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Fortsættes ...

DESCRIPTION

Technical Field

[0001] The invention relates to the technical field of flexible DC transmission of power systems, in particular to a control system and control method for a parallel converter system.

Background

[0002] The flexible DC transmission technology can fulfill large-scale new-energy grid connection more effectively, and can guarantee efficient collection, flexible transmission, decentralization and consumption of new energy. When the new energy is collected by high-voltage large-capacity flexible DC systems, from the perspective of reliability improvements, a plurality of converters is generally connected in parallel, so that after one converter is broken down, other converters can transfer parts power to reduce power losses. A bipolar topology is commonly adopted, and the converters are connected in parallel to the same AC bus or to connected AC buses through a voltage source converter.

[0003] When the flexible DC grid is accessed to new-energy island systems, the converters should supply stable AC voltage to island networks, and at this moment, the total power of the flexible DC systems is determined by the new-energy island systems. When a plurality of converters is connected in parallel to the island systems containing the new energy, in addition to the supply of stable AC voltage to the island networks, coordinated control over the plurality of converters, such as balanced power transmission or power transmission in a preset proportion by the plurality of converters in normal conditions, and the limitation on the maximum power of the converters when the converters are overloaded should also be taken into consideration.

[0004] In order to realize outward transmissions of large-capacity new energy through a plurality of parallel converters by means of island access, an island control method and system for the plurality of parallel converters need to be adopted to fulfil coordinated control over the plurality of converters.

[0005] CN103904676A discloses a method for controlling drooping of VSC-HVDC. According to the method, a VSC is used for simulating the external characteristic of a synchronous generator, the synchronous generator can achieve networking power generation and also can directly supply power to a passive island, and therefore the VSC-HVDC control strategy without switching a controller structure can be designed by the aid of the control characteristic of the synchronous generator. According to the method, the VSC can actively control the frequency, the phase and the amplitude of AC voltage modulation waveforms, so that it is guaranteed that the stable voltage waveforms can be provided in the process of providing power for a passive

network. In addition, the method enables the VSC to have a frequency deviating regulation characteristic so as to be adaptive to load fluctuation of an AC network during networking operation. Accordingly, the method for controlling drooping of the VSC-HVDC is suitable for a VSC-HVDC networking operation mode and an islanding operation mode, and it can be guaranteed that the VSC-HVDC is smoothly and stably switched between the two operation modes.

[0006] CN103730908A discloses a method for controlling energy storage converters in a large-scale off-grid micro-grid. The method includes the steps of firstly, setting up the large-scale off-grid micro-grid; secondly, conducting primary frequency modulation on the off-grid micro-grid by means of an energy storage power station through a Droop work mode; thirdly, conducting secondary frequency modulation on the off-grid micro-grid; fourthly, conducting thrice frequency modulation on the off-grid micro-grid through a micro-grid energy management module; fifthly, conducting master and slave control on the multiple energy storage converters in the energy storage power station. According to the method, by means of flexible control over the energy storage converters, the problem of reliable power supply for independent power supply systems in remote electricity-free areas or island grids or other areas can be effectively solved, and the power supply systems can independently run in a safe, stable and economical mode. The method is applied to the multi-energy complementation alternating current bus shared type off-grid micro-grid, the multi-machine parallel operation of the energy storage power station is achieved through high-speed master and slave communication in the energy storage power station, and safe, stable and economical running of the micro-grid is achieved through interstation peer-to-peer control of the energy storage power station.

[0007] Hassanzahraee, Mohammad et al, ("Transient droop control strategy for parallel operation of voltage source converters in an islanded mode microgrid." Telecommunications Energy Conference IEEE, 2011) investigates the small signal analysis of paralleled voltage source converters (VSCs) in an islanded multi bus microgrid. Studying small signal stability of a microgrid, it can be observed that dominant low-frequency modes of the system are highly sensitive to network configuration and the parameters of power sharing controller of VSCs. These low frequency modes are highly dependent to system parameters as well as operating points and as the demanded power increases, they drift to new locations that may eventually cause instability. To have a better transient characteristic in a microgrid, a novel transient control strategy based on the static droop characteristics is presented in this paper. To provide the active damping of the low-frequency power sharing modes at different loading conditions, the derivative terms of active and reactive powers have been added to droop functions. The transient droop gains are scheduled by small signal analysis of the power sharing mechanism in such a way that yield to desired transient and steady-state response. The proposed controller ensures a stable and robust performance of paralleled VSCs.

[0008] Milczarek, Adam et al ("Proportional reactive power sharing algorithm in Islanded AC microgrid." Workshop on Smart Grid and Renewable Energy) discloses that a microgrid (MG) is a local energy system consisting a number of energy sources (e.g. wind turbine or solar

panels), energy storage units and loads that operate connected to the main electrical grid or autonomously. MGs require complex management and advanced control. One of the most important parts in microgrid structure are power electronic converters (PEC). They provide correct energy conversion from every Renewable Energy Sources (RES) and common control structure for whole system. In islanded microgrid a Classical Droop Control is usually implemented, which allows for the correct operation of parallel voltage source converters (VSC). However, additional complex power management algorithm is required, which balances system and improves reliability. The novel reactive power sharing algorithm is described in this paper, which takes into account the converter parameters as apparent power limit and maximum active power. The developed solution is verified in experimental research and compared with other known reactive power control methods.

Summary

[0009] The objective of the invention is to provide an island control method and system for a parallel converter system. In the method, a common AC voltage controller generates a current control reference signal of a plurality of converters to realize the AC voltage control of an island power grid and the power distribution and limitation of the plurality of parallel converters.

[0010] The technical solution adopted by the invention to fulfill the above-mentioned objective is as follows:

[0011] The control method for a parallel converter system is characterized in that the parallel converter system comprises at least two parallel voltage source converters connected in parallel to the same AC bus or to connected AC buses, at least one of the converters operating in an island control mode; and the control method comprises the following steps:

1. (1) Calculating a system voltage phase reference value θ_{ref} according to a frequency reference value F_{ref} ;
2. (2) Acquiring a bus voltage across the AC bus;
3. (3) Processing the acquired bus voltage to obtain an active current reference value I_{dref} and a wattless current reference value I_{qref} , which are exclusively determined by an effective bus voltage reference value and the system voltage phase reference value θ_{ref} ;
4. (4) Outputting the active current reference value I_{dref} , the wattless current reference value I_{qref} and the system voltage phase reference value θ_{ref} , served as converter control signal, to each converter in island control mode; and
5. (5) Controlling an active current of any converter in the island control modes to follow the active current reference value I_{dref} and controlling a wattless current of any converter in the island control modes to follow the wattless current reference value I_{qref} according to the received control signal; and

[0012] The converters in the island control modes aim to control the amplitude and frequency of the voltage of the AC bus.

when active power of any converter needs to be limited, the active current reference value is limited to be less than or equal to an active current limit value I_{dlim} ; and when wattless power of any converter needs to be limited, the wattless current reference value is limited to be less than or equal to a wattless current limit value I_{qlim} ;

the active current limit value I_{dlim} is generated through the following solution:

the active current limit value I_{dlim} is generated by modulating a deviation between an active power limit value and actual active power of the converter through a PI controller;

the wattless current limit value I_{qlim} is generated through the following solution:

the wattless current limit value I_{qlim} is generated by modulating a deviation between a wattless power limit value and actual wattless power of the converter through a PI controller

[0013] According to the control method for a parallel converter system, the frequency reference value F_{ref} is a rated system frequency F_n or meets $F_{ref} = F_n + K_f(P_{ref}P)$, wherein K_f is a proportionality coefficient ranging from -100 to 100, P_{ref} is a total active power reference value of the parallel converters, and P is actual total active power of the parallel converters.

[0014] According to the control method for a parallel converter system, before the converter control signal is outputted to the i^{th} converter in the island control mode in Step (4), the active current reference value I_{dref} is multiplied by an active power distribution coefficient K_{di} to obtain an active current reference value I_{drefi} of the i^{th} converter in the island control mode, and the wattless current reference value I_{qref} is multiplied by a wattless power distribution coefficient K_{qi} to obtain a wattless current reference value I_{qrefi} of the i^{th} converter in the island control mode, wherein $0 \leq K_{di} \leq 1$, $0 \leq K_{qi} \leq 1$, i range from 1 to the number of the converters in the island control modes, and the active power distribution coefficients K_d or the wattless power distribution coefficients K_q of the converters are identical or different from each other.

[0015] According to the control method for a parallel converter system, current vector control is adopted for any converter in the island control modes in Step (5).

[0016] The control system for a parallel converter system is characterized in that the parallel converter system comprises at least two parallel voltage source converters connected in parallel to the same AC bus or to connected AC buses, the control system comprises a common AC voltage controller and a separate current controller for each converter, and the AC voltage controller conducts the following stages:

[0017] A reference phase generating stage: a system voltage phase reference value θ_{ref} is calculated according to a frequency reference value F_{ref} ;

[0018] An AC voltage sampling stage: a bus voltage across the AC bus is acquired;

[0019] A current reference value calculating stage: the acquired bus voltage is processed to obtain an active current reference value I_{dref} and a wattless current reference value I_{qref} which are exclusively determined by an effective bus voltage reference value and the system voltage phase reference value θ_{ref} , wherein:

[0020] The AC voltage controller outputs the active current reference value I_{dref} , the wattless current reference value I_{qref} , and the system voltage phase reference value θ_{ref} , served as converter control signal, to the current controller of each converter in island control mode by means of communication, to make an active current outputted by the converter follow the active current reference value I_{dref} and a wattless current outputted by each converter follow the wattless current reference value I_{qref} .

[0021] The AC voltage controller is configured through one of the following two solutions:

1. (i) The AC voltage controller and the current controllers of the converters are configured in the same control device;
2. (ii) The AC voltage controller and the current controllers of the converters are configured in different control devices; and

[0022] When AC voltage controllers are configured in a plurality of control devices, at same time the current controllers of all the converters merely adopt the converter control signal outputted by one of the AC voltage controllers according to a preset priority.

the current controller of said converter comprises a power limitation stage: the active current reference value is limited to be less than or equal to an active current limit value I_{dlim} , and the wattless current reference value is limited to be less than or equal to a wattless current limit value I_{qlim} ;

the active current limit value I_{dlim} is generated through the following solution:

the active current limit value I_{dlim} is generated by modulating a deviation between an active power limit value and actual active power of the converter through a PI controller;

the wattless current limit value I_{qlim} is generated through the following solution:

the wattless current limit value I_{qlim} is generated by modulating a deviation between a wattless power limit value and actual wattless power of the converter through a PI controller.

[0023] According to the control system for a parallel converter system, the AC voltage controller is a proportional-integral controller, a sliding mode controller, a dead-beat controller, or a non-linear controller, and the current controllers are selected from proportional-integral controllers, sliding mode controllers, dead-beat controllers, or non-linear controllers.

[0024] According to the control system for a parallel converter system, the AC voltage controller further comprises a power distribution stage: the active current reference value I_{dref} is multiplied by an active power distribution coefficient K_{di} to obtain an active current reference value I_{drefi} of the i^{th} converter in the island control mode, and the wattless current reference value I_{qref} is multiplied by a wattless power distribution coefficient K_{qi} to obtain a wattless current reference value I_{qrefi} of the i^{th} converter in the island control mode, wherein $0 \leq K_{di} \leq 1$, $0 \leq K_{qi} \leq 1$, i ranges from 1 to the number of the converters of the island control modes, and the active power distribution coefficients K_d or the wattless power distribution coefficients K_q of the converters are identical or different from each other.

[0025] According to the control system for a parallel converter system, when the AC voltage controller and the current controllers are configured in the same control device, a reference signal is transmitted via a backplane bus; and when the AC voltage controller and the current controllers are configured in different devices, the communication is by means of a standard protocol which is an IEC60044-8 protocol, an Ethernet protocol, or a TDM protocol.

[0026] By adoption of the above solution, the invention has the following beneficial effects:

1. (1) According to the control method and system for a parallel converter system of the invention, through the cooperation of the upper AC voltage controller and a plurality of lower current controllers of the converters to fulfill functional decoupling, so that the object-oriented design requirements are met, and the reliability is high.
2. (2) According to the control method and system for a parallel converter system of the invention, a system voltage phase is generated by the common upper AC voltage controller, so that the synchronization of a plurality of converters is effectively guaranteed.
3. (3) The control method and system for a parallel converter system of the invention has the capacity to distribute the power of the parallel converters, so that the power of the plurality of parallel converters can be controlled to be balanced or unbalanced as needed.
4. (4) According to the control method and system for a parallel converter system of the invention, a power limitation function is fulfilled, so that a sent instruction is prevented from exceeding the power limit of the converters.
5. (5) According to the control method and system for a parallel converter system of the invention, the power limitation function is fulfilled by limiting a current instruction, and after the current instruction is limited during an AC fault, the converters are turned to adopt a constant current control, so that the fault ride-through of an AC system is

realized.

Brief Description of the Drawings

[0027]

Fig. 1 is a schematic diagram of a parallel converter system including four converters;

Fig. 2 is a flow diagram of a control method for the parallel converter system;

Fig. 3 is a structural view of a control system for the parallel converter system;

Fig. 4 is a block diagram illustrating the control function of a parallel converter system including two converters.

Detailed Description of Embodiments

[0028] The technical solution of the invention is expounded below in combination with the accompanying drawings and embodiments.

[0029] Fig. 1 shows a schematic diagram of a parallel converter system including four converters. The parallel converter system comprises four parallel converters, namely a converter C1, a converter C2, a converter C3, and a converter C4, wherein the converter C1 is connected to an AC bus B1 through a converter transformer T1 and an incoming switch Q1, the converter C2 is connected to the AC bus B1 through a converter transformer T2 and an incoming switch Q2, the converter C3 is connected to an AC bus B2 through a converter transformer T3 and an incoming switch Q3, and the converter C4 is connected to the AC bus B2 through a converter transformer T4 and an incoming switch Q4; the AC bus B1 is connected to the AC bus B2 through a bus-bar switch QM; and the AC bus B1 and the AC bus B2 are both connected to an island AC system including a new-energy power generation system.

[0030] Fig. 2 shows a flow diagram of a control method for the parallel converter system. To keep the AC voltage amplitude and frequency of the island AC systems stable, the AC bus to which the parallel connectors are connected is controlled through the following steps:

[0031] 101: A system voltage phase reference value θ_{ref} is calculated according to a frequency reference value F_{ref} . In a preferred implementation, $\theta_{ref}(t) = \theta_{ref}(t-\Delta t) + 2\pi F_{ref}\Delta t$, wherein $\theta_{ref}(t)$ is a system voltage phase reference value at the current moment, and $\theta_{ref}(t-\Delta t)$ is a

system voltage phase reference value before interval control by a Δt cycle and is set as 0 initially; and F_{ref} is valued in two approaches which are respectively as follows:

1. (i) F_{ref} is a rated system frequency F_n such as 50HZ; and
2. (ii) F_{ref} meets $F_{ref} = F_n + K_f(P_{ref} - P)$, wherein K_f is a proportionality coefficient, which is appropriately selected from -100 to 100 according to an actual system, P_{ref} is a total active power reference value of the parallel converters, and P is actual total active power of the parallel converters.

[0032] 102: A bus voltage across the AC bus is acquired. In a preferred implementation, a three-phase bus voltage across the AC bus is acquired and is subject to park transformation according to the system voltage phase reference value e_{ref} to obtain a bus voltage d-axis component U_{sd} and a bus voltage q-axis component U_{sq} .

[0033] 103: The acquired bus voltage is processed to obtain an active current reference value I_{dref} and a wattless current reference value I_{qref} . In a preferred implementation, a deviation between the bus voltage d-axis component U_{sd} and an effective bus voltage reference value is modulated by a PI controller to generate the active current reference value I_{drefi} , a deviation between the bus voltage q-axis component U_{sq} and 0 is modulated by a PI controller to generate the wattless current reference value I_{qrefi} , so that the active current reference value I_{dref} and the wattless current reference value I_{qref} are actually exclusively determined by the effective bus voltage reference value and the system voltage phase reference value θ_{ref} determining d-axis and q-axis angles.

[0034] 104: The active current reference value I_{drefi} , the wattless current reference value I_{qrefi} , and the system voltage phase reference value θ_{ref} , served as a converter control signal, are outputted to each converter in island control mode. When a power distribution function is required to distribute power of a plurality of converters, for converters having the output power required to be reduced, the active current reference value I_{dref} is multiplied by a power distribution coefficient less than 1. For instance, when the active power of the i^{th} converter in the island control mode is expected to be 0.5 of that of other converters and wattless power of the i^{th} converter in the island control mode is expected to be 0.6 of that of other converters, the active current reference value I_{dref} sent to the i^{th} converter in the island control mode is multiplied by an active power distribution coefficient $K_{di}=0.5$ to obtain an active current reference value I_{drefi} of the i^{th} converter in the island control mode, and the wattless current reference value I_{qref} is multiplied by a wattless power distribution coefficient $K_{qi}=0.6$ to obtain a wattless current reference value I_{qrefi} of the i^{th} converter in the island control mode; and the active power distribution coefficient and the wattless power distribution coefficient of other converters are 1. Particularly, when the active power distribution coefficient and the wattless

power distribution coefficient of all the converters in the island control modes are 1, the power of the converters is balanced in operation.

[0035] 105: According to the received control signal, an active current of any converter in the island control mode is controlled to follow the active current reference value I_{drefi} and a wattless current of any converter in the island control mode is controlled to follow the wattless current reference value I_{qref} . When the active power of any converter in the island control modes needs to be limited, the active current reference value is limited to be less than or equal to an active current limit value I_{dlim} , that is, the active current reference value is in the range of $[-I_{dlim}, I_{dlim}]$; and when the wattless power of any converter in the island control modes needs to be limited, the wattless current reference value is limited to be less than or equal to a wattless current limit value I_{qlim} , that is, the wattless current reference value is in the range of $[-I_{qlim}, I_{qlim}]$. The active current limit value I_{dlim} is generated through the following solution:

The active current limit value I_{dlim} is generated by modulating a deviation between an active power limit value such as the maximum overloading active power and actual active power of the converters through a PI controller;

The wattless current limit value I_{qlim} is generated through the following solution:

The wattless current limit value I_{qlim} is generated by modulating a deviation between a wattless power limit value such as the maximum wattless power limited by a power range and actual wattless power of the converters through a PI controller.

[0036] In the case where converters which do not adopt the island control modes and the converters which adopt the island control modes are connected in parallel to the same bus, active power control or DC voltage control is adopted for active control, and wattless power control is adopted for wattless control.

[0037] Fig. 3 shows a structural view of a control system for a parallel converter system. The control system comprises a common AC voltage controller and current controllers 1-N, wherein N is the number of converters in island control modes in the parallel converter system; the current controller i is a controller of the i^{th} converter in the island control mode, i is selected from 1 to N, and the current controllers are independent of one another. The AC voltage controller and any current controller are configured in different control devices, and a control signal, including an active current reference value I_{drefi} , a wattless current reference value I_{qref} , and a system voltage phase reference value θ_{ref} of the i^{th} converter is sent to the current controller i of the corresponding converter by means of communication through a standard protocol. The AC voltage controller and the current controllers can be configured in the same control device. Or a plurality of AC voltage controllers are configured in a plurality of control devices, and if this is the case, a switching logic should be set to guarantee that the current controllers of all the converters merely adopt the converter control signal outputted by one of

the AC voltage controllers at a same time according to a preset priority.

[0038] Fig. 4 shows a block diagram illustrating the control function of a parallel converter system including two converters. An AC voltage controller comprises a reference phase generation stage, an AC voltage sampling stage, a current reference value calculating stage, and a power distribution stage, wherein in the reference phase generating stage, a system voltage phase reference value θ_{ref} is calculated according to a frequency reference value F_{ref} ; in the AC voltage sampling stage, and a three-phase bus voltage across the AC bus is acquired and is subject to park transformation according to the system voltage phase reference value θ_{ref} to obtain a bus voltage d-axis component U_{sd} and a bus voltage q-axis component U_{sq} ; in the current reference value calculating stage, a deviation between the bus voltage d-axis component U_{sd} and an effective bus voltage reference value is modulated by a PI controller to generate an active current reference value I_{dref} ; a deviation between the bus voltage q-axis component U_{sq} and 0 is modulated by a PI controller to generate a wattless current reference value I_{qref} ; and a sliding mode controller, a dead-beat controller, or a non-linear controller may be adopted; in the power distribution stage, with regard to the 1st converter in the island control mode, the active current reference value I_{dref} is multiplied by an active power distribution coefficient K_{d1} to obtain an active current reference value I_{dref1} , and the wattless current reference value I_{qref} is multiplied by a wattless power distribution coefficient K_{q1} to obtain a wattless current reference value I_{qref1} ; with regard to the 2nd converter in the island control mode, the active current reference value I_{dref} is multiplied by an active power distribution coefficient K_{d2} to obtain an active current reference value I_{dref2} , and the wattless current reference value I_{qref} is multiplied by a wattless power distribution coefficient K_{q2} to obtain a wattless current reference value I_{qref2} , wherein, $0 \leq K_{d1} \leq 1$, $0 \leq K_{q1} \leq 1$, $0 \leq K_{d2} \leq 1$, and $0 \leq K_{q2} \leq 1$, and when the two converters operate symmetrically, $K_{d1} = K_{q1} = K_{d2} = K_{q2} = 1$; and in this case, it is equivalent to no configuration of the power distribution stage. Corresponding current controllers, namely a current controller 1 and a current controller 2, are configured for the two converters, and the power limitation stage is configured for the two current controllers. With regard to the ith converter ($i = 1$ or 2), an active current limit value I_{dlimi} is generated by modulating a deviation between the maximum overloading active power P_{limi} and actual active power P_{si} through a PI controller, and a wattless current limit value I_{qlimi} is generated by modulating a deviation between the maximum wattless power Q_{limi} and actual wattless power Q_{si} through a PI controller; and an active current reference value I_{drefi} is defined as a boundary value when out of the range of $[-I_{dlimi}, I_{dlimi}]$, and a wattless current reference value I_{qrefi} is defined as a boundary value when out of the range of $[-I_{qlimi}, I_{qlimi}]$. Vector control is adopted for inner loop current control of the converters, and the ith converter is controlled according to active and wattless current instructions outputted in the power limitation stage and the system voltage phase reference value θ_{ref} .

[0039] The above embodiments are only used for explaining the technical idea of the

invention, and are not intended to limit the protection scope of the invention.

REFERENCES CITED IN THE DESCRIPTION

Cited references

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- [CN103730908A](#) [0006]

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Patentkrav

1. Styringsmetode til et parallelt omformersystem, idet det parallelle omformersystem omfatter mindst to parallelle spændingskildeomformere, der er parallelforbundet til den samme vekselstrømsbus eller til forbundne vekselstrømsbusser, idet mindst en af omformerne arbejder i en θ -styringstilstand, og styringsmetoden omfatter følgende trin:

- (1) beregning af en systemspændingsfase-referenceværdi θ_{ref} i overensstemmelse med en frekvensreferenceværdi F_{ref} (101);
 - (2) erhvervelse af en busspænding over vekselstrømsbussen (102);
 - (3) behandling af den erhvervede busspænding for at opnå en aktiv strømreferenceværdi I_{dref} og en wattløs strømreferenceværdi I_{qref} , som bestemmes af en effektiv busspændingsreferenceværdi og systemspændingsfasereferenceværdien θ_{ref} (103);
 - (4) udsender den aktive strømreferencestyringsværdi I_{dref} , den wattløse strømreferencestyringsværdi I_{qref} og systemspændingsfasereferenceværdien θ_{ref} , der tjener som et konverterstyringssignal, til hver konverter i den nævnte θ -styringstilstand (104); og
 - (5) styring af en aktiv strøm af enhver omformer i θ -styringstilstanden til at følge den aktive strømreferenceværdi I_{dref} og styring af en wattløs strøm af enhver omformer i θ -styringstilstanden til at følge den wattløse strømreferenceværdi I_{qref} i overensstemmelse med det modtagne styresignal(105);
- hvor omformeren i θ -styringstilstand har til formål at styre amplituden og frekvensen af spændingen i vekselstrømsbussen;
- karakteriseret ved, at** når aktiv effekt af en omformer skal begrænses, begrænses den aktive strømreferenceværdi til at være mindre end eller lig med en aktivstrømsgrænseværdi I_{dlim} , og når wattløs effekt af en omformer skal begrænses, begrænses den wattløse strømreferenceværdi til at være mindre end eller lig med en wattløs strømgrænseværdi I_{qlim} ;
- den aktive strømgrænseværdi I_{dlim} genereres ved hjælp af følgende løsning:
- den aktive strømgrænseværdi I_{dlim} genereres ved at modulere en afvigelse mellem en grænseværdi for aktiv effekt og konverterens faktiske aktive effekt gennem en PI-regulator;

den wattløse strømgrænseværdi I_{qlim} genereres ved hjælp af følgende løsning:

Grænseværdien for strøm uden effekt I_{qlim} genereres ved at modulere en afvigelse mellem en grænseværdi for strøm uden effekt og konverterens faktiske strøm uden effekt gennem en PI-regulator.

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2. Styringsmetode til et parallelt omformersystem i henhold til krav 1, hvor frekvensreferensværdien F_{ref} er en nominel systemfrekvens F_n eller opfylder $F_{ref} = F_n + K_f(P_{ref} - P)$, hvor K_f er en proportionalitetskoefficient, der ligger mellem -100 og 100, P_{ref} er en referenceværdi for den samlede aktive effekt for de parallelle omformere, og P er den faktiske samlede aktive effekt for de parallelle omformere.

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3. Styringsmetode til et parallelomformer-system i henhold til krav 1, hvor før omformerstyresignalet udgives til en i^{te} omformer i $\emptyset$ -styringstilstanden i trin (4), ganges den aktive strømreferencestyringsværdi I_{dref} med en aktiv effektfordelingskoefficient K_{di} for at opnå en aktiv strømreferencestyringsværdi I_{drefi} for den i^{te} omformer i $\emptyset$ -styringstilstanden, og referenceværdien for den wattløse strøm I_{qref} ganges med en koefficient for fordeling af wattløs effekt K_{qi} for at opnå en referenceværdi for den wattløse strøm I_{qrefi} for den i^{te} omformer i $\emptyset$ -reguleringstilstand, hvor $0 \leq K_{di} \leq 1$, $0 \leq K_{qi} \leq 1$, i er fra 1 til et antal af omformerne i $\emptyset$ -reguleringstilstand, og omformerens aktive effektfordelingskoefficienter K_d eller de wattløse effektfordelingskoefficienter K_q er identiske eller forskellige fra hinanden.

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4. Styringsmetode for et parallelt omformer-system i henhold til krav 1, hvor der anvendes strømvektorstyring for enhver omformer i $\emptyset$ -styringstilstand i trin (5).

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5. Et styresystem til et parallelt omformersystem, idet det parallelle omformersystem omfatter mindst to parallelle spændingskildeomformere, der er parallelforbundet til den samme vekselstrømsbus eller til forbundne vekselstrømsbusser, idet styresystemet omfatter en fælles vekselspændingsregulator og en strømregulator med separate omformere, og vekselspændingsregulatoren udfører følgende trin:

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et trin til generering af referencefasen: en systemspændingsfase-reference-værdi θ_{ref} beregnes i overensstemmelse med en frekvensreferenceværdi F_{ref} ; et trin til prøveudtagning af vekselspænding: en busspænding på tværs af vekselstrømsbussen registreres;

5 et trin til beregning af strømreferencerværdien: den erhvervede busspænding behandles for at opnå en aktiv strømreferencerværdi I_{dref} og en wattløs strømreferencerværdi I_{qref} , som udelukkende bestemmes af en effektiv busspændingsreferencerværdi og systemspændingsfasereferenceværdien θ_{ref} , hvor:

10 vekselspændingsregulatoren udsender den aktive strømreferencerværdi I_{dref} , den wattløse strømreferencerværdi I_{qref} og systemspændingsfasereferenceværdien θ_{ref} , søgte som et konverterstyresignal, til strømregulatoren for hver omformer i den nævnte ϕ -styringstilstand ved hjælp af kommunikation, for at få en aktiv strøm, der udgives af hver omformer, til at følge den aktive strømreferencerværdi I_{dref} og få en wattløs strøm, der udgives af hver omformer, til at følge den wattløse strømreferencerværdi I_{qref} ;

15 vekselspændingsregulatoren konfigureres ved hjælp af en af følgende to løsninger:

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- (i) vekselspændingsregulatoren og strømregulatorerne for konverterne er konfigureret i en og samme reguleringsanordning;
 - (ii) vekselspændingsregulatoren og strømregulatorerne for konverterne er konfigureret i forskellige reguleringsenheder; og

25 når vekselspændingsregulatorer er konfigureret i flere styreenheder, anvender strømregulatorerne for alle omformerne det omformerstyresignal, som kun er afgivet af en af vekselspændingsregulatorerne på samme tid i henhold til en forudindstillet prioritet;

30 **karakteriseret ved, at** strømregulatoren for omformeren omfatter et effektbegrænsningstrin: den aktive strømreferencerværdi er begrænset til at være mindre end eller lig med en aktiv strømgrænseværdi I_{dim} , og den wattløse strømreferencerværdi er begrænset til at være mindre end eller lig med en wattløs strømgrænseværdi I_{qlim} ;

35 den aktive strømgrænseværdi I_{dim} genereres ved hjælp af følgende løsning:

den aktive strømgrænseværdi I_{dlim} genereres ved at modulere en afvigelse mellem en grænseværdi for aktiv effekt og konverterens faktiske aktive effekt gennem en PI-regulator;

den wattløse strømgrænseværdi I_{qlim} genereres ved hjælp af følgende løsning:

- 5 den wattløse strømgrænseværdi I_{qlim} genereres ved at modulere en afvigelse mellem en grænseværdi for den wattløse effekt og konverterens faktiske wattløse effekt gennem en PI-regulator.

- 10 **6.**Styringssystem til et parallelt omformersystem i henhold til krav 5, hvor vekselspændingsregulatoren er en proportional-integralregulator, en glidende styring, en deadbeat-regulator eller en ikke-lineær regulator, og strømregulatorerne er udvalgt blandt proportional-integralregulatorer, glidende styring, deadbeat-regulatorer eller ikke-lineære regulatorer.

- 15 **7.**Styringssystem til et parallelomformersystem i henhold til krav 5, hvor vekselspændingsregulatoren desuden omfatter et strømfordelingstrin: For en ite omformer i θ -reguleringstilstand multipliceres den aktive strømreferenceværdi I_{dref} med en aktiv effektfordelingskoefficient K_{di} for at opnå en aktiv strømreferenceværdi I_{drefi} for den ite omformer i θ -reguleringstilstand, og den wattløse strømreferenceværdi I_{qref} ganges med en wattløs effektfordelingskoefficient K_{qi} for at opnå en wattløs strømreferenceværdi I_{qrefi} for den i_{qrefi} omformer i θ -reguleringstilstand, hvor $0 \leq K_{di} \leq 1$, $0 \leq K_{qi} \leq 1$, i er fra 1 til et antal af omformerne i θ -styringstilstand, og omformernes aktive effektfordelingskoefficienter K_d eller de wattløse effektfordelingskoefficienter K_q er identiske eller forskellige fra hinanden.

- 25 **8.**Styresystem til et parallelt omformersystem i henhold til krav 5, hvor, når vekselspændingsregulatoren og strømregulatorerne er konfigureret i en og samme styreenhed, et referencesignal overføres via en bagplansbus; og når vekselspændingsregulatoren og strømregulatorerne er konfigureret i forskellige enheder, foregår kommunikationen ved hjælp af en standardprotokol, som er en IEC60044-8-protokol, en Ethernet-protokol eller en TDM-protokol.
- 30

DRAWINGS

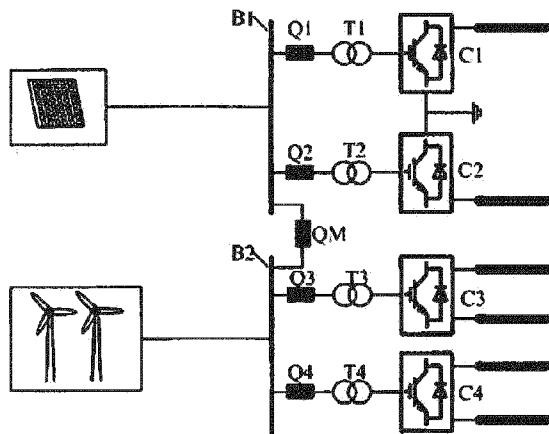


Fig. 1

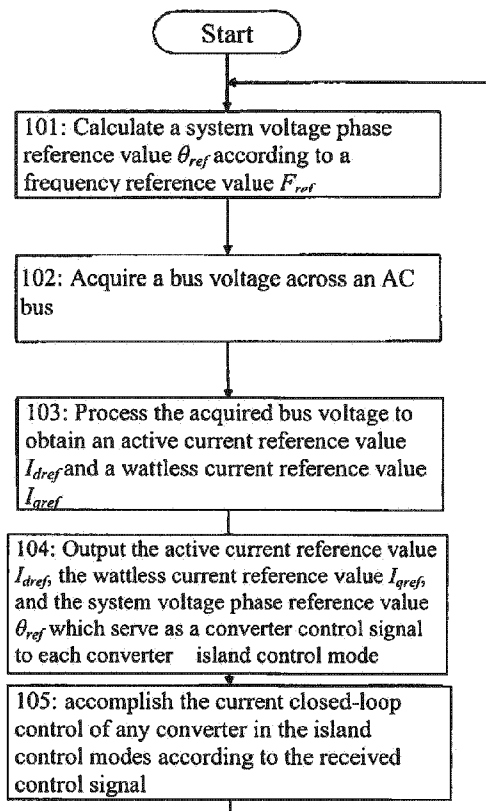


Fig. 2

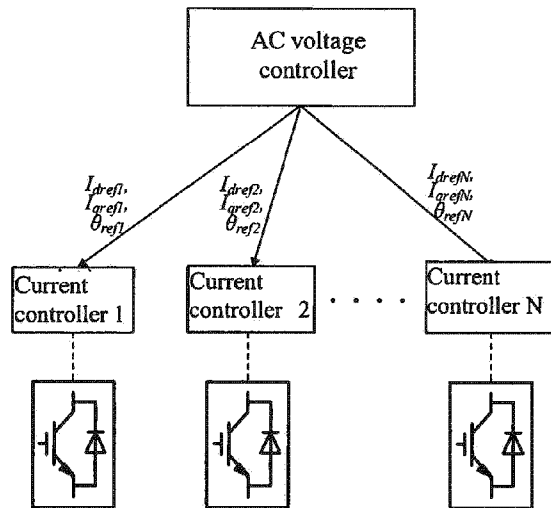


Fig. 3

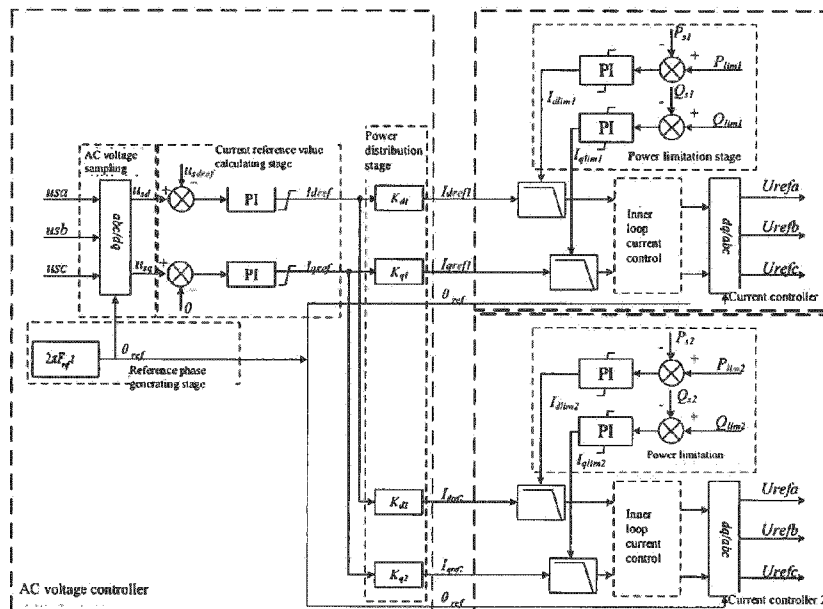


Fig. 4