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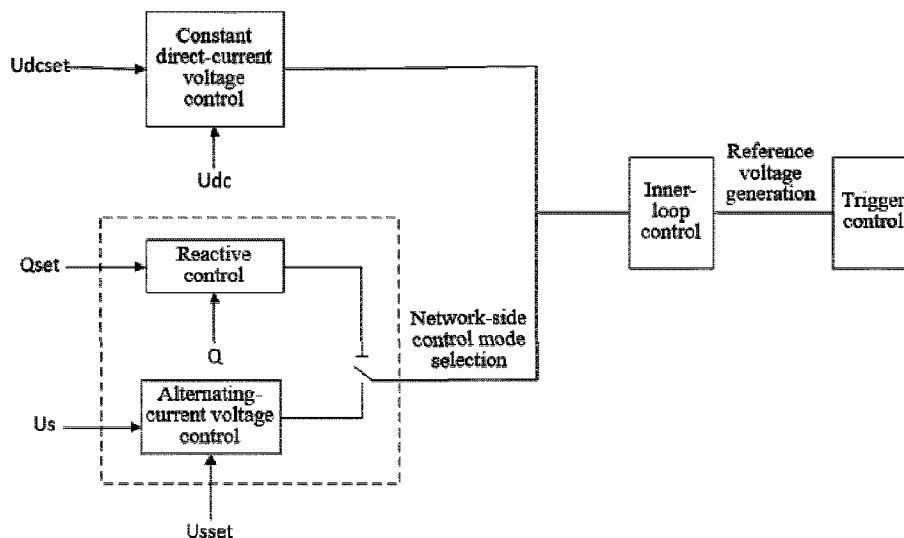
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(54) Title: PASSIVE ISLANDING-TO-GRID-CONNECTED SWITCH METHOD



(57) Abrégé/Abstract:

The present invention discloses a passive islanding to grid-connection switching method for a VSC HVDC transmission system. When the VSC HVDC transmission system in an island operation state, whether the VSC HVDC transmission system enters a grid-connection state is determined by detecting whether an overcurrent phenomenon has occurred in a converter valve-side three-phase alternating-current or a converter bridge arm current, and detecting a change status of an alternating-current voltage. The system is controlled to switch from an island operation control mode to a grid-connection control mode. At a moment of switching, the online control mode is smoothly switched to by changing a power instruction and performing phase tracking on a current grid voltage, so that continuous operation of the system is maintained.

ABSTRACT

The present invention discloses a passive islanding to grid-connection switching method for a VSC HVDC transmission system. When the VSC HVDC transmission system in an island operation state, whether the VSC HVDC transmission system enters a grid-connection state is determined by detecting whether an overcurrent phenomenon has occurred in a converter valve-side three-phase alternating-current or a converter bridge arm current, and detecting a change status of an alternating-current voltage. The system is controlled to switch from an island operation control mode to a grid-connection control mode. At a moment of switching, the online control mode is smoothly switched to by changing a power instruction and performing phase tracking on a current grid voltage, so that continuous operation of the system is maintained.

PASSIVE ISLANDING-TO-GRID-CONNECTED SWITCH METHOD

BACKGROUND

5 Technical Field

The present invention relates to the field of power electronics, and in particular, to an island-to-active network switching method for a VSC-HVDC transmission system.

Related Art

10 The voltage source type converter is used for high direct-current transmission, and active power and reactive power can be controlled independently and fast, so as to improve system stability, inhibit fluctuation of a system frequency and a system voltage, and improve stable performance of a grid-connection alternating-current system. Flexible direct-current transmission has great advantages in fields such as new energy grid connection, distributed power generation grid connection, island power supply, and
15 urban distribution network power supply. Therefore, researches on technologies related to flexible direct-current transmission have important meanings.

When a flexible direct-current transmission system is in an island operation state, a proximal-end in a converter station is closed to connect to an alternating-current grid or a remote-end switch is closed. A flexible direct-current converter station is connected in
20 parallel to an active grid for operation. The flexible direct-current system needs to switch from a current island operation control mode to an grid-connected operation control mode, to maintain continuous operation of the direct-current transmission system.

When a flexible direct-current transmission system is in an island operation state, if
25 the flexible direct-current transmission system enters an grid-connected state because of a close operation on a switch, a moment at which the flexible direct-current transmission system enters the grid-connected state needs to be accurately detected, and the current island operation needs to be switch into active operation in time. Otherwise, relatively long duration will cause the grid to be out-of-synchronization, and

consequently the VSC HVDC transmission system stops operation. Meanwhile, smooth switching to operation in an online manner is also required, so that the VSC HVDC transmission system is prevented from performing a protection action and being out of service that are caused by an overcurrent or overvoltage phenomenon aroused at a switching moment. Currently, there no report related to a detection manner for detecting a change of a grid operation manner by a flexible direct-current transmission system in an island operation state for entering an online state and smoothness control.

SUMMARY

An objective of the present invention is to provide a method for detecting a change of a grid operation manner by a flexible direct-current transmission system in an island operation state for entering an grid-connected state, so as to ensure accurate and smooth switching of the flexible direct-current transmission system from an island operation state to an online operation state.

To achieve the foregoing objective, a technical solution is used in the present invention:

A control system determines, by detecting whether an overcurrent phenomenon occurs in a converter bridge arm current and change statuses of network-side and valve-side voltages, whether a VSC HVDC transmission system enters a grid-connected state, including the following steps:

(1) when a converter station of the VSC HVDC transmission system is in an island operation state, detecting whether an overcurrent phenomenon occurs in a converter valve-side three-phase alternating-current or a converter bridge arm current, wherein an overcurrent constant value setting is taken as n times a rated bridge arm current; and if the overcurrent phenomenon occurs and the overcurrent phenomenon lasts for a duration t_1 , performing step (2); and otherwise, performing step (1) again;

(2) Blocking a converter, and detecting whether an alternating-current voltage is lower than a threshold; if the voltage is lower than the threshold and lasts for a duration t_2 , deblocking the converter and performing step (1) again; and otherwise, performing step (3); and

(3) controlling setting of a system phase-locked loop to track the current alternating-current voltage phase, at the same time, starting to switch a control mode, switching from a current island control mode of the converter station of the flexible direct-current transmission system to an active control mode, and deblocking the converter.

- 5 In the foregoing step (1), the overcurrent constant value setting is set to n times a converter rated valve-side current or a converter bridge arm current. A value range of n is 1 to 10, a value range of the duration t_1 is 0 to 1s, and a value range of t_2 is 0 to 1s.

In the foregoing step (2), a value range of the threshold of the alternating-current voltage is 0 to 0.99 pu, and a value range of a duration t is 0 to 1s.

- 10 At a moment of switching the control mode in step (3), active power and reactive power instructions maintain current operation values of an active power and a reactive power. Alternatively, an active power and a reactive power may be 0, and may gradually increase, by means of a slope, to current operation values.

- 15 The present invention further includes an island-to-online control apparatus, including a converter overcurrent detection unit, an alternating-current voltage detection unit, and an island-to-online mode switching unit.

- 20 When a converter station of a VSC HVDC transmission system is in island operation state, the converter overcurrent detection unit detects whether an overcurrent phenomenon occurs in a converter valve-side three-phase alternating-current or a converter bridge arm current, wherein an overcurrent constant value setting is taken as n times rated bridge arm current; and if the overcurrent phenomenon occurs, and the overcurrent phenomenon lasts for a duration t_1 , the alternating-current voltage detection unit works; and otherwise, the converter overcurrent detection unit works again.

- 25 The alternating-current voltage detection unit first locks a converter, and then detects whether an alternating-current voltage is lower than a threshold; if the voltage is lower than the threshold and lasts for a duration t_2 , the converter is unlocked, and the converter overcurrent detection unit continues to perform detection; and otherwise, the island-to-online mode switching unit works.

- 30 A function of the island-to-online mode switching unit is switching a control mode; at a moment of switching the control mode, active power and reactive power instructions

maintain current operation values of an active power and a reactive power; or, after the switching, an active power and a reactive power are converted to 0, and gradually increase to operation values before the switching.

The present invention further includes an island-to-online control system, including
5 a converter, an upper layer controller, and a valve-controlled apparatus, where (1) when a converter station of a flexible direct-current transmission system is in an island operation state, the upper layer controller detects whether an overcurrent phenomenon occurs in a converter valve-side three-phase alternating-current or a converter bridge arm current, wherein an overcurrent constant value setting is taken as n times a rated bridge
10 arm current; if the overcurrent phenomenon occurs, and the overcurrent phenomenon lasts for a duration t_1 , step (2) is performed, otherwise, step (1) is performed again;

(2) a converter is blocked, and it is detected whether an alternating-current voltage is lower than a threshold; if the voltage is lower than the threshold and lasts for a duration t_2 , the converter is deblocked, and step (1) is performed again; and otherwise, step (3) is
15 performed;

(3) the upper layer controller sets a phase-locked loop to track the current alternating-current voltage phase, at the same time, starts to switch a control mode, switches from a current island control mode of the converter station of the flexible direct-current transmission system to an active control mode, and unlocks the converter.

20 The present invention further includes a passive islanding to grid-connection switching method for a VSC HVDC transmission system, including the following steps:

(a) when a converter station of the VSC HVDC transmission system is in a passive islanding operation state, detecting whether an overcurrent phenomenon occurs in a converter valve-side three-phase alternating-current or a converter bridge arm current, and wherein an overcurrent constant value setting is taken as n times a rated bridge arm
25 current; and if the overcurrent phenomenon occurs, and the overcurrent phenomenon lasts for a duration t_1 , performing step (b); and otherwise, performing step (a) again;

(b) blocking a converter, and detecting whether an alternating-current voltage is lower than a threshold; if the voltage is lower than the threshold and lasts for a duration
30 t_2 , deblocking the converter and performing step (a) again; and otherwise, performing step (c); and

(c) controlling setting of a system phase-locked loop to track a current alternating-current voltage phase, at the same time, starting to switch a control mode, switching from a current island control mode of the converter station of the VSC HVDC transmission system to an active control mode, and deblocking the converter.

5 The present invention further includes a passive islanding to grid-connection control apparatus, including a converter overcurrent detection unit, an alternating-current voltage detection unit, and a passive islanding to grid-connection mode switching unit, wherein when a converter station of a VSC HVDC transmission system is in an island operation state, the converter overcurrent detection unit detects whether an overcurrent
10 phenomenon occurs in a converter valve-side three-phase alternating-current or a converter bridge arm current, wherein an overcurrent constant value setting is taken as n times a rated bridge arm current; if the overcurrent phenomenon occurs, and the overcurrent phenomenon lasts for a duration t_1 , the alternating-current voltage detection unit works; and otherwise, the converter overcurrent detection unit works again; the
15 alternating-current voltage detection unit first blocks a converter, and then detects whether an alternating-current voltage is lower than a threshold; if the voltage is lower than the threshold and lasts for a duration t_2 , the converter is deblocked, and the converter overcurrent detection unit continues to perform detection; and otherwise, an island-to-online mode switching unit works; a function of the passive islanding to grid-connection
20 mode switching unit is switching a control mode; at a moment of switching the control mode, active power and reactive power instructions maintain current operation values of an active power and a reactive power; or, after the switching, an active power and a reactive power are converted to 0, and gradually increase to operation values before the switching.

25 The present invention further includes a passive islanding to grid-connection control system, comprising a converter, an upper layer controller, and a valve-controlled apparatus, wherein the passive islanding to grid-connection control system is configured to implement the following steps:

30 (a) when a converter station of a flexible direct-current transmission system is in an island operation state, the upper layer controller detects whether an overcurrent phenomenon occurs in a converter valve-side three-phase alternating-current or a

converter bridge arm current, wherein an overcurrent constant value setting is taken as n times a rated bridge arm current; wherein if the overcurrent phenomenon occurs, and the overcurrent phenomenon lasts for a duration t_1 , step (b) is performed, otherwise, step (a) is performed again;

5 (b) a converter is blocked, and it is detected whether an alternating-current voltage is lower than a threshold; if the voltage is lower than the threshold and lasts for a duration t_2 , the converter is deblocked, and step (a) is performed again; and otherwise, step (c) is performed; and

10 (c) the upper layer controller sets a phase-locked loop to track a current alternating-current voltage phase, at the same time, starts to switch a control mode, switches from a current island control mode of the converter station of the flexible direct-current transmission system to an active control mode, and deblocks the converter.

After the foregoing solutions are adopted, the present invention has the following beneficial effects:

15 In the method for detecting a change of a grid operation manner by a flexible direct-current transmission system in an island operation state for entering an online state provided in the present invention, detection on a grid connection moment is accurate, and an online operation manner may be smoothly switched to without causing an impact on a grid.

20 **BRIEF DESCRIPTION OF THE DRAWINGS**

FIG. 1 is a schematic structural diagram of double stations of a VSC HVDC transmission system;

FIG. 2 is a schematic diagram of a control mode of a grid connection detection converter station;

25 FIG. 3 is a schematic diagram of a control mode of a constant direct-current voltage control station; and

FIG. 4 is a flowchart of VSC HVDC grid connection detection in an island operation mode.

DETAILED DESCRIPTION

The technical solutions are described below in detail with reference to accompany drawings and specific embodiments

As shown in FIG. 1, flexible direct-current transmission converter stations 201 and 202 are in an island operation state. A remote-end switch 102 is not closed, the converter stations 201 and 202 are not connected to an alternating-current grid 400, and the converter stations 201 and 202 are in the island operation state. 202 is a constant direct-current voltage control side. Refer to FIG. 3 for a control mode of 202. 201 uses a control mode in FIG. 2. FIG. 3 shows a constant direct-current voltage control mode, which remains unchanged before and after switching. An active control mode is switched to when an online state is detected in a grid connection detection section in FIG. 2. If the switch 102 is closed, whether to switch from island operation to online state operation is detected (refer to FIG. 4) according to the following steps:

(1) When a converter station of the flexible direct-current transmission system is in an island operation state, detect whether an overcurrent phenomenon occurs in a converter valve-side three-phase alternating-current or a converter bridge arm current, wherein an overcurrent constant value setting is taken as n times a rated bridge arm current; and if the overcurrent phenomenon occurs and the overcurrent phenomenon lasts for a duration t_1 , perform step (2); and otherwise, perform step (1) again.

(2) Block a converter, and detect whether an alternating-current voltage is lower than a threshold; if the voltage is lower than the threshold and lasts for a duration t_2 , unlock the converter and perform step (1) again; and otherwise, perform step (3).

(3) Control setting of a system phase-locked loop to track a current alternating-current voltage phase, at the same time, start to switch a control mode, switch from a current island control mode of the converter station of the flexible direct-current transmission system to an active control mode, and unlock the converter.

A value range of the duration t_1 is 0 to 1s, and a value range of t_2 is 0 to 1s.

After the switch 102 is closed, if a network side 400 is in an active state, the converter station 201 switches from an island control mode to an active control mode according to the foregoing steps. In a special case, the network side 400 is a passive system. After the

switch 102 is closed, a bridge arm overcurrent phenomenon does not occur in a normal status. Therefore, the control mode is not switched. Alternatively, after the converter is locked, if it is detected that an alternating-current voltage is lower than a threshold, an online detection condition is immediately barred for a period of time, it is forbidden to
5 switch from island operation to online operation, and at the same time, the converter is immediately released to trigger a pulse. The online detection process ends, and the converter station 201 still maintains an original island operation state.

The present invention further provides a passive islanding-to-grid connected control apparatus, including a converter overcurrent detection unit, an alternating-current voltage
10 detection unit, and an island-to-online mode switching unit. When a converter station of a VSC HVDC transmission system is in an island operation state, the converter overcurrent detection unit detects whether an overcurrent phenomenon occurs in a converter valve-side three-phase alternating-current or a converter bridge arm current, wherein an overcurrent constant value setting is taken as n times a rated bridge arm
15 current; and if the overcurrent phenomenon occurs, and the overcurrent phenomenon lasts for a duration t_1 , the alternating-current voltage detection unit works; and otherwise, the converter overcurrent detection unit works again.

The alternating-current voltage detection unit first locks a converter, and then detects whether an alternating-current voltage is lower than a threshold; if the voltage is lower
20 than the threshold and lasts for a duration t_2 , the converter is deblocked, and the converter overcurrent detection unit continues to perform detection; and otherwise, the passive islanding to grid-connection mode switching unit works.

A function of the passive islanding to grid-connection mode switching unit is switching a control mode; at a moment of switching the control mode, active power and
25 reactive power instructions maintain current operation values of an active power and a reactive power; or, after switching, an active power and a reactive power are converted to 0, and gradually increase to operation values before the switching.

The present invention further provides a passive islanding to grid-connection control system, including a converter, an upper layer controller, and a valve-controlled apparatus,
30 where (1) when a converter station of a VSC HVDC transmission system is in an island operation state, the upper layer controller detects whether an overcurrent phenomenon

occurs in a converter valve-side three-phase alternating-current or a converter bridge arm current, wherein an overcurrent constant value setting is taken as n times a rated bridge arm current; and if the overcurrent phenomenon occurs, and the overcurrent phenomenon lasts for a duration t_1 , step (2) is performed, otherwise, step (1) is performed again;

5 (2) A converter is blocked, and it is detected whether an alternating-current voltage is lower than a threshold; if the voltage is lower than the threshold and lasts for a duration t_2 , the converter is unlocked, and step (1) is performed again; and otherwise, step (3) is performed.

10 (3) The upper layer controller sets a phase-locked loop to track a current alternating-current voltage phase, at the same time, starts to switch a control mode, switches from a current island control mode of the converter station of the VSC HVDC transmission system to an active control mode, and deblocked the converter.

15 The foregoing embodiments are merely used to describe technical ideas of the present invention and do not define the protection scope of the present invention. All the technical ideas proposed according to the present invention and any modifications made based on the technical solutions all fall into the protection scope of the present invention.

CLAIMS

What is claimed is:

1. A passive islanding to grid-connection switching method for a VSC HVDC transmission system, the method comprising the following steps:
 - 5 (a) when a converter station of the VSC HVDC transmission system is in a passive islanding operation state, detecting whether an overcurrent phenomenon occurs in a converter valve-side three-phase alternating-current or a converter bridge arm current, and wherein an overcurrent constant value setting is taken as n times a rated bridge arm current; and if the overcurrent phenomenon occurs, and the overcurrent phenomenon lasts
10 for a duration t_1 , performing step (b); and otherwise, performing step (a) again;
 - (b) Blocking a converter, and detecting whether an alternating-current voltage is lower than a threshold; if the voltage is lower than the threshold and lasts for a duration t_2 , deblocking the converter and performing step (a) again; and otherwise, performing step (c); and
 - 15 (c) controlling setting of a system phase-locked loop to track a current alternating-current voltage phase, at the same time, starting to switch a control mode, switching from a current island control mode of the converter station of the VSC HVDC transmission system to an active control mode, and deblocking the converter.
2. The passive islanding to grid-connection switching method according to claim 1,
20 wherein in step (a), the overcurrent constant value setting is set to n times a converter rated valve-side current or the rated bridge arm current; a value range of n is 1 to 10, a value range of the duration t_1 is 0 to 1s, and a value range of t_2 is 0 to 1s.
3. The passive islanding to grid-connection switching method according to claim 1,
25 wherein in step (b), a value range of the threshold of the alternating-current voltage is 0 to 0.99 pu, and a value range of the duration t_2 is 0 to 1s.
4. The passive islanding to grid-connection method according to claim 1, wherein at a moment of switching the control mode in step (c), active power and reactive power instructions maintain current operation values of an active power and a reactive power.

5. The passive islanding to grid-connection method according to claim 1, wherein after the switching, an active power and a reactive power are converted to 0, and gradually increase to operation values before the switching.

6. A passive islanding to grid-connection control apparatus, comprising a converter
5 overcurrent detection unit, an alternating-current voltage detection unit, and a passive
islanding to grid-connection mode switching unit, wherein when a converter station of a
VSC HVDC transmission system is in an island operation state, the converter overcurrent
detection unit detects whether an overcurrent phenomenon occurs in a converter valve-
side three-phase alternating-current or a converter bridge arm current, wherein an
10 overcurrent constant value setting is taken as n times a rated bridge arm current; if the
overcurrent phenomenon occurs, and the overcurrent phenomenon lasts for a duration t_1 ,
the alternating-current voltage detection unit works; and otherwise, the converter
overcurrent detection unit works again;

the alternating-current voltage detection unit first blocks a converter, and then
15 detects whether an alternating-current voltage is lower than a threshold; if the voltage is
lower than the threshold and lasts for a duration t_2 , the converter is deblocked, and the
converter overcurrent detection unit continues to perform detection; and otherwise, an
island-to-online mode switching unit works;

a function of the passive islanding to grid-connection mode switching unit is
20 switching a control mode; at a moment of switching the control mode, active power and
reactive power instructions maintain current operation values of an active power and a
reactive power; or, after the switching, an active power and a reactive power are converted
to 0, and gradually increase to operation values before the switching.

7. A passive islanding to grid-connection control system, comprising a converter, an
25 upper layer controller, and a valve-controlled apparatus, wherein the passive islanding to
grid-connection control system is configured to implement the following steps:

(a) when a converter station of a flexible direct-current transmission system is in an
island operation state, the upper layer controller detects whether an overcurrent
phenomenon occurs in a converter valve-side three-phase alternating-current or a
30 converter bridge arm current, wherein an overcurrent constant value setting is taken as n
times a rated bridge arm current; wherein if the overcurrent phenomenon occurs, and the

overcurrent phenomenon lasts for a duration t_1 , step (b) is performed, otherwise, step (a) is performed again;

5 (b) a converter is blocked, and it is detected whether an alternating-current voltage is lower than a threshold; if the voltage is lower than the threshold and lasts for a duration t_2 , the converter is deblocked, and step (a) is performed again; and otherwise, step (c) is performed; and

10 (c) the upper layer controller sets a phase-locked loop to track a current alternating-current voltage phase, at the same time, starts to switch a control mode, switches from a current island control mode of the converter station of the flexible direct-current transmission system to an active control mode, and deblocks the converter.

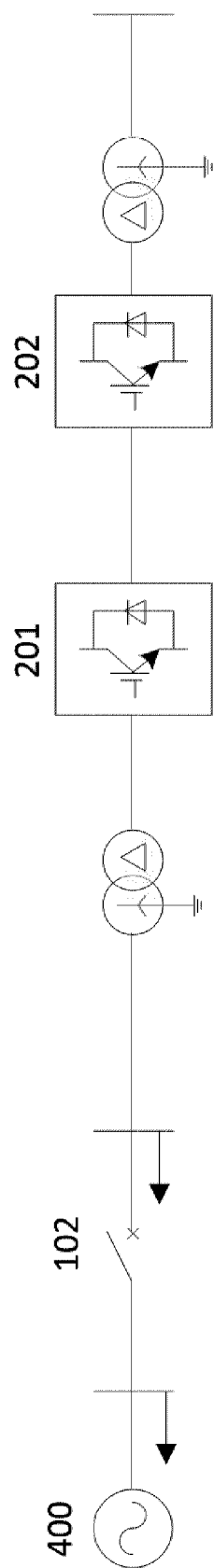


FIG. 1

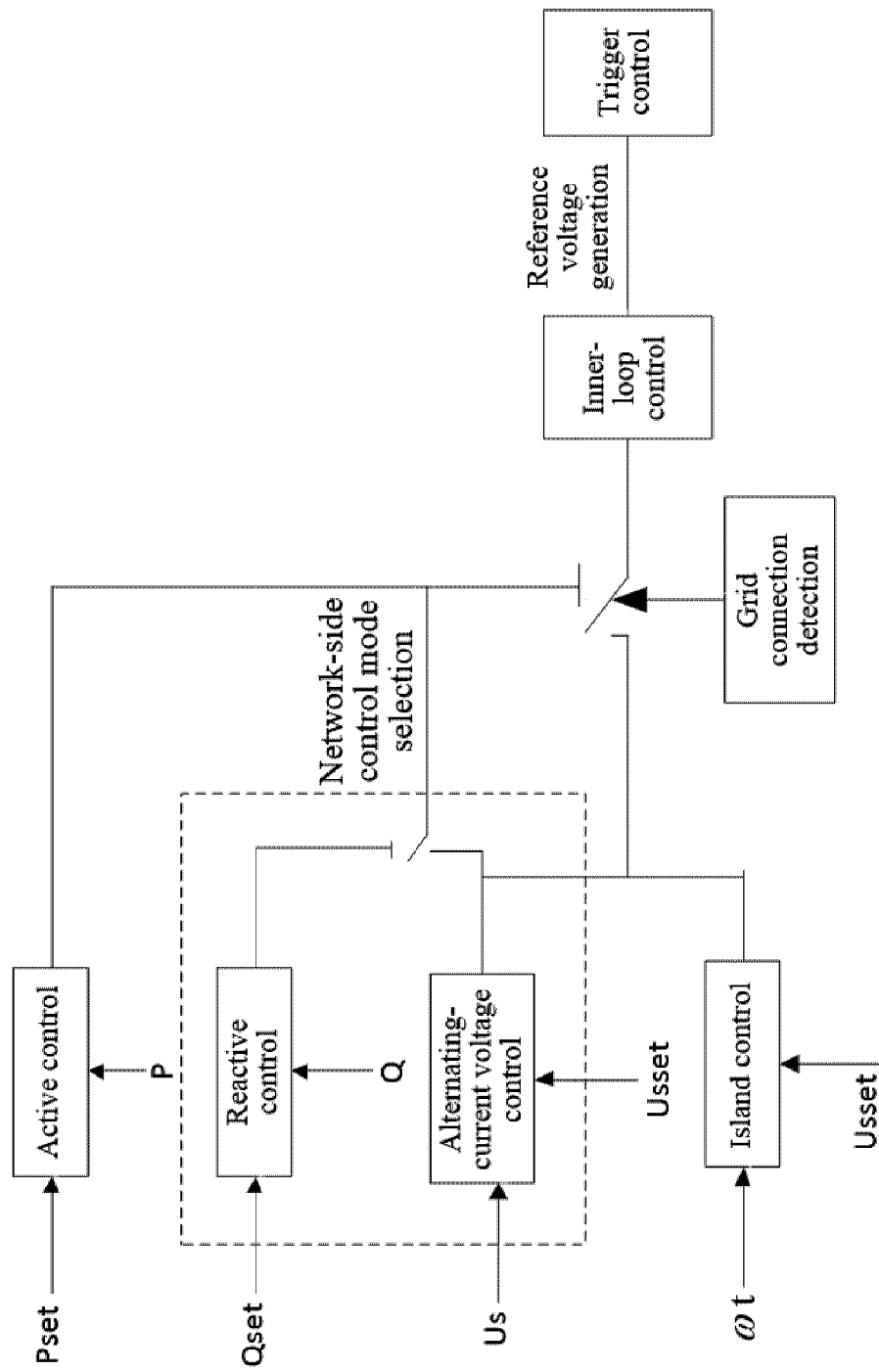


FIG. 2

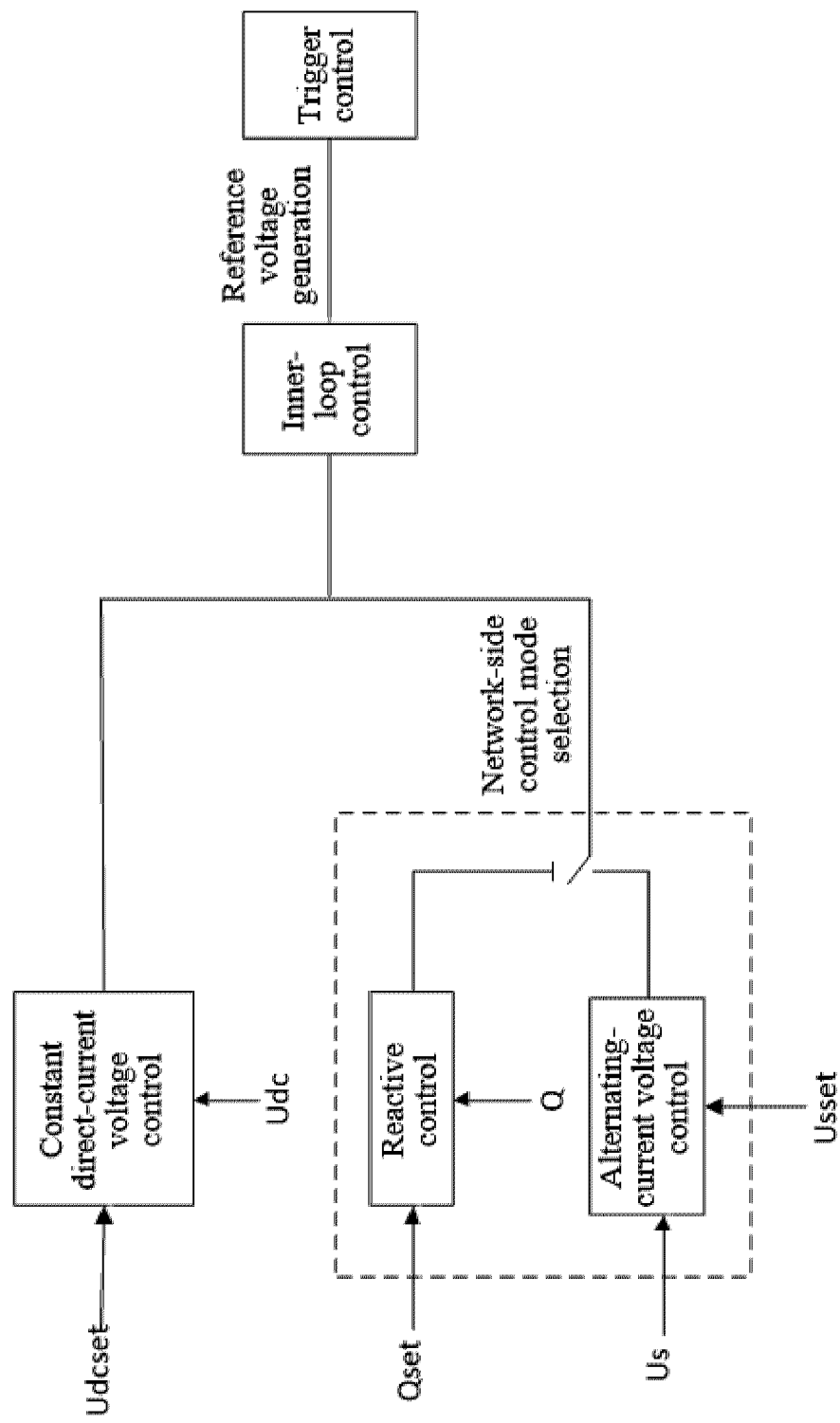


FIG. 3

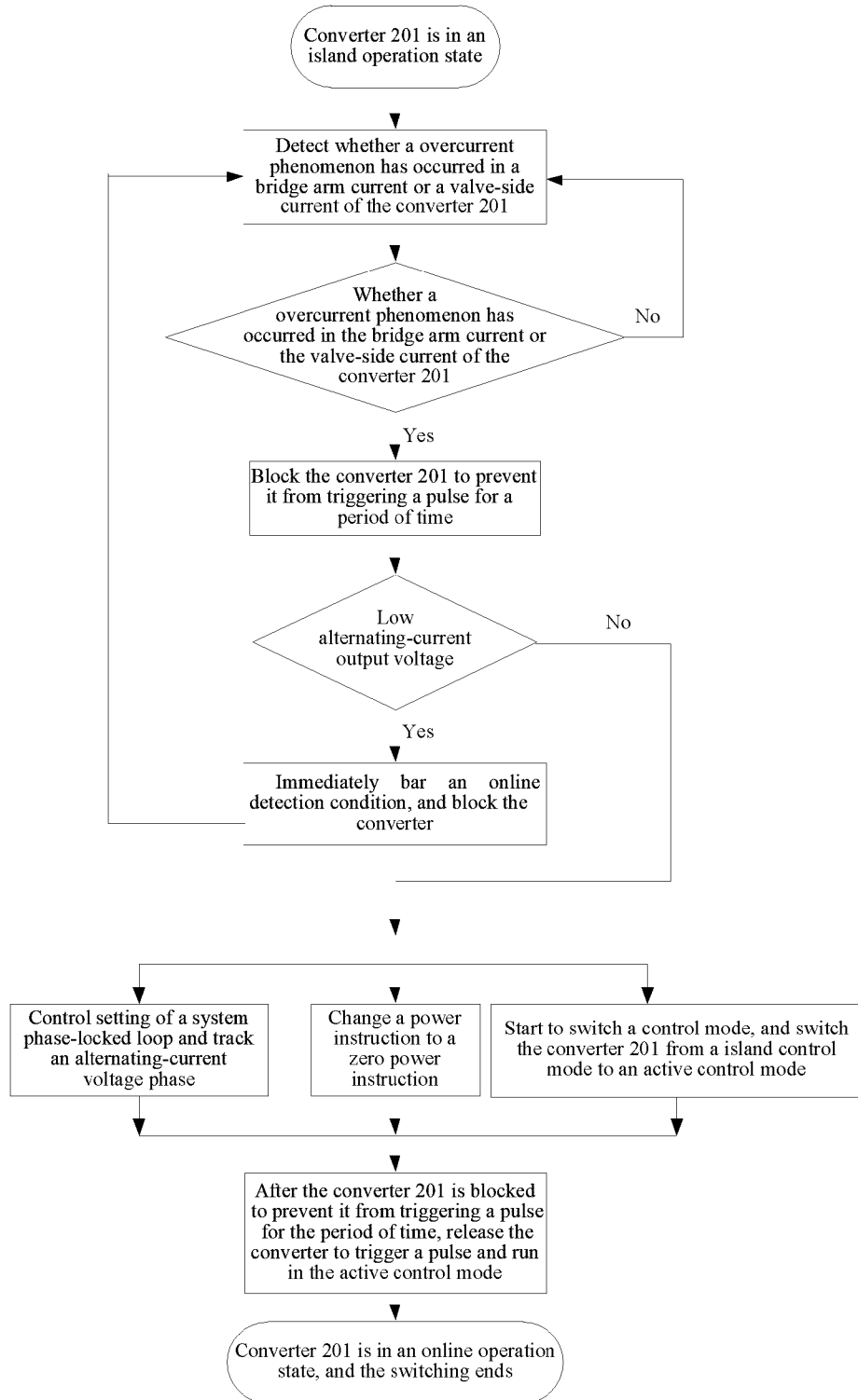


FIG. 4

