)
33(4)
Line 4
19(4)

Fig. 4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Line 1
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35(2)
Line 2
19(2)
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18(4)
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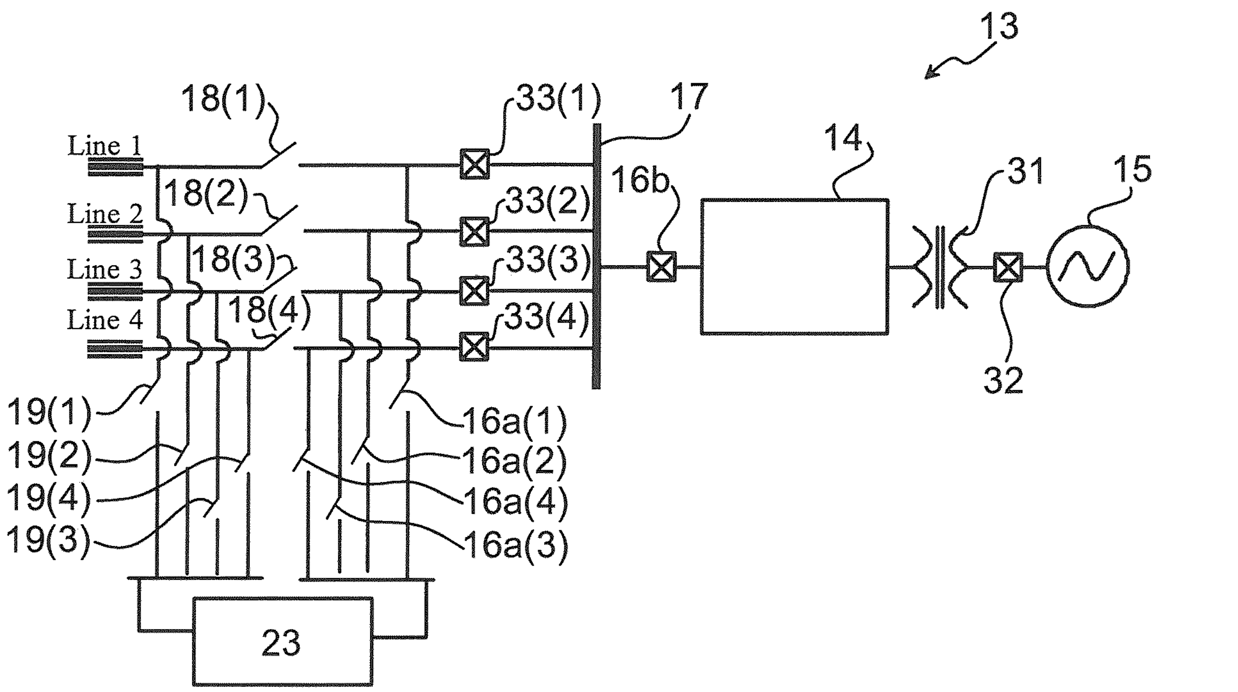
Line 4
19(4)

Fig. 5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17
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15
18(2)
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16b
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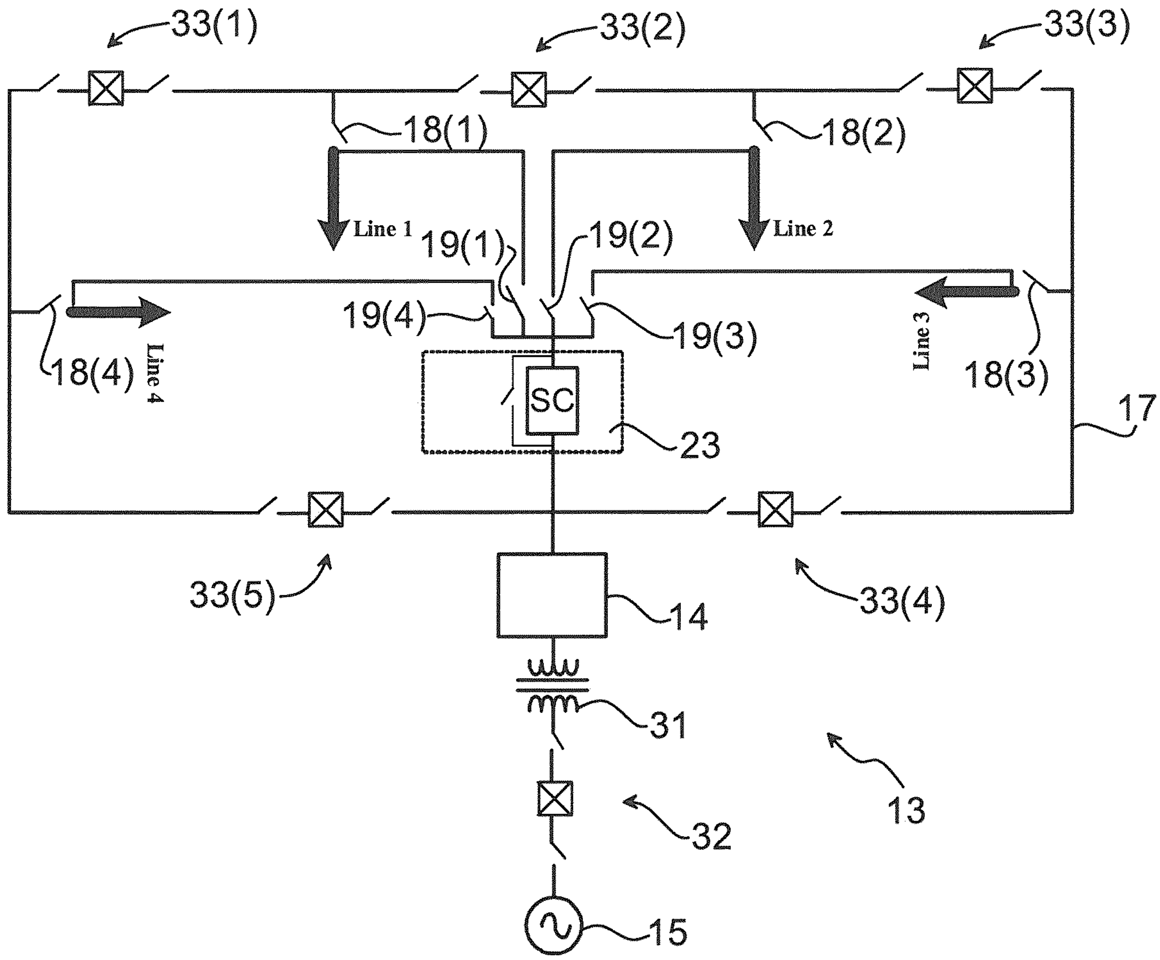
Line 3
18(4)
33(4)
Line 4
32
19(1)
16a(1)
19(2)
16a(2)
19(4)
16a(4)
19(3)
16a(3)
23

Fig. 6


33(1)
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33(3)
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18(2)
Line 1
Line 2
19(1)
19(2)
19(4)
19(3)
Line 3
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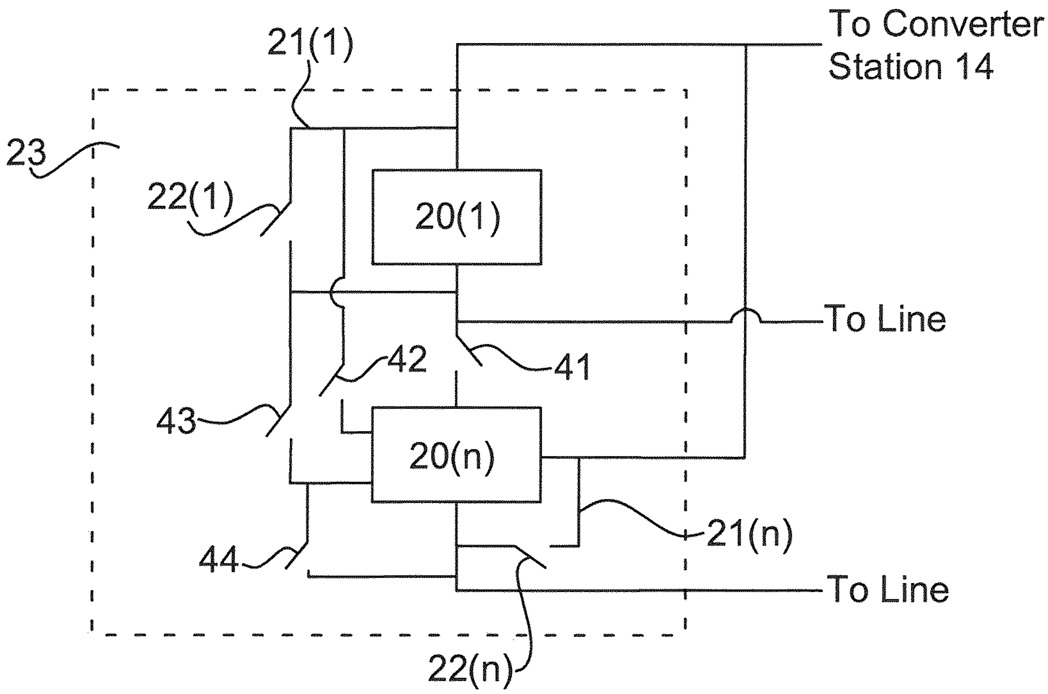
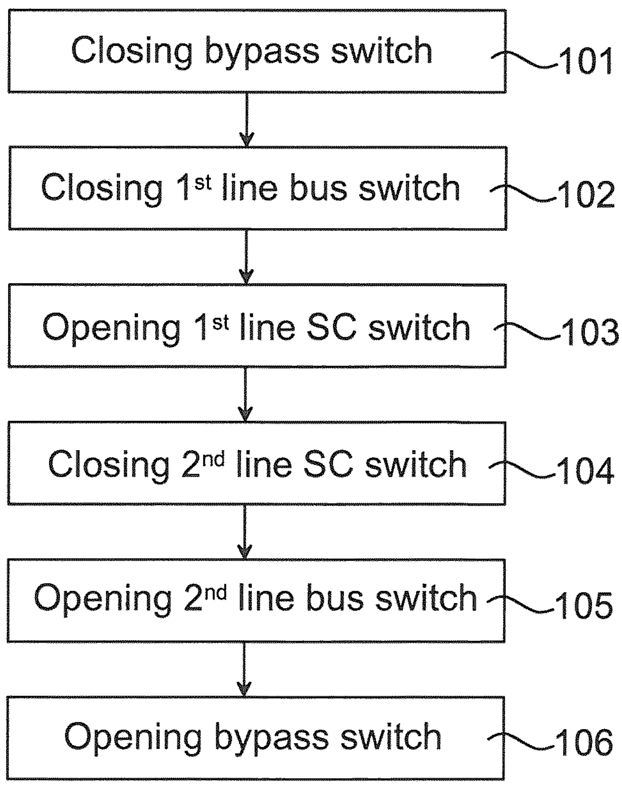
18(3)
SC
17
23
33(5)
33(4)
14
31
13
32
15

Fig. 7



To Converter Station 14
21(1)
23
22(1)
20(1)
To Line
42
41
43
20(n)
21(n)
44
To Line
22(n)

Fig. 8



Closing bypass switch
101
Closing 1st line bus switch
102
Opening 1st line SC switch
103
Closing 2nd line SC switch
104
Opening 2nd line bus switch
105
Opening bypass switch
106

Fig. 9

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2012/055023

A. CLASSIFICATION OF SUBJECT MATTER
INV. H02J3/36
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

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	DE 15 13 827 A1 (SIEMENS AG) 18 September 1969 (1969-09-18) cited in the application the whole document -----	1,11

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents :

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"O" document referring to an oral disclosure, use, exhibition or other means

"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

"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
20 December 2012	10/01/2013

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	Poth, Hartwig

1

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/EP2012/055023

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
DE 1513827 A1	18-09-1969	DE 1513827 A1	18-09-1969
		JP 44010330 B1	14-05-1969