(19) DANMARK

(10) **DK/EP 3042429 T3**

Patent- og
Varemærkestyrelsen

(12) Oversættelse af
europæisk patentskrift

(51) Int.Cl.: ***H 02 J 3/38 (2006.01)*** ***H 02 J 3/46 (2006.01)*** ***H 02 J 3/48 (2006.01)***

(45) Oversættelsen bekendtgjort den: **2025-01-13**

(80) Dato for Den Europæiske Patentmyndigheds
bekendtgørelse om meddelelse af patentet: **2024-11-06**

(86) Europæisk ansøgning nr.: **13753891.4**

(86) Europæisk indleveringsdag: **2013-09-03**

(87) Den europæiske ansøgnings publiceringsdag: **2016-07-13**

(86) International ansøgning nr.: **EP2013068163**

(87) Internationalt publikationsnr.: **WO2015032420**

(84) Designerede stater: **AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR**

(73) Patenthaver: **Hitachi Energy Ltd, Brown-Boveri-Strasse 5, 8050 Zürich, Schweiz**

(72) Opfinder: **MAJUMDER, Ritwik, Klockartorpsgatan 34A, S-723 44 Västerås, Sverige**

(74) Fuldmægtig i Danmark: **Dennemeyer & Associates S.A, P.O. Box 700425, DE-81304 Munich, Tyskland**

(54) Benævnelse: **MIKRONET MED REDUNDANTE PUNKTER MED FÆLLES KOBLING OG FREMGANGSMÅDE TIL KONTROL TIL DETTE, FOR REDUKTION AF RISIKO FOR SEKTIONERING AF MIKRONETTET**

(56) Fremdragne publikationer:
EP-A1- 2 600 479
WO-A2-2012/032111
US-A1- 2013 155 734
RITWIK MAJUMDER: "MODELING, STABILITY ANALYSIS AND CONTROL OF MICROGRID", 1 January 2010 (2010-01-01), Queensland, Australia, pages 1 - 182, XP055115574, Retrieved from the Internet <URL:http://eprints.qut.edu.au/37670/1/Ritwik_Majumder_Thesis.pdf> [retrieved on 20140428]

DESCRIPTION

Description

TECHNICAL FIELD

[0001] The present disclosure relates to a microgrid connecting at least one distributed electricity generator and having first and second points of common couplings (PCC) to an alternating current (AC) power grid.

BACKGROUND

[0002] A microgrid is a localized grouping of electricity generation, energy storage, and loads that normally operates connected to a traditional centralized grid (macrogrid) via a point of common coupling (PCC). This single point of common coupling with the macrogrid can be disconnected, islanding the microgrid. Micrograds are part of the structure for so called distributed generation (DG) aiming at producing electrical power locally from many small energy sources.

[0003] A microgrid (in grid connected mode, i.e. connected to the macrogrid) supplies the optimized or maximum power outputs from the connected DG sites and the rest of the power is supplied by the macrogrid. The microgrid is connected to the macrogrid at a PCC through a controllable switch. This grid connection is lost during grid fault and microgrid is islanded.

[0004] US8,447,435 generally discloses connection between and control of a plurality of microgrids with a PCC to the macrogrid. As an another example of prior art, WO2012/032111 relates to a method for detecting islanding conditions in a lower voltage electric power network. In this method, the electrical power network comprises a plurality of sub-networks and the sub-networks comprise at least one power electrical unit and are separable from each other and a main grid supplying the network by switching devices. The method comprises determining topological information of at least one subnetwork of interest, detecting islanding conditions in at least one sub-network of interest on the basis of the topological information by using separate detecting means for each sub-network of interest, and sending, on the basis of the islanding conditions detected by using the detecting means, a disconnect signal to at least one power electrical unit in at least one sub-network of interest.

[0005] US 2013/155734 A1 discloses a method and system for detecting an islanding condition in a grid. The method comprises detecting a potential islanding condition in a grid; and, in response to the detected potential islanding condition, ramping up an amount of reactive power, active power, or a combination of active and reactive power that is generated from a power conversion system until the earlier of the power conversion system shutting down or a threshold condition being reached.

[0006] To avoid islanding, multiple PCC can be used. Multiple PCC connection may provide improved grid reliability but power management, protection, power flow control, stability and islanding detection (at one PCC point) become more complex.

SUMMARY

[0007] It is an objective of the present invention to alleviate the problems of the prior art mentioned above, by reducing the risk of islanding while avoiding the increased complexity of using a plurality of PCCs. The solution of the present invention is to connect at only one PCC, but being able to connect via another PCC when islanding is detected.

[0008] The invention is to be found in the appended independent claims 1 and 10.

[0009] By means of embodiments of the present invention, islanding can be handled by having a plurality of available PCC:s, while control complexity is kept low by not having all the available PCC:s active at the same time.

[0010] In some embodiments, the control unit is configured for acting to open the second switch, bringing it to its open position, in response to the detected islanding. This may be convenient to avoid any interference to occur via the second PCC.

[0011] In some embodiments, the first network line is comprised in the same network grid as the second network line.

[0012] In some other embodiments, the first network line is comprised in a first network grid and the second network line is comprised in a second network grid, different than the first network grid.

[0013] In some embodiments, the control unit is configured for receiving information about a voltage of at least one bus in the microgrid and a power of the distributed generator.

[0014] In some embodiments, the control unit is configured for periodically receiving information about a power flow in the microgrid.

[0015] In some embodiments, the control unit is configured for periodically receiving information about a grid voltage of the first network line when the first switch is in its open position.

[0016] In some embodiments, the control unit is configured for calculating a flow reference for the first PCC when the first switch is in its open position, and for using said power reference for controlling power flow over the first PCC when the first switch is in its closed position.

[0017] In some embodiments, the control unit comprises a central controller as well as a first interface controller for controlling power flow over the first PCC and a second interface controller for controlling power flow over the second PCC.

[0018] In some embodiments, the microgrid comprises a third switch configured for, in a closed position, connecting the microgrid to a third network line at a third PCC, and for, in an open position, disconnecting the microgrid from the third network line at the third PCC; wherein the control unit is configured for acting to close the third switch, bringing it from its open position to its closed position, in response to the detected islanding.

BRIEF DESCRIPTION OF THE DRAWINGS

[0019] Embodiments will be described, by way of example, with reference to the accompanying drawings, in which:

Fig 1 is a schematic block diagram of an embodiment of a microgrid in accordance with the present invention.

Fig 2 is a schematic block diagram of another embodiment of a microgrid in accordance with the present invention.

Fig 3 is a schematic block diagram of another embodiment of a microgrid in accordance with the present invention.

Fig 4 is a schematic block diagram of another embodiment of a microgrid in accordance with the present invention.

Fig 5 is a schematic block diagram of another embodiment of a microgrid in accordance with the present invention.

Fig 6 is a schematic block diagram of another embodiment of a microgrid in accordance with the present invention.

Fig 7 is a schematic flow chart of an embodiment of a method in accordance with the present invention.

DETAILED DESCRIPTION

[0020] Embodiments will now be described more fully hereinafter with reference to the accompanying drawings, in which certain embodiments are shown. However, other embodiments in many different forms are possible within the scope of the present disclosure. Rather, the following embodiments are provided by way of example so that this disclosure will be thorough and complete, and will fully convey the scope of the disclosure to those skilled in the art. Like numbers refer to like elements throughout the description.

[0021] Figure 1 schematically illustrates an embodiment of a microgrid 100. The microgrid comprises at least one distributed generator (DG) 130, often several DG:s 130, and possibly one or several loads. The DG 130 may typically generate direct current (DC) why the microgrid may typically be a DC grid. The microgrid 100 comprises a first switch 111 configured for, in a closed position, connecting the microgrid 100 to a first network line 121 at a first PCC 141 and for, in an open position, disconnecting the microgrid from the first network line at the first PCC. The first network line 121 is part of a first network grid 101, such as an alternating current (AC) grid e.g. a public AC network or macrogrid. The microgrid 100 comprises also a second switch 112 configured for, in a closed position, connecting the microgrid 100 to a second network line 122 at a second PCC 142, and for, in an open position, disconnecting the microgrid from the second network line at the second PCC. The second network line 122 may also be part of the first network grid 101, or it may be part of a different (second) network grid 102, such as an alternating current (AC) grid e.g. a public AC network or macrogrid, which is separate from the first network grid 101. The microgrid 100 also comprises a control unit 150 for controlling the opening and closing of the first and second switches 111 and 112, as well as for performing other control of e.g. flow and voltages of the microgrid 100 and/or the first and second PCC 141 and 142 as desired. Figure 1 shows the situation where the second switch 112 is in its closed position and the first switch 111 is in its open position, why only the second PCC 142 is active, a flow of electrical power (P, Q), where P is active power and Q is reactive power, passing over the second PCC 142. Depending on whether the power produced by the at least one DG 130 is more or less than any power consumed by any loads in the microgrid 100, the flow over the second PCC 142 may be from the microgrid 100 and into the network 102 via the second network line 122, or from the network 102 via the second network line 122 and into microgrid 100. Although the microgrid 100 is disconnected from the first network line 121, the control unit 150 may still obtain information relating to the first PCC 141 and may calculate reference(s) (P_{ref} and Q_{ref}) for the flow over the first PCC 141 in case the first PCC needs to be activated (closing the first switch 111) due to a failure (islanding) at the second PCC 142. The power flow (P, Q) before islanding may be used by the control unit 150 to calculate the power references (P_{ref}, Q_{ref}) for the new (first) PCC 141.

[0022] Figure 2 schematically illustrates another embodiment of a microgrid 100. The figure is similar to figure 1 above and reference is made to that discussion. Figure 2 specifically shows the situation where the first network line 121 and the second network line 122 both are part of the same network grid, the first network grid 101. Thus, the first network line 121 may be comprised in the same network grid 101 as the second network line 122.

[0023] Figure 3 schematically illustrates another embodiment of a microgrid 100. The figure is similar to figure 1 above and reference is made to that discussion. Figure 3 specifically illustrates an embodiment where the control unit 150 receives measurements of the voltage (V_{grid1} and δ_{grid1}), where V_{grid1} is the voltage magnitude and δ_{grid1} is the voltage phase angle, at the first PCC 141. These voltage measurements may then be used for calculating the power references (P, Q) for the first PCC 141, for use if the first PCC 141 needs to be activated by closing the first switch 111. Thus, the control unit 150 may be configured for receiving, e.g. periodically, information about a grid voltage of the first network line 121, e.g. at the first PCC 141, when the first switch 111 is in its open position.

[0024] Figure 4 schematically illustrates another embodiment of a microgrid 100, having more than two PCC:s, here four PCC:s. In addition to the first and second switches 111 and 112, the microgrid 100 also comprises a third switch 113 able to connect, in its closed position, the microgrid to a third network grid 103 via a third network line 123, and a fourth switch 114 able to connect, in its closed position, the microgrid to a fourth network grid 104 via a fourth network line 124. As shown in figure 4, the microgrid 100 may be connected over more than one PCC, and/or may have more than one PCC in reserve in case of islanding. Here, the microgrid has two active PCC:s, the second PCC 142 by means of the second switch 112 being closed and the fourth PCC 144 by means of the fourth switch 114 being closed. Further, the microgrid has two inactive PCC:s, the first PCC 141 which can be activated by closing the first switch 111 and the third PCC 143 which can be activated by closing the third switch 113. Thus, the microgrid 100 may further comprise a third switch 113 configured for, in a closed position, connecting the microgrid 100 to a third network line 123 at a third PCC 143, and for, in an open position, disconnecting the microgrid from the third network line at the third PCC; wherein the control unit 150 is also configured for acting to close the third switch 113, bringing it from its open position to its closed position, in response to the detected islanding. The control unit 150 is here shown schematically outside of the microgrid for easier display in the figure, and is called a microgrid central control 150. Although, the control unit 150 is herein described as being part of the microgrid 100, it may of course physically be located elsewhere, e.g. in a control room, not necessarily close to the DG(s) and any loads of the microgrid 100. As is schematically illustrated in the figure, the control unit 150 may obtain measurements of flow (P, Q) of the active PCC:s, i.e. P_2 and Q_2 of the second PCC 142 and P_4 and Q_4 of the fourth PCC 144 in order to be able to calculate the flow references for the inactive PCC:s, i.e. P_{ref1} and Q_{ref1} of the first PCC 141 and P_{ref3} and Q_{ref3} of the third PCC 143. Additionally or alternatively, the flow references may be based on voltage measurements of the inactive PCC:s obtained by the control unit 150, i.e. V_{grid1} and δ_{grid1} of the first PCC 141 and V_{grid3} and δ_{grid3} of the third PCC 143. In some embodiments, the microgrid 100 is not grid interfaced via a power flow controller (through power flow control, P_{ref1} and Q_{ref1}). Then the power flow is determined only by the grid voltage (V_{grid1} and δ_{grid1}) which is used to calculate reference voltage for microgrid controllable buses. The control unit 150 may also or alternatively obtain information about a voltage of at least one bus in the microgrid 100 and a power of the distributed generator 130 in order to be able to better control the microgrid. In addition to the microgrid central controller (MGCC), the control unit may comprise interface controllers at each PCC, e.g. for executing opening and closing of the respective switches at each PCC and/or for performing flow and/or voltage measurements at the respective PCC:s as desired.

[0025] Figures 5 and 6 illustrates how the power flow references for inactive PCC:s, here the first PCC 141 and the third PCC 143, are calculated by the control unit 150. An input stage 151 of the control unit 150 receives information about measurements made, based on which measurements the control unit 150 calculates the flow references (P, Q) for the inactive PCC:s 111 and 113. In addition to the flow references, the control unit outputs a command for closing the first and/or the third switch 111/113 is islanding is detected die to failure at the second PCC 142. If the microgrid 100 is not connected through power flow controller (as shown in figure 6), voltage references for microgrid controllable buses are generated instead of flow references as in figure 5. As discussed above and as illustrated in figures 5 and 6, input measurment information to the control unit 150 may comprise any or all of power flow (P, Q) of active PCC(s) 142; closed switches 112 and open switches 111,113; node voltages in the microgrid 100; power output of the DG(s) 130, power consumption of any loads in the microgrid; and grid voltage (V, δ) at inactive PCC(s) 111 and 113. The power references are calculated through load flow imposing acceptable voltage variation at microgrid buses. The power/voltage references and switch closing command are then sent to the inactive PCC(s) which should be activated e.g. to PCC interface controller(s) of the inactive PCC(s). This is an example of how the control unit 150 may act to activate a PCC in case of islanding, by acting to close a corresponding switch.

[0026] Figure 7 is a schematic flow chart of an embodiment of a method of the present invention. The method is performed by an embodiment of a control unit 150 of a microgrid 100 as discussed herein. The control unit detects 701 that an islanding event has occurred. Typically, an active PCC 142 has failed, islanding the microgrid 100. The control unit then acts 702 to close the first switch 111 which was previously open, bringing it to its closed position, in response to the detected 701 islanding. Thereby, the first PCC 141 is activated and is used instead of the second PCC 142.

REFERENCES CITED IN THE DESCRIPTION

Cited references

Patent documents cited in the description

- US8447435B [0004]
- WO2012032111A [0004]
- US2013155734A1 [0005]

MIKRONET MED REDUNDANTE PUNKTER MED FÆLLES KOBLING OG FREMGANGSMÅDE TIL KONTROL TIL DETTE, FOR REDUKTION AF RISIKO FOR SEKTIONERING AF MIKRONETTET

PATENTKRAV

1. Kontrolenhed (150) til et mikronet (100) som forbinder mindst en distribueret elektricitetsgenerator (130), hvor mikronettet omfatter en første afbryder (111) konfigureret til, i en åben position, at frakoble mikronettet fra en første netværkslinje (121) på et første punkt med fælles kobling, PCC, (141) og en anden afbryder (112) konfigureret til, i en lukket position, at forbinde mikronettet (100) til en anden netværkslinje (122) på et andet PCC (142);
hvori kontrolenheden er konfigureret til at indhente informationer relateret til flow af elektrisk strøm (P, Q) der passerer over det andet PCC (142), og hvori kontrolenheden (150), når den anden afbryder (112) er i sin lukkede position og den første afbryder (111) er i sin åbne position, ydermere er konfigureret til:
detektere en sektioneringshændelse på det andet PCC (142),
som reaktion på den detekterede sektioneringshændelse, at agere for at lukke den første afbryder for at bringe den til dens lukkede position, og agere for at åbne den anden afbryder (112) for at bringe den til dens åbne position, og
beregne en strømreference (P_{ref}, Q_{ref}) for flowet over det første PCC (141) baseret på flowet af elektrisk strøm (P, Q) der passerer over det andet PCC (142) før den detekterede sektioneringshændelse, og anvende ovennævnte strømreference til at kontrollere flow af strøm over det første PCC (141), når den første afbryder (111) er i sin lukkede position.

2. Kontrolenhed ifølge krav 1, hvori kontrolenheden (150) også er konfigureret til at modtage information om en spænding på mindst en bus i mikronettet (100) og en strøm på den distribuerede generator (130).

3. Kontrolenhed ifølge ethvert foregående krav, hvori kontrolenheden (150) også er konfigureret til periodisk at modtage information om et flow af strøm i mikronettet (100).

4. Kontrolenhed ifølge ethvert foregående krav, hvori kontrolenheden (150) omfatter en central styreenhed såvel som en første interface-styreenhed til at kontrollere flow af

strøm over det første PCC (141) og en anden interface-styreenhed til at kontrollere flow af strøm over det andet PCC (142).

5. Kontrolenhed ifølge ethvert foregående krav,
hvori kontrolenheden (150) også er konfigureret til at agere for at lukke en tredje afbryder (113) for at bringe den fra dens åbne position til dens lukkede position, som reaktion på den detekterede sektionering,
hvori den tredje afbryder (113) er konfigureret til, i en lukket position, at forbinde mikronettet (100) til en tredje netværkslinje (123) på et tredje PCC (143), og til, i en åben position, at frakoble mikronettet fra den tredje netværkslinje på det tredje PCC.

6. Kontrolenhed ifølge ethvert foregående krav, hvori kontrolenheden (150), når den anden afbryder (112) er i sin lukkede position og den første afbryder (111) er i sin åbne position, er konfigureret til:
periodisk at modtage information om en netspænding på det første PCC (141).

7. Mikronet som forbinder mindst en distribueret elektricitetsgenerator (130), hvor mikronette omfatter:
en kontrolenhed som defineret i ethvert af de foregående krav,
hvori den første afbryder (111) på mikronettet ydermere er konfigureret til, i en lukket position, at forbinde mikronettet (100) til den første netværkslinje (121) på det første PCC (141) og hvori den anden afbryder (112) på mikronettet ydermere er konfigureret til, i en åben position, at frakoble mikronettet fra den anden netværkslinje på det andet PCC.

8. Mikronet ifølge krav 7, hvori den første netværkslinje (121) er omfattet i det samme netværksnet (101) som den anden netværkslinje (122).

9. Mikronet ifølge krav 7, hvori den første netværkslinje (121) er omfattet i et første netværksnet (101) og den anden netværkslinje (122) er omfattet i et andet netværksnet (102), der er forskelligt fra det første netværksnet.

10. Fremgangsmåde udført af en kontrolenhed (150) til et mikronet (100) der forbinder mindst en distribueret elektricitetsgenerator (130) og omfatter en anden afbryder (112) i en lukket position, der forbinder mikronettet (100) til en anden netværkslinje (122) på et andet punkt med fælles kobling, PCC, (142) og en første afbryder (111) i en åben position,

der frakobler mikronettet fra en første netværkslinje (121) på et første PCC (141), hvor fremgangsmåden omfatter:

at indhente af information relateret til flow af elektrisk strøm (P, Q) der passerer over det andet PCC (142);

at detektere (701) en sektioneringshændelse på det andet PCC (142); og

at agere (702) for at lukke den første afbryder (111) for at bringe den til dens lukkede position, og agere for at åbne den anden afbryder (112) for at bringe den til dens åbne position, som reaktion på den detekterede (701) sektioneringshændelse, og

at beregne en strømreference (P_{ref}, Q_{ref}) for flowet over det første PCC (141) baseret på flowet af elektrisk strøm (P, Q) der passerer over det andet PCC (142) før den detekterede sektioneringshændelse, og anvende ovennævnte strømreference til at kontrollere flow af strøm over det første PCC (141), når den første afbryder (111) er i sin lukkede position.

DRAWINGS

Drawing

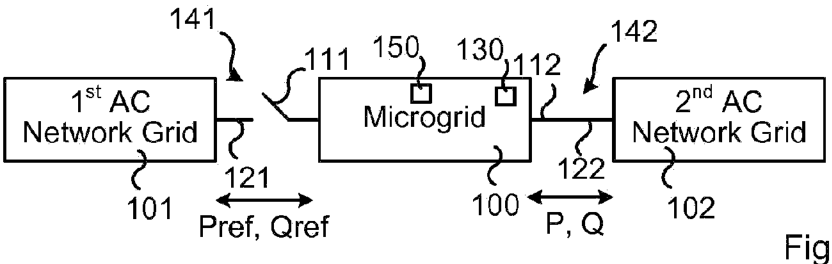

Fig. 1

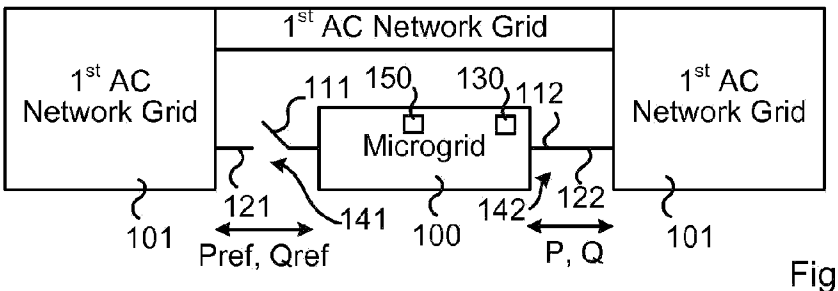

Fig. 2

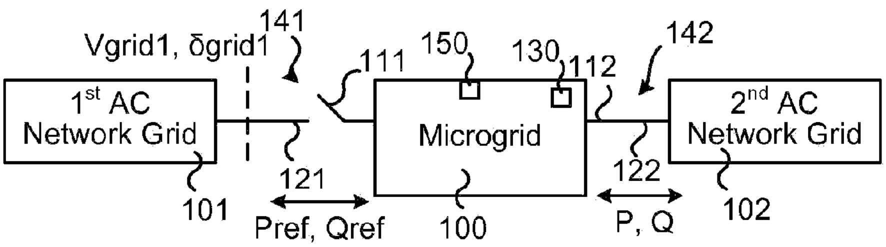

Fig. 3

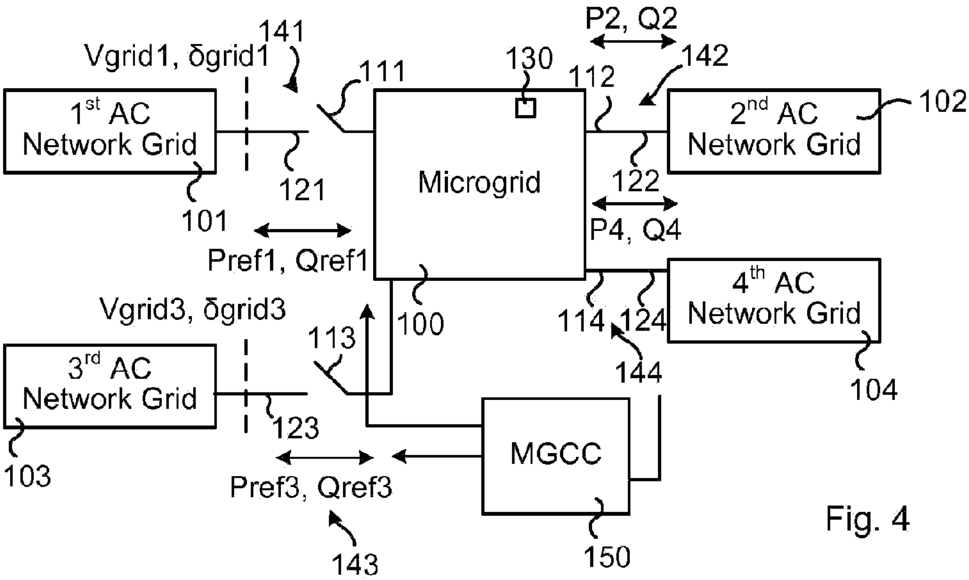

Fig. 4

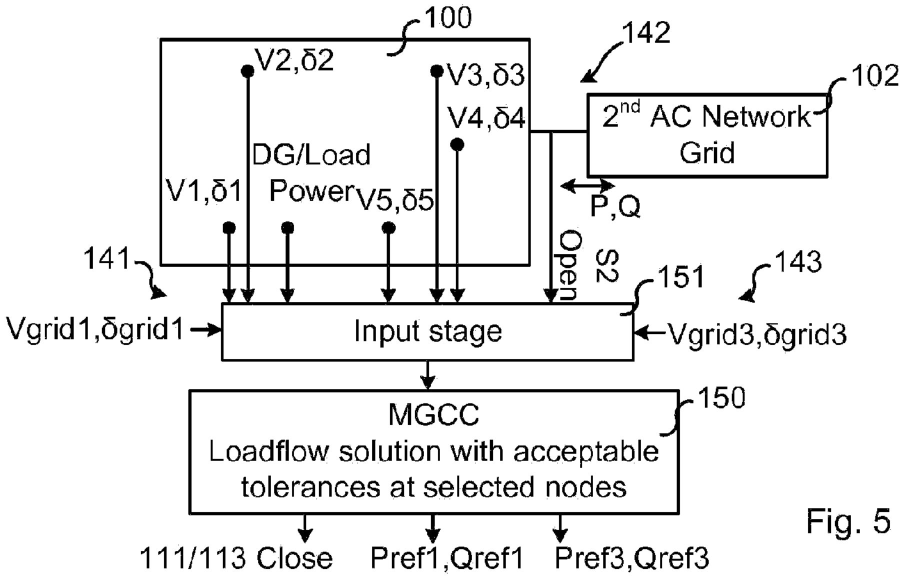

Fig. 5

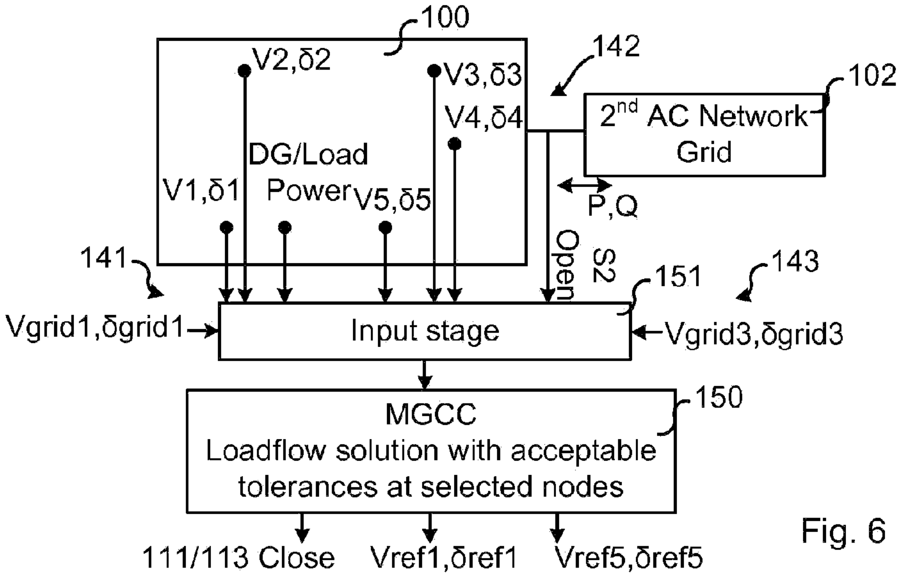

Fig. 6

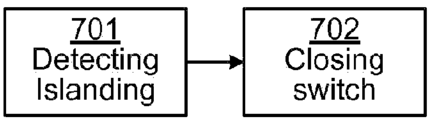

Fig. 7