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

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
09 November 2017 (09.11.2017)

WIPO | PCT

(10) International Publication Number
WO 2017/190291 A1

(51) International Patent Classification:
H02J 3/18 (2006.01) *H02J 3/36* (2006.01)

(21) International Application Number:
PCT/CN2016/080981

(22) International Filing Date:
04 May 2016 (04.05.2016)

(25) Filing Language: English

(26) Publication Language: English

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

(72) Inventors; and
(71) Applicants *(for UG only)*: **ANDERSSON, Mats** [SE/CN]; Room 807, Building No. 2, Boya Garden, No. 9 Nongzhanguan South Road, Chaoyang District, Beijing 100125 (CN). **CAI, Rong** [CN/CN]; Room 1401, Building No. 2, Yachengyili, Huangshanmudian Road, Chaoyang District, Beijing 100025 (CN). **XIE, Hailian** [CN/CN]; Hongyuan Apartment B2106, No. 4 Jiuxianqiao Road, Chaoyang District, Beijing 100015 (CN). **ZHANG, Lidong** [SE/SE]; Drevkarlsgatan 4, S-722 45 Vasteras (SE).

(74) Agent: **BOSS&YOUNG PATENT AND TRADEMARK LAW OFFICE**; 5/F., Tower A, GT International Center, Jia 3 Yongandongli, Jianguomenwai Ave., Chaoyang District, Beijing 100022 (CN).

(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, BN, 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, IR, IS, JP, KE, KG, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME, MG, MK, MN,

(54) Title: POWER CONVERSION CIRCUIT, POWER SYSTEM AND METHOD THEREFOR

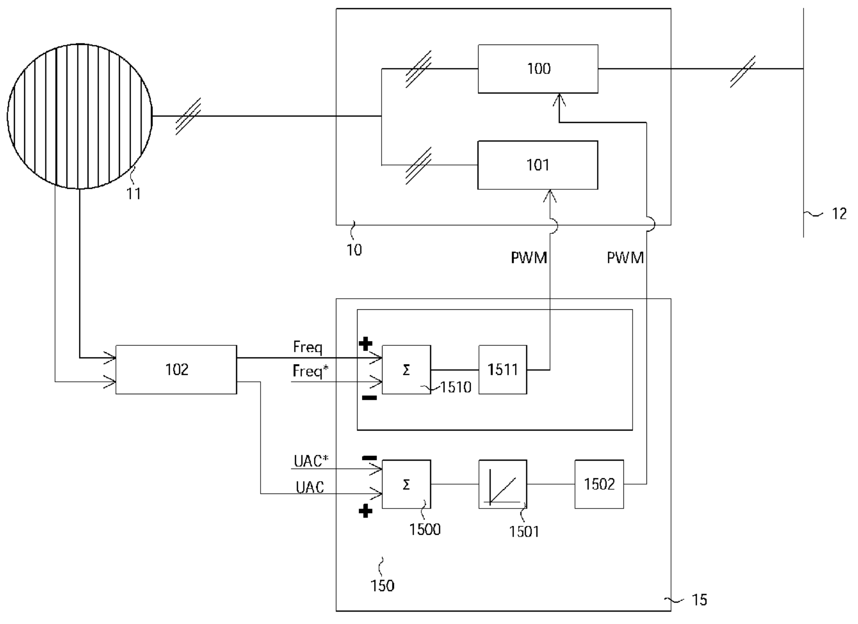

Figure 2

(57) Abstract: It provides a power conversion circuit for interfacing an AC grid to an HVDC transmission line in islanding condition, a power system and the method thereof. The power conversion circuit includes: a current source conversion circuit configured to supply a power output from the AC grid to a load through the HVDC transmission line; a voltage source conversion circuit configured to compensate a reactive AC power of the AC grid; a measurement unit configured to provide a voltage magnitude measurement and a voltage frequency measurement indicative of the AC grid voltage magnitude and the AC grid voltage frequency; and a controller configured to control the current source conversion circuit to adjust an active power balance between the AC grid and the load based on a voltage magnitude deviation of the voltage magnitude measurement from a predetermined voltage magnitude command and control the voltage source conversion circuit to adjust a reactive power balance between the AC grid and the load based on a voltage frequency

WO 2017/190291 A1

[Continued on next page]

MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, 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, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, 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, KM, ML, MR, NE, SN, TD, TG).

Published:

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

deviation of the voltage frequency measurement from a predetermined voltage frequency command. This makes it possible for reducing the complexity of the control for distributed system and thus increasing the power system stability.

POWER CONVERSION CIRCUIT, POWER SYSTEM AND METHOD THEREFOR

Technical Field

The invention relates to DC distribution, and more particularly to balancing the load in DC distribution networks under islanded AC network condition.

Background Art

AC grids are known for distribution of electric power. A utility power generator is generally known to provide a substantial amount of power to the AC grid, while distributed power sources, such as wind turbine generators and fuel cells, are connected to the AC grid to provide a local grid power and reduced dependence on the utility power generator. In order to transmit the power generated by utility power generator and the distributed power sources over long distance to a load, a power conversion circuit may be used for interfacing the AC grid and an HVDC transmission line. A current source conversion circuit, such as line-commutated converter, can be an option for the power conversion circuit.

Each of the distributed power sources is connected to the AC grid through a converter to provide consistent and efficient coupling of the distributed power source to the AC grid. Under certain conditions, the AC grid may experience one or more grid fault events, such as low voltage, high voltage, zero voltage, low frequency, high frequency, phase jumping, etc. The utility power generator may be disconnected from the AC grid, leaving distributed power sources connected to the loads, which is referred to as islanding.

According to conventional analysis of islanding operation, an active power unbalance in the AC grid system is reflected in the AC voltage frequency, and a reactive power unbalance in the AC grid is reflected in the AC voltage amplitude.

On the contrary, it is described in a paper "Intentional Islanded Operation of Converter Fed Microgrids", Charles K. Sao, Peter W. Lehn, IEEE Power Engineering Society General Meeting, Montreal, Canada, June 18-22, 2006 that the AC grid voltage amplitude depends on the active power balance between the converter and the load, while the frequency is determined by the reactive power balance. The microgrid voltage (AC grid voltage) and frequency control scheme is synthesized to allow converters of the distributed power sources with standard inductor interface and dq frame current control to operate in islanding mode.

However, in order to coordinate a number of converters of the distributed power sources, there is a need for inter-converter signal exchange, which increases the complexity of the power system and thus reduces the stability of the power system. Furthermore, if signal relay stations in between two converter have a blackout, the power balancing is not achieved in a reliable manner.

Brief Summary of the Invention

According to one aspect of present invention, it provides a power conversion circuit for interfacing an AC grid to an HVDC transmission line in islanding condition, including: a current source conversion circuit configured to supply a power output from the AC grid to a load through the HVDC transmission line; a voltage source conversion circuit configured to compensate a reactive AC power of the AC grid; a measurement unit configured to provide a voltage magnitude measurement and a voltage frequency measurement indicative of the AC grid voltage magnitude and the AC grid voltage frequency; and a controller configured to control the current source conversion circuit to adjust an active power balance between the AC grid and the load based on a voltage magnitude deviation of the voltage magnitude measurement from a predetermined voltage magnitude command and control the voltage source conversion circuit to adjust a reactive power balance between the AC grid and the load based on a voltage frequency deviation of the voltage frequency measurement from a predetermined voltage frequency command.

According to another aspect of present invention, it provides a power system, including: the power conversion circuit interface the AC grid to the HVDC transmission line, the AC grid; and a plurality of power-electronics-based generators configured to supply power to the AC grid.

According to another aspect of present invention, it provides a method for use in interfacing an AC grid to an HVDC transmission line in islanding condition, including: converting a power output from the AC grid with use of current source conversion circuit and supplying the converted power to a load through the HVDC transmission line; compensating a reactive AC power of the AC grid with a voltage source conversion circuit; providing a voltage measurement and a voltage frequency measurement indicative of the AC grid voltage and the AC grid voltage frequency; and controlling the current source conversion circuit to adjust an active power balance between the AC grid and the load based on a voltage deviation of the voltage measurement from a predetermined voltage command and control the voltage source conversion circuit to adjust a reactive power balance between the AC grid and the load based on a voltage frequency deviation of the voltage frequency measurement from a predetermined voltage frequency command.

The power conversion circuit interfacing the AC grid and the HVDC transmission line and the method thereof can centrally regulate the active power balance and the reactive power balance between the AC grid and the load as of DC power transmitted to the power consumers. The centralized control according to present invention mainly addresses the line commutation conversion circuit and the voltage source conversion circuit of the power conversion circuit, leaving the converters of the distributed power sources operating under normal control. This makes it possible for reducing the complexity of the control for distributed system and thus increasing the power system stability. Furthermore, the centralized control involves a relatively small number of power conversion circuits, such as the current source conversion circuit and the voltage source conversion circuit. Therefore, their installation locations are relatively less restricted. For example, they can be installed in a substation of the HVDC system. This thereby increases the flexibility of the deployment of the HVDC system. Preferably, the measurement unit 102 can be arranged in the substation, too.

Preferably, the power conversion circuit further includes: a reactive power source element; a reactive power sink element; a shunt configured to switch between connection of the reactive power source element and the reactive power sink element with the AC grid; wherein: the controller is further configured to control the switch of the shunt to tune the adjusted reactive power balance between the AC grid and the load based on the voltage frequency deviation of the voltage frequency measurement from a predetermined voltage frequency command. If the measured AC voltage frequency is higher than the command, the voltage source conversion circuit injects more capacitive reactive power to the AC grid;

otherwise, the voltage source conversion circuit injects more inductive reactive power to the AC grid. This makes it possible to compensate the capacity of the current source conversion circuit due to its reactive power limit.

Preferably, the power conversion circuit further includes a filter, and the controller is further configured to control the filter to tune the adjusted reactive power balance between the AC grid and the load based on the voltage frequency deviation of the voltage frequency measurement from a predetermined voltage frequency command. Similar to the above analysis, it makes it possible to compensate the capacity of the current source conversion circuit due to its reactive power limit, as well.

Preferably, the current source conversion circuit is a line-commutated converter, and the voltage source conversion circuit is a static synchronous compensator.

Preferably, the current source conversion circuit and the voltage source conversion circuit are disposed in a substation. This thereby increases the flexibility of the deployment of the HVDC system. Preferably, the measurement unit can be arranged in the substation, too.

Preferably, the current source conversion circuit is disposed in a location closer to the voltage source conversion circuit than any of the plurality of the power-electronics-based generators. Consequently, the signal exchange concerning the power balancing of the power system travels on a relatively short communication route. This decreases the response time of the power system. Furthermore, if signal relay stations in between the converters of the distributed power sources have a blackout, the power balancing operation will be not affected.

Brief Description of the Drawings

The subject matter of the invention will be explained in more detail in the following text with reference to preferred exemplary embodiments which are illustrated in the drawings, in which:

Figure 1 illustrates a power system according to an embodiment of present invention;

Figure 2 illustrates a diagram of the power conversion circuit according to an embodiment of present invention; and

Figure 3 illustrates a diagram of the power conversion circuit according to another embodiment of present invention.

The reference symbols used in the drawings, and their meanings, are listed in summary form in the list of reference symbols. In principle, identical parts are provided with the same reference symbols in the figures.

Preferred Embodiments of the Invention

In the following description, for purposes of explanation and not limitation, specific details are set forth, such as particular circuits, circuit components, interfaces, techniques, etc. in order to provide a thorough understanding of the present invention. However, it will be apparent to one skilled in the art that the present invention may be practiced in other embodiments that depart from these specific details. In other instances, detailed descriptions of well-known methods and programming procedures, devices, and circuits are omitted so not to obscure the description of the present invention with unnecessary detail.

Figure 1 illustrates a power system according to an embodiment of present invention. As shown in figure 1, the power system 1 includes a power conversion circuit 10, an AC grid 11, and an HVDC transmission line 12, a utility power generator 13, a plurality of distributed power sources 14, and a controller 15. The power conversion circuit 10 is configured to interface the AC grid 11 and the HVDC transmission line 12 for converting the AC power suppled from the AC grid 11 and output the converted power to the HVDC transmission line 12 which in turn transmits the DC power to power consumers (load). The utility power generator 13 is coupled to the AC grid 11 through a switch 16, being configured to provide a relatively major portion of power to the AC grid 11, as compared to each of the distributed power sources 14. The utility power generator 13 may include a hydro, nuclear, coal, or natural gas power generator. Each of the distributed power sources 14 is coupled to the AC grid 11 through its converter 140 and a switch 17. Each distributed power source may include one or more photovoltaic cells, wind turbines, hydroelectric generators, fuel generators, and other power generator devices, etc. In normal condition, the controller 15 may control to close the switch 16 and all or some of the switches 17 so that the utility power generator 13 provides a substantial amount of power to the AC grid 11, while distributed power sources 14 are connected to the AC grid 11 to provide a local grid power. In islanding condition, the controller 15 may control to open the switch 16 and close all or some of the switches 17 so that the connected distributed power sources 14 supply power to the AC grid 11. The controller 15 may be further configured to control the power conversion circuit 10 to operate adjusting the active power and reactive power balance between the AC grid 11 and the load. The skilled person should understand that the control of power balancing can be performed by a separate controller communicating with the controller 15.

Figure 2 illustrates a diagram of the power conversion circuit 10 according to an embodiment of present invention. As shown in figure 2, the power conversion circuit 10 includes a current source conversion circuit 100, a voltage source conversion circuit 101, and a measurement unit 102. An input of the current source conversion circuit 100 is coupled to the AC grid 11 and an output of the current source conversion circuit 100 is coupled to the HVDC transmission line 12, for supplying a power output from the AC grid 11 to the load through the HVDC transmission line 12. The current source conversion circuit 100 includes switching devices having characteristics of current reversal turn off, such as thyristors. The current source conversion circuit 100 is configured such that its conversion process relies on the line voltage of the AC grid 11 to which it is connected in order to effect the commutation from one switching device to its neighbour. In current source conversion circuit, the DC current does not change direction; it flows through a large inductance and can be considered almost constant. On the AC side, the converter behaves approximately as a current source, injecting both grid-frequency and harmonic currents into the AC grid. For example, the current source conversion circuit 100 can be a line-commutated converter.

As shown in figure 2, the input of the voltage source conversion circuit 101 is coupled to the AC grid 11 and an output of the voltage source conversion circuit 101 is coupled to the HVDC transmission line 12, for compensating a reactive AC power of the AC grid 11. The voltage source conversion circuit 101 includes switching devices having characteristics of gate turn on and gate turn off, such as IGBTs. In the voltage source conversion circuit, the polarity of DC voltage is usually fixed and the DC voltage, being smoothed by a large capacitance, can be considered constant. The additional controllability gives many advantages, notably the ability to switch the IGBTs on and off many times per cycle in order to improve the harmonic performance, and the fact that (being self-commutated) the voltage source conversion circuit no longer relies on synchronous machines in the AC system for its operation. In contrast to current source conversion circuit, the voltage source conversion circuit maintains a constant polarity of DC voltage and power reversal is achieved instead by reversing the direction of current. The voltage source conversion circuit can act as either a source or sink of reactive AC power to an AC grid. The voltage source is created from a DC capacitor and therefore a voltage source conversion circuit has very little active power capability. The reactive power at the terminals of the voltage source conversion circuit depends on the frequency of the voltage source. For example, if the terminal frequency of the voltage source conversion circuit is higher than the AC grid voltage frequency at the point of connection, the voltage source conversion circuit generates reactive power; conversely, when the frequency of the voltage source is lower than the AC grid voltage frequency, it absorbs reactive power. For example, the voltage source conversion circuit 101 is a static synchronous compensator.

The power conversion circuit 10 further includes a measurement unit 102 coupled to the AG grid 11. The measurement unit 102 is configured to provide a voltage magnitude measurement UAC and a voltage frequency measurement Freq indicative of the AC grid voltage and the AC grid voltage frequency. For example, the measurement unit 102 may include a voltmeter for measuring the voltage, a bandpass filter to extract only the fundamental frequency, a frequency measurement based on voltage zero crossings, and an amplitude measurement based on peak values.

The controller 15 is configured to control the current source conversion circuit 100 to adjust an active power balance between the AC grid 11 and the load based on a voltage magnitude deviation of the voltage magnitude measurement UAC from a predetermined voltage magnitude command UAC* and control the voltage source conversion circuit 101 to adjust a reactive power balance between the AC grid 11 and the load based on a voltage frequency deviation of the voltage frequency measurement Freq from a predetermined voltage frequency command Freq*. In the exemplary embodiment, the controller 15 is coupled to the current source conversion circuit 100, the voltage source conversion circuit 101, and the measurement unit 102. The controller 15 includes an active power regulator 150 and a reactive power regulator 151. The active power regulator 150 responds to the voltage magnitude measurement UAC from the measurement unit 102 and the predetermined voltage magnitude command UAC* to control the current source conversion circuit 100. The values for the commands UAC* and Freq* can be set arbitrarily, in a preferred embodiment they are set to the nominal AC network values.

As shown in figure 2, more specifically, the active power regulator 150 includes a comparator 1500, a proportional integral control module 1501 and a modulator 1502 coupled in the signal flow direction. During operation, the measurement unit 102 provides to the comparator 1500 a feedback signal indicative of the voltage magnitude measurement UAC of the AC grid 11, which is provided with the predetermined voltage magnitude command UAC*, as well. In turn, the comparator 1500 calculates the deviation of the voltage magnitude measurement UAC from a predetermined voltage magnitude command UAC* and provides the deviation to the proportional integral control module 1501. For example, the proportional integral control module 1501 detects the voltage magnitude deviation of a voltage associated with electric grid 11, such as the voltage at the AC grid 11 or the voltage provided from the current source conversion circuit 100. For example, the voltage magnitude deviation is detected based on a nominal value of the voltage associated with the AC grid 11. If the measured AC voltage amplitude is higher than the command, the proportional integral control module 1501 outputs an increased DC active power order/DC current order. If the measured AC voltage amplitude is lower than command, it outputs a decreased DC active power order/DC current order. Modulator 1502 responds to the order from the proportional integral control module 1501, and is configured to provide a PWM (pulse-width-modulated) signal to switching devices of the current source conversion circuit 100 based on signals from the proportional integral control module 1501. Modulator 1502 outputs the PWM signal with a frequency, angle, and/or duty cycle to provide suitable active power to the HVDC transmission line 12. Preferably, a dead band module may be inserted between the comparator 1500 and the proportional integral control module 1501 since continuously active regulation can be neither necessary nor desirable.

As shown in figure 2, the reactive power regulator 151 includes a comparator 1510 and a modulator 1511 coupled in the signal flow direction. During operation, the measurement unit 102 provides to the comparator 1510 a feedback signal indicative of the voltage frequency measurement Freq of the AC grid 11, which is provided with the predetermined voltage frequency command Freq*, as well. In turn, the comparator 1510 calculates the deviation of the voltage frequency measurement Freq from the predetermined voltage frequency command Freq* and provides the deviation to the modulator 1511. For example, the comparator 1510 calculates the voltage frequency deviation of a voltage associated with electric grid 11, such as the voltage at the AC grid 11 or the voltage provided from the voltage source conversion circuit 101. For example, the voltage frequency deviation is detected based on a nominal value of the voltage frequency associated with the AC grid 11. For example, where the voltage source conversion circuit 101 is common dq-frame controlled, if the measured AC voltage frequency is higher than the command, the comparator 1510 outputs an increased Δiq current reference, according to which the voltage source conversion circuit 101 injects more capacitive reactive power to the AC grid 11. If the measured AC voltage frequency is lower than the command, the comparator 1510 outputs a decreased Δiq current reference, according to which the voltage source conversion circuit 101 injects more inductive reactive power to the AC grid 11. Modulator 1511 responds to the reference from the comparator 1510, and is configured to provide a PWM (pulse-width-modulated) signal to switching devices of the voltage source conversion circuit 101 based on signals from the comparator 1510. Modulator 1511 outputs the PWM signal with a frequency, angle, and/or duty cycle to provide suitable reactive power to the AC grid 11. Preferably, a low pass filter and/or a dead band module may be inserted between the comparator 1510 and the modulator 1511 since continuously active regulation can be neither necessary nor desirable.

In this manner, the power conversion circuit 10 interfacing the AC grid 11 and the HVDC transmission line 12 centrally regulates the active power balance and the reactive power balance between the AC grid 11 and the load as of DC power transmitted to the power consumers. The centralized control according to present invention mainly addresses the line commutation conversion circuit 100 and the voltage source conversion circuit 101 of the power conversion circuit 10, leaving the converters of the distributed power sources 14 operating under normal control. This makes it possible for reducing the complexity of the control for distributed system and thus increasing the power system stability. Furthermore, the centralized control involves a relatively small number of power conversion circuits, such as the current source conversion circuit 100 and the voltage source conversion circuit 101. Therefore, their installation locations are relatively less restricted. For example, they can be installed in a substation of the HVDC system. This thereby increases the flexibility of the deployment of the HVDC system. Preferably, the measurement unit 102 can be arranged in the substation, too.

As an alternative, the current source conversion circuit 100 can be installed in a location closer to the voltage source conversion circuit 101 than any of the plurality of the power-electronics-based generators 14. Consequently, the signal exchange concerning the power balancing of the power system travels on a relatively short communication route. This decreases the response time of the power system. Furthermore, if signal relay stations in between the converters of the distributed power sources have a blackout, the power balancing operation will be not affected.

Figure 3 illustrates a diagram of the power conversion circuit 10 according to another embodiment of present invention. Depending on operational circumstances of the power conversion circuit 10, its voltage source conversion circuit 101 might be close to, or at its reactive power limits (either very/fully capacitive or very/fully inductive reactive power output). In addressing such a situation, as shown in figure 3, the power conversion circuit 10 further includes a reactive power source element 103, a reactive power sink element 104 and a shunt 106. The shunt 106 is configured to switch among connection of the reactive power source element 103 and the reactive power sink element 104 with the AC grid 11. In the exemplary embodiment, the reactive power source element 103 and the reactive power sink element 104 may be capacitor, reactor or AC filter. The controller 15 is further configured to control the switch of the shunt 106, in order to optimize the ability of voltage source conversion circuit 101 to tune the adjusted reactive power balance between the AC grid 11 and the load based on the voltage frequency deviation of the voltage frequency measurement from a predetermined voltage frequency command. According to the discussion of figure 2, if the measured AC voltage frequency is higher than the command, the voltage source conversion circuit 101 injects more capacitive reactive power to the AC grid 11; otherwise, the voltage source conversion circuit 101 injects more inductive reactive power to the AC grid 11. In this exemplary embodiment, the reactive power regulator 106 of the power conversion circuit 10 may further include an absolute value module 1061 coupled to the comparator 1062. The threshold module 1603 detects that the voltage source conversion circuit 101 is operating close to, or at or at its reactive power limits, and initiates a shunt switch command. Q_STATCOM is the reactive power output from 101, while Q_STATCOM* is the reference value (for exampel, practical value would be something like 0.8 p.u of the STATCOM rated power).

In the exemplary embodiments, controller 15 is implemented in one or more processing devices, such as a microcontroller, a microprocessor, a programmable gate array, a reduced instruction set circuit (RISC), an application specific integrated circuit (ASIC), etc. Accordingly, in the exemplary embodiments, the comparator 1500, the proportional integral control module 1501, the modulator 1502, the comparator 1510, the modulator 1511, and/or the threshold module 1512 are constructed of software and/or firmware embedded in one or more processing device. In this manner, controller 15 is programmable, such that instructions, intervals, thresholds, and/or ranges, etc. may be programmed for the current source conversion circuit 100 and the voltage source conversion circuit 101. As shown, the measurement unit 102 is separate from the controller 15, and thus separate from the processing device. In other embodiments, the measurement unit 102 may be integrated and/or programmed into one or more processing devices utilized to provide controller 15. Likewise, one or more of the comparator 1500, the proportional integral control module 1501, the modulator 1502, the comparator 1510, the modulator 1511, and the threshold module 1512 may be wholly or partially provide by discrete components, external to one or more processing devices.

Though the present invention has been described on the basis of some preferred embodiments, those skilled in the art should appreciate that those embodiments should by no way limit the scope of the present invention. Without departing from the spirit and concept of the present invention, any variations and modifications to the embodiments should be within the apprehension of those with ordinary knowledge and skills in the art, and therefore fall in the scope of the present invention which is defined by the accompanied claims.

CLAIMS

1. A power conversion circuit for interfacing an AC grid to an HVDC transmission line in islanding condition, including:

   a current source conversion circuit configured to supply a power output from the AC grid to a load through the HVDC transmission line;

   a voltage source conversion circuit configured to compensate a reactive AC power of the AC grid;

   a measurement unit configured to provide a voltage magnitude measurement and a voltage frequency measurement indicative of the AC grid voltage magnitude and the AC grid voltage frequency; and

   a controller configured to control the current source conversion circuit to adjust an active power balance between the AC grid and the load based on a voltage magnitude deviation of the voltage magnitude measurement from a predetermined voltage magnitude command and control the voltage source conversion circuit to adjust a reactive power balance between the AC grid and the load based on a voltage frequency deviation of the voltage frequency measurement from a predetermined voltage frequency command.

2. The power conversion circuit according to claim 1, further including:

   a reactive power source element;

   a reactive power sink element;

   a shunt configured to switch between connection of the reactive power source element and the reactive power sink element with the AC grid;

   wherein:

   the controller is further configured to control the switch of the shunt to tune the adjusted reactive power balance between the AC grid and the load based on the voltage frequency deviation of the voltage frequency measurement from a predetermined voltage frequency command.

3. The power conversion circuit according to claim 1, further including:

   a filter;

   the controller is further configured to control the filter to tune the adjusted reactive power balance between the AC grid and the load based on the voltage frequency deviation of the voltage frequency measurement from a predetermined voltage frequency command.

4. The power conversion circuit according to any of the preceding claims, wherein:

   the current source conversion circuit is a line-commutated converter; and

   the voltage source conversion circuit is a static synchronous compensator.

5. The power conversion circuit according to any of the preceding claims, wherein:

   the current source conversion circuit and the voltage source conversion circuit are disposed in a substation.

6. The power conversion circuit according to claim 5, wherein:

   the measurement unit is arranged in the substation.

7. A power system, including:

   the power conversion circuit according to any of the preceding claims;

   the AC grid; and

   a plurality of power-electronics-based generators configured to supply power to the AC grid.

8. The power system according to claim 7, wherein:

   the current source conversion circuit is disposed in a location closer to the voltage source conversion circuit than any of the plurality of the power-electronics-based generators.

9. A method for use in interfacing an AC grid to an HVDC transmission line in islanding condition, including:

   converting a power output from the AC grid with use of current source conversion circuit and supplying the converted power to a load through the HVDC transmission line;

   compensating a reactive AC power of the AC grid with a voltage source conversion circuit;

   providing a voltage measurement and a voltage frequency measurement indicative of the AC grid voltage and the AC grid voltage frequency; and

   controlling the current source conversion circuit to adjust an active power balance between the AC grid and the load based on a voltage deviation of the voltage measurement from a predetermined voltage command and control the voltage source conversion circuit to adjust a reactive power balance between the AC grid and the load based on a voltage frequency deviation of the voltage frequency measurement from a predetermined voltage frequency command.

10. The method according to claim 9, wherein:

    the current source conversion circuit is a line-commutated converter; and

    the voltage source conversion circuit is a static synchronous compensator.

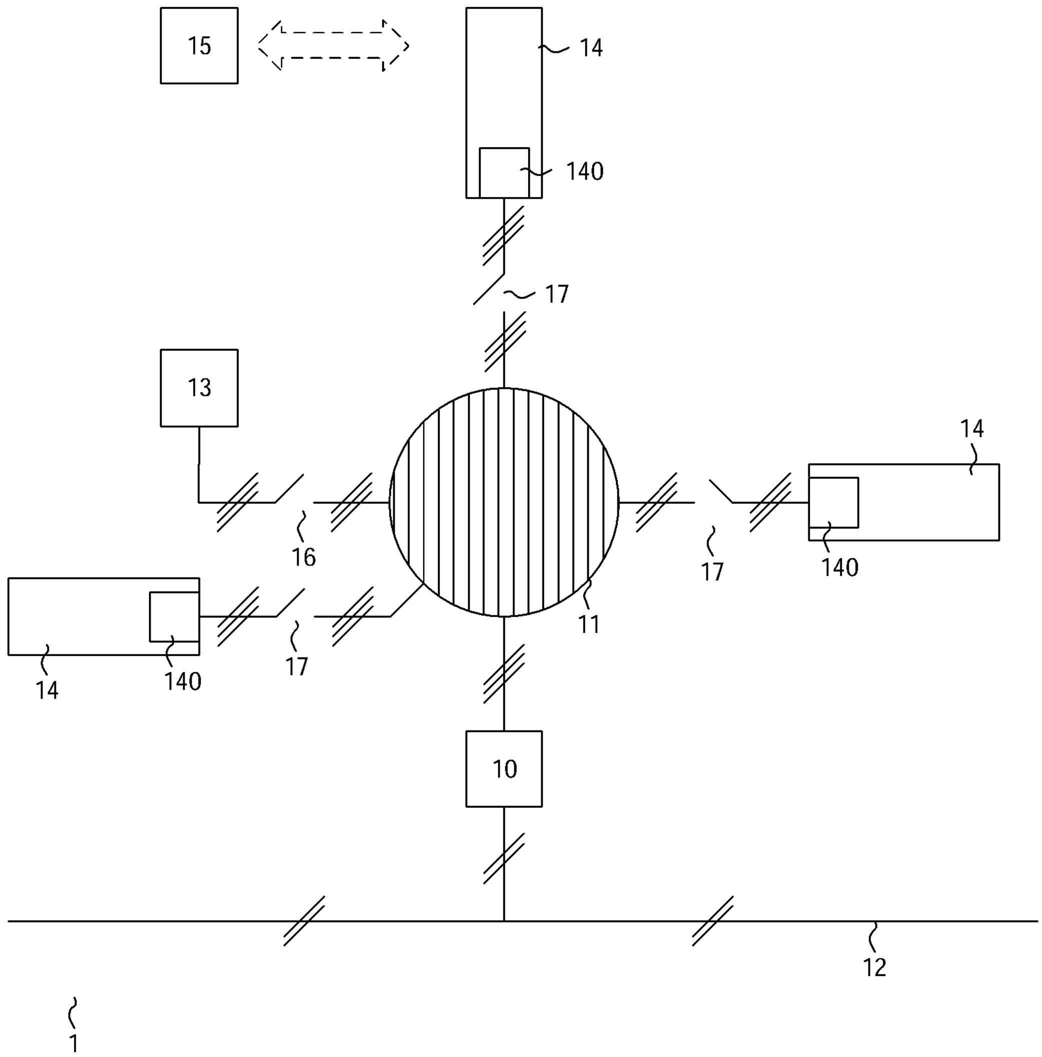

Figure 1

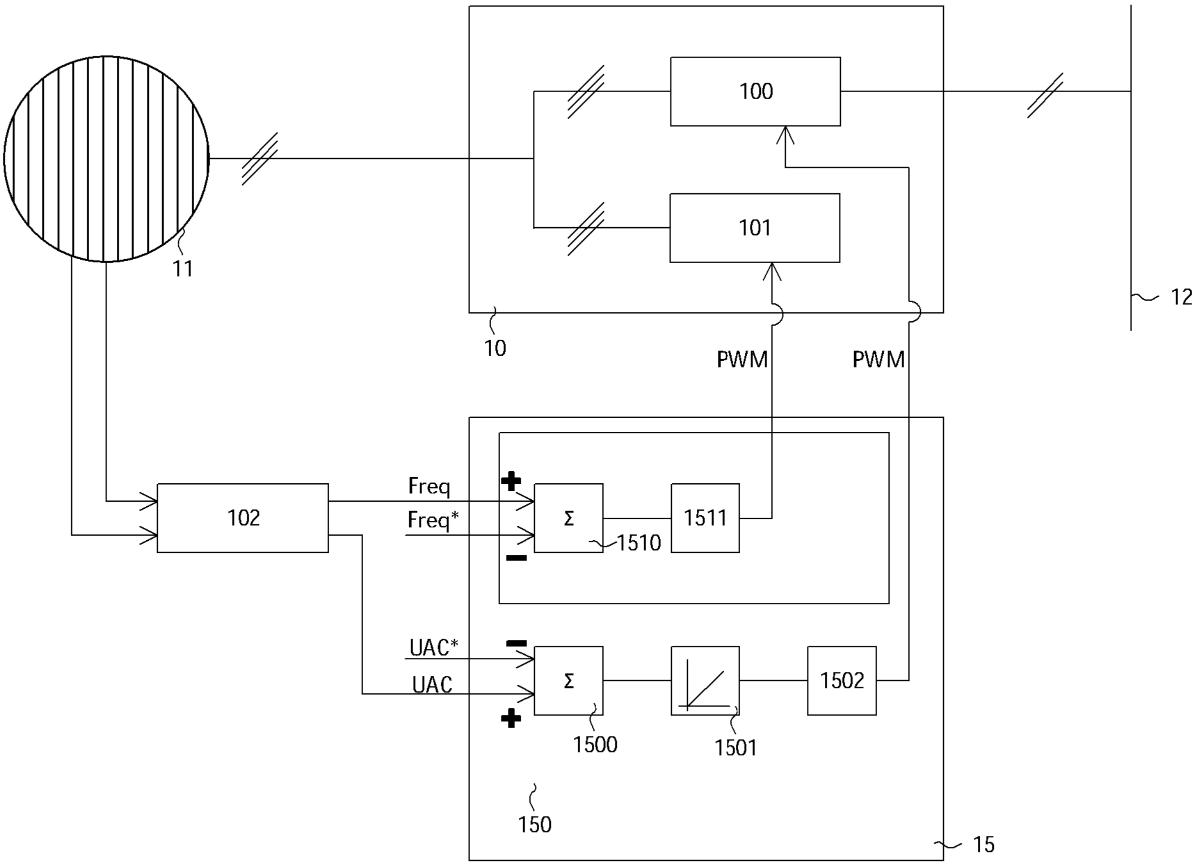
100
101
11
10
12
PWM
PWM
102
Freq
Freq*
Σ
1510
1511
UAC*
UAC
Σ
1500
1501
1502
150
15

Figure 2

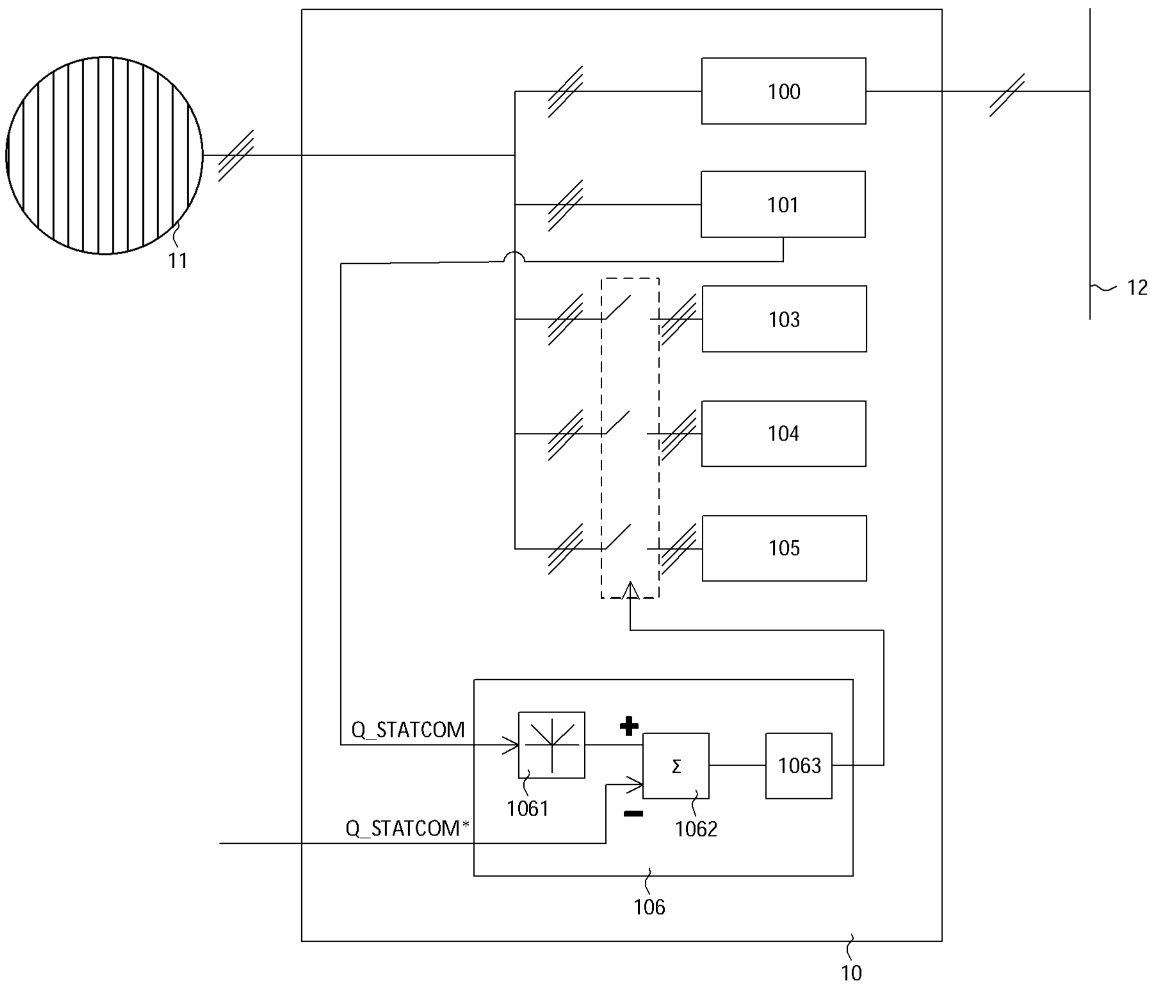
100
101
11
103
104
105
12
Q_STATCOM
+
Σ
1063
1061
1062
Q_STATCOM*
106
10

Figure 3

INTERNATIONAL SEARCH REPORT

International application No.
PCT/CN2016/080981

A. CLASSIFICATION OF SUBJECT MATTER

H02J 3/18(2006.01)i; H02J 3/36(2006.01)i

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)

DWPI, CNABS, CNTXT, CNKI: HVDC, current source conversion circuit, voltage source conversion circuit, line-commutated converter, static synchronous compensator, LCC, STATCOM, active power, reactive power

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	CN 102904242 A (UNIV NORTH CHINA ELECTRIC POWER) 30 January 2013 (2013-01-30) description, paragraphs [0023]-[0026], and figure 1	1-10
Y	CN 102222922 A (UNIV HUNAN) 19 October 2011 (2011-10-19) description, paragraphs [0042]-[0072], and figures 1-3	1-10
A	CN 104967141 A (XJ ELECTRIC CO LTD ET AL.) 07 October 2015 (2015-10-07) the whole document	1-10
A	US 2015035371 A1 (AHMED S ET AL.) 05 February 2015 (2015-02-05) the whole document	1-10

☐ Further documents are listed in the continuation of Box C.　☑ 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
- "E" earlier application or patent but published on or after the international filing date
- "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
- "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
16 January 2017	**07 February 2017**

Name and mailing address of the ISA/CN	Authorized officer
STATE INTELLECTUAL PROPERTY OFFICE OF THE P.R.CHINA **6, Xitucheng Rd., Jimen Bridge, Haidian District, Beijing 100088** **China**	**SHI,Weiping**
Facsimile No. **(86-10)62019451**	Telephone No. **(86-10)62089414**

Patent document cited in search report			Publication date (day/month/year)	Patent family member(s)			Publication date (day/month/year)
CN	102904242	A	30 January 2013	CN	102904242	B	15 April 2015
CN	102222922	A	19 October 2011	CN	102222922	B	23 January 2013
CN	104967141	A	07 October 2015		None		
US	2015035371	A1	05 February 2015	US	9236743	B2	12 January 2016
				WO	2015017682	A1	05 February 2015