CONTROL METHOD AND SYSTEM FOR PARALLEL POWER SUPPLY SYSTEM, AND DEVICE, MEDIUM AND PRODUCT

FIELD

[0001] The present disclosure relates to the technical field of converter power supply, and in particular to a method and a system for controlling a parallel power-supply system, and a device, a medium, and a product.

BACKGROUND

[0002] In rail transit, a power supply system formed by multiple inverters connected in parallel to an alternating-current bus is typically used to supply power to loads in a train. This power supply manner is crucial for ensuring the stability and safety of train operation.

[0003] Currently, the multiple inverters in the parallel power-supply system are respectively controlled by multiple controllers. To avoid conflicts during the startup processes of the multiple inverters, communication among the multiple controllers is required via a network to control the multiple inverters to start one by one. However, this method increases the complexity of the system for controlling the parallel power-supply system, and causes the system for controlling the parallel power-supply system to rely heavily on the network. In addition, since the inverters are started one by one in this method, the capacity of the loads directly connected to the alternating-current bus is limited to avoid overloading the first-started inverter.

SUMMARY

[0004] An objective of the present disclosure is to provide a method and a system for controlling a parallel power-supply system, and a device, a medium, and a product. The method and the system for controlling a parallel power-supply system, and the device, the medium, and the product according to the present disclosure enable the complexity of the system for controlling the parallel power-supply system to be effectively reduced, effectively reducing the dependence of the system for controlling the parallel power-supply system on the network, and effectively improving the starting capability of the parallel power-supply system with directly

connected loads.

[0005] The technical solutions of the present disclosure are as follows.

[0006] A method for controlling a parallel power-supply system is provided. The method is applied to a system for controlling the parallel power-supply system. The parallel power-supply system includes multiple inverters, multiple contactors, and an alternating-current bus. The multiple inverters are connected in parallel to the alternating-current bus via the multiple contactors. Each of multiple voltage sensors is provided between a respective contactor of the multiple contactors and the alternating-current bus. Each of multiple current sensors is provided on a bridge arm of a respective inverter of the multiple inverters. The system for controlling the parallel power-supply system includes multiple controllers. Each controller of the multiple controllers is connected to the respective inverter of the multiple inverters, the respective contactor of the multiple contactors, a respective voltage sensor of the multiple voltage sensors, and a respective current sensor of the multiple current sensors. The method is executed by each of the multiple controllers, and the method includes: for each controller of the multiple controllers: acquiring a first bus voltage collected by the voltage sensor which is connected to the controller; in response to the acquired first bus voltage being less than a first preset voltage, controlling the contactor connected to the controller to be turned on, controlling a timer to start timing, and controlling an output voltage of the inverter connected to the controller to remain at a second preset voltage within a preset duration; acquiring a first real-time output voltage of the inverter collected by the voltage sensor, and a first real-time bridge arm current of the inverter collected by the current sensor connected to the controller; adjusting or maintaining a phase of a modulation wave of the inverter based on the first real-time output voltage and the first real-time bridge arm current, until a timing value of the timer reaches the preset duration; acquiring a second real-time output voltage of the inverter collected by the voltage sensor; and adjusting an amplitude of the modulation wave of the inverter based on the second real-time output voltage and a rated voltage such that the output voltage of the inverter is equal to the rated voltage.

[0007] In an embodiment, the adjusting or maintaining a phase of a modulation wave of the inverter based on the first real-time output voltage and the first real-time bridge arm current, until a timing value of the timer reaches the preset duration includes: acquiring, based on the first real-time output voltage, the first real-time bridge arm current, and a formula for

calculating an active power, the active power of the inverter; and adjusting or maintaining the phase of the modulation wave of the inverter based on the active power, until the timing value of the timer reaches the preset duration.

[0008] In an embodiment, the method executed by each of the multiple controllers further includes: acquiring a third real-time output voltage of the inverter collected by the voltage sensor, and a second real-time bridge arm current of the inverter collected by the current sensor; acquiring a voltage error based on the third real-time output voltage and the rated voltage; acquiring, based on the third real-time output voltage, the second real-time bridge arm current, and a formula for calculating a reactive power, the reactive power of the inverter; and adjusting or maintaining the amplitude of the modulation wave of the inverter based on the voltage error and the reactive power.

[0009] In an embodiment, before the acquiring a first bus voltage collected by the voltage sensor which is connected to the controller, the method further includes: controlling, by a first controller of the multiple controllers, the contactor connected to the first controller to be turned on; acquiring, by the first controller, a second bus voltage collected by the voltage sensor connected to the first controller, and sampling, by the first controller, the acquired second bus voltage to obtain a first sampling value; acquiring, by a remaining controller other than the first controller among the multiple controllers, a third bus voltage collected by the voltage sensor connected to the at least one controller; sampling, by the remaining controller, the third bus voltage to obtain a second sampling value; and adjusting, in response to the second sampling value being not equal to the first sampling value, a voltage sampling coefficient such that a real-time sampling value obtained based on the adjusted voltage sampling coefficient is equal to the first sampling value; and controlling, by the first controller, the contactor connected to the first controller to be turned off.

[0010] In an embodiment, the method executed by each of the multiple controllers further includes: acquiring a fourth real-time output voltage of the inverter collected by the voltage sensor, and a third real-time bridge arm current of the inverter collected by the current sensor; acquiring a phase and an amplitude of a specific-order harmonic voltage and an amplitude of a specific-order harmonic current based on the fourth real-time output voltage and the third real-time bridge arm current; acquiring a harmonic suppression-calculation amplitude based on the amplitude of the specific-order harmonic voltage and a preset harmonic amplitude; determining

whether the amplitude of the specific-order harmonic current is greater than or equal to a preset current threshold, determining, in response to the amplitude of the specific-order harmonic current being less than the preset current threshold, the harmonic suppression-calculation amplitude as a target harmonic-suppression amplitude, and determining, in response to the amplitude of the specific-order harmonic current being greater than or equal to the preset current threshold, a current harmonic-suppression amplitude as the target harmonic-suppression amplitude; and acquiring a harmonic suppression wave based on the phase of the specific-order harmonic voltage and the target harmonic-suppression amplitude, and adjusting the modulation wave of the inverter based on the harmonic suppression wave.

[0011] According to the present disclosure, a system for controlling a parallel power-supply system is further provided. The parallel power-supply system includes: multiple inverters, multiple contactors, and an alternating-current bus. The multiple inverters are connected in parallel to the alternating-current bus via the multiple contactors. Each of multiple voltage sensors is provided between a respective contactor of the multiple contactors and the alternating-current bus. Each of multiple current sensors is provided on a bridge arm of a respective inverter of the multiple inverters. The system for controlling the parallel power-supply system includes multiple controllers. Each controller of the multiple controllers is connected to the respective inverter of the multiple inverters, the respective contactor of the multiple contactors, a respective voltage sensor of the multiple voltage sensors, and a respective current sensor of the multiple current sensors. Each controller of the multiple controllers is configured to: acquire a first bus voltage collected by the voltage sensor which is connected to the controller; in response to the acquired first bus voltage being less than a first preset voltage in amplitude, control the contactor connected to the controller to be turned on, control a timer to start timing, and control an output voltage of the inverter connected to the controller to remain at a second preset voltage within a preset duration; acquire a first real-time output voltage of the inverter collected by the voltage sensor, and a first real-time bridge arm current of the inverter collected by the current sensor connected to the controller; adjust or maintain a phase of a modulation wave of the inverter based on the first real-time output voltage and the first real-time bridge arm current, until a timing value of the timer reaches the preset duration; acquire a second real-time output voltage of the inverter collected by the voltage sensor; and adjust an amplitude of the modulation wave of the inverter based on the second real-time output voltage and a rated voltage such that the output voltage of the inverter is equal to the rated

voltage.

[0012] In an embodiment, each controller of the multiple controllers, when adjusting or maintaining a phase of a modulation wave of the inverter based on the first real-time output voltage and the first real-time bridge arm current, until a timing value of the timer reaches the preset duration, is further configured to: acquire, based on the first real-time output voltage, the first real-time bridge arm current, and a formula for calculating an active power, the active power of the inverter; and adjust or maintain the phase of the modulation wave of the inverter based on the active power, until the timing value of the timer reaches the preset duration.

[0013] In an embodiment, each controller of the multiple controllers is further configured to: acquire a third real-time output voltage of the inverter collected by the voltage sensor, and a second real-time bridge arm current of the inverter collected by the current sensor; acquire a voltage error based on the third real-time output voltage and the rated voltage; acquire, based on the third real-time output voltage, the second real-time bridge arm current, and a formula for calculating a reactive power, the reactive power of the inverter; and adjust or maintain the amplitude of the modulation wave of the inverter based on the voltage error and the reactive power.

[0014] In an embodiment, a first controller of the multiple controllers is further configured to control the contactor connected to the first controller to be turned on, acquire a second bus voltage collected by the voltage sensor connected to the first controller, and sample the acquired second bus voltage to obtain a first sampling value. A remaining controller other than the first controller among the multiple controllers is further configured to acquire a third bus voltage collected by the voltage sensor connected to the remaining controller, sample the third bus voltage to obtain a second sampling value, and adjust, in response to the second sampling value being not equal to the first sampling value, a voltage sampling coefficient such that a real-time sampling value obtained based on the adjusted voltage sampling coefficient is equal to the first sampling value. The first controller is further configured to control the contactor connected to the first controller to be turned off.

[0015] In an embodiment, each controller of the multiple controllers is further configured to: acquire a fourth real-time output voltage of the inverter collected by the voltage sensor, and a third real-time bridge arm current of the inverter collected by the current sensor; acquire a phase and an amplitude of a specific-order harmonic voltage and an amplitude of a specific-order

harmonic current based on the fourth real-time output voltage and the third real-time bridge arm current; acquire a harmonic suppression-calculation amplitude based on the amplitude of the specific-order harmonic voltage and a preset harmonic amplitude; determine whether the amplitude of the specific-order harmonic current is greater than or equal to a preset current threshold, determine, in response to the amplitude of the specific-order harmonic current being less than the preset current threshold, the harmonic suppression-calculation amplitude as a target harmonic-suppression amplitude, and determine, in response to the amplitude of the specific-order harmonic current being greater than or equal to the preset current threshold, a current harmonic-suppression amplitude as the target harmonic-suppression amplitude; and acquire a harmonic suppression wave based on the phase of the specific-order harmonic voltage and the target harmonic-suppression amplitude, and adjust the modulation wave of the inverter based on the harmonic suppression wave.

[0016] According to the present disclosure, an electronic device is further provided. The electronic device includes: a processor, a memory, and a communication bus. The communication bus is configured to implement connection and communication between the processor and the memory. The processor is configured to execute a control processing program for a parallel power-supply system stored in the memory, to implement the method for controlling the parallel power-supply system according to any one of the above embodiments.

[0017] According to the present disclosure, a computer-readable storage medium is further provided. The computer-readable storage medium stores computer-executable instructions. The computer-executable instructions, when loaded and executed by a processor, are configured to implement the method for controlling a parallel power-supply system according to any one of the above embodiments.

[0018] According to the present disclosure, a computer program product is further provided. The computer program product includes computer-executable instructions. The computer-executable instructions, when loaded and executed by a processor, are configured to implement the method for controlling a parallel power-supply system according to any one of the above embodiments.

[0019] Compared with the related art, in the method and the system for controlling a parallel power-supply system, and a device, a medium, and a product according to the present disclosure, each controller of the multiple controllers acquires the first bus voltage collected by the voltage

sensor which is connected to the controller, and in response to the acquired first bus voltage being less than the first preset voltage, the controller controls the contactor connected to the controller to be turned on, controls the timer to start timing, and controls the output voltage of the inverter connected to the controller to remain at the second preset voltage within the preset duration. The controller acquires the first real-time output voltage of the inverter collected by the voltage sensor and the first real-time bridge arm current of the inverter collected by the current sensor connected to the controller, and adjusts or maintains the phase of the modulation wave of the inverter based on the first real-time output voltage and the first real-time bridge arm current, until a timing value of the timer reaches the preset duration. In this way, when the timing value of the timer reaches the preset duration, the phases of the respective output voltages of the multiple inverters are the same. The controller acquires the second real-time output voltage of the inverter collected by the voltage sensor, and adjusts the amplitude of the modulation wave of the inverter based on the second real-time output voltage and the rated voltage such that the output voltage of the inverter is equal to the rated voltage. In this way, the amplitudes of the respective output voltages of the multiple inverters are the same. In the present disclosure, when the acquired first bus voltage is less than the first preset voltage in amplitude, each controller of the multiple controllers controls the contactor connected to the controller to be turned on, controls the timer to start timing, and controls the output voltage of the inverter connected to the controller to remain at the second preset voltage within the preset duration. The controller adjusts or maintains the phase of the modulation wave of the inverter based on the first real-time output voltage and the first real-time bridge arm current, until a timing value of the timer reaches the preset duration. In this way, when the timing value of the timer reaches the preset duration, the phases of the respective output voltages of the multiple inverters are the same. Each controller adjusts the amplitude of the modulation wave of the inverter connected to the controller based on the second real-time output voltage and the rated voltage such that the output voltage of the inverter is equal to the rated voltage. In this way, the multiple inverters in the parallel power-supply system are activated synchronously without network communication among the multiple controllers, effectively reducing the complexity of the system for controlling the parallel power-supply system, effectively reducing the dependence of the system for controlling the parallel power-supply system on the network, and effectively improving the starting capability of the parallel power-supply system with directly-connected loads.

BRIEF DESCRIPTION OF THE DRAWINGS

[0020] To clearly illustrate the technical solutions in the embodiments of the present disclosure or in the related art, the drawings required for describing the embodiments or the related art are briefly introduced below. Apparently, the drawings in the following description show only some embodiments of the present disclosure, and for those skilled in the art, other drawings can also be obtained based on these drawings without creative efforts.

[0021] FIG. 1 is a flowchart of a method for controlling a parallel power-supply system according to an embodiment of the present disclosure;

[0022] FIG. 2 is a structural block diagram of a parallel power-supply system according to an embodiment of the present disclosure;

[0023] FIG. 3 is a structural block diagram of a system for controlling a parallel power-supply system according to an embodiment of the present disclosure;

[0024] FIG. 4 is a schematic diagram of multiple controllers connected to multiple inverters, multiple contactors, multiple voltage sensors, and multiple current sensors according to an embodiment of the present disclosure; and

[0025] FIG. 5 is a structural schematic diagram of an electronic device according to an embodiment of the present disclosure.

DETAILED DESCRIPTION

[0026] To enable those skilled in the art to better understand the technical solutions in the present disclosure, the technical solutions in the embodiments of the present disclosure are clearly and completely described below. Apparently, the described embodiments are only some, but not all, of the embodiments of the present disclosure. Based on the embodiments in the present disclosure, all other embodiments obtained by those skilled in the art without creative efforts shall fall within the protection scope of the present disclosure.

[0027] It should be noted that when an element is referred to as being “fixed to” or “provided on” another element, the element may be directly on the another element or indirectly provided on the another element. When an element is referred to as being “connected to” another element,

the element may be directly connected to the another element or indirectly connected to the another element.

[0028] It should be understood that terms such as “length,” “width,” “upper,” “lower,” “front,” “rear,” “left,” “right,” “vertical,” “horizontal,” “top,” “bottom,” “inner,” “outer,” and the like indicate orientations or positional relationships based on those shown in the drawings, which are only used to facilitate describing the present disclosure and simplifying the description, rather than indicating or implying that the referenced device or element must have a particular orientation, be constructed and operated in a particular orientation. Therefore, the above terms should not be construed as a limitation to the present disclosure.

[0029] In addition, the terms “first” and “second” are used for descriptive purposes only, and should not be construed as indicating or implying relative importance or implicitly indicating the number of indicated technical features. Thus, features defined by “first” or “second” may explicitly or implicitly include one or more of such features. In the description of the present disclosure, “multiple” or “several” means two or more, unless otherwise explicitly and specifically defined.

[0030] It should be noted that the structure, scale, and size illustrated in the drawings of this specification are only used to cooperate with the contents disclosed in the specification for those skilled in the art to understand and read, instead of limiting the conditions for the implementation of the present disclosure, and therefore have no technical substantive significance. Any structural modifications, changes in scale, or adjustments in size, without affecting effectiveness and objectives of the present disclosure, should fall within the scope of the technical contents disclosed in the present disclosure.

[0031] As shown in FIG. 1, a method for controlling a parallel power-supply system is provided according to an embodiment of the present disclosure. The method is applied to a system for controlling the parallel power-supply system. As shown in FIG. 2, the parallel power-supply system includes multiple inverters 100, multiple contactors 200, and an alternating-current bus. The multiple inverters 100 are connected in parallel to the alternating-current bus via the multiple contactors 200. Each of multiple voltage sensors 300 is provided between a respective contactor 200 of the multiple contactors 200 and the alternating-current bus. Each of multiple current sensors 400 is provided on a bridge arm of a respective inverter 100 of the multiple inverters 100. The multiple voltage sensors 300 and the multiple current sensors 400

are not shown in FIG. 2. As shown in FIG. 3, the system for controlling the parallel power-supply system includes multiple controllers 500. As shown in FIG. 4, each controller 500 of the multiple controllers 500 is connected to the respective inverter 100 of the multiple inverters 100, the respective contactor 200 of the multiple contactors 200, a respective voltage sensor 300 of the multiple voltage sensors 300, and a respective current sensor 400 of the multiple current sensors 400. The method is executed by each controller of the multiple controllers, and the method includes: steps S11 to S16.

[0032] In step S11, a first bus voltage collected by the voltage sensor which is connected to the controller is acquired.

[0033] In step S12, in response to the acquired first bus voltage being less than a first preset voltage, the contactor connected to the controller is turned on, a timer is controlled to start timing, and an output voltage of the inverter connected to the controller is controlled to remain at a second preset voltage within a preset duration.

[0034] In this embodiment, the first preset voltage and the second preset voltage are set in advance, and the preset duration is set in advance. The first preset voltage may be 50V, the second preset voltage may be 10V or 20V, and the preset duration may be 50ms. When the acquired first bus voltage is less than the first preset voltage, it indicates no high voltage on the bus, that is, other inverters are not connected to the bus. In this case, the contactor is turned on such that the inverter is connected to the bus, a timer in the controller is controlled to start timing, and the output voltage of the inverter is controlled to remain at the second preset voltage which is relatively low and constant within the preset duration. If the acquired first bus voltage is greater than or equal to the first preset voltage, the inverter is controlled to output in a phase-locked manner.

[0035] In step S13, a first real-time output voltage of the inverter collected by the voltage sensor, and a first real-time bridge arm current of the inverter collected by the current sensor connected to the controller are acquired.

[0036] In step S14, a phase of a modulation wave of the inverter is adjusted or maintained based on the first real-time output voltage and the first real-time bridge arm current, until a timing value of the timer reaches the preset duration.

[0037] In this embodiment, an active power of the inverter is obtained based on the first real-

time output voltage, the first real-time bridge arm current, and a formula for calculating an active power, and then the phase of the modulation wave of the inverter is adjusted or maintained based on the active power until the timing value of the timer reaches the preset duration. In this way, when the timing value of the timer reaches the preset duration, the phases of the respective output voltages of the multiple inverters are the same.

[0038] In step S15, a second real-time output voltage of the inverter collected by the voltage sensor is acquired.

[0039] In step S16, an amplitude of the modulation wave of the inverter is adjusted based on the second real-time output voltage and a rated voltage such that the output voltage of the inverter is equal to the rated voltage.

[0040] In this embodiment, the rated voltage may be 380V. Based on the second real-time output voltage, the rated voltage, and a preset slope, the amplitude of the modulation wave of the inverter is increased such that the output voltage of the inverter is equal to the rated voltage. During increasing the amplitude of the output voltage of the inverter, if the amplitude of the output voltage of the inverter suddenly becomes too large due to external interference, current limiting is triggered to limit the excessively large amplitude, such that the inverter starts with the same amplitude or a substantially-similar amplitude increase during starting the inverter.

[0041] Compared with the related art, in the method and the system for controlling a parallel power-supply system, and a device, a medium, and a product according to the present disclosure, each controller of the multiple controllers acquires the first bus voltage collected by the voltage sensor which is connected to the controller, and in response to the acquired first bus voltage being less than the first preset voltage, the controller controls the contactor connected to the controller to be turned on, controls the timer to start timing, and controls the output voltage of the inverter connected to the controller to remain at the second preset voltage within the preset duration. The controller acquires the first real-time output voltage of the inverter collected by the voltage sensor and the first real-time bridge arm current of the inverter collected by the current sensor connected to the controller, and adjusts or maintains the phase of the modulation wave of the inverter based on the first real-time output voltage and the first real-time bridge arm current, until a timing value of the timer reaches the preset duration. In this way, when the timing value of the timer reaches the preset duration, the phases of the respective output voltages of the multiple inverters are the same. The controller acquires the second real-time

output voltage of the inverter collected by the voltage sensor, and adjusts the amplitude of the modulation wave of the inverter based on the second real-time output voltage and the rated voltage such that the output voltage of the inverter is equal to the rated voltage. In this way, the amplitudes of the respective output voltages of the multiple inverters are the same. In the present disclosure, when the acquired first bus voltage is less than the first preset voltage in amplitude, each controller of the multiple controllers controls the contactor connected to the controller to be turned on, controls the timer to start timing, and controls the output voltage of the inverter connected to the controller to remain at the second preset voltage within the preset duration. The controller adjusts or maintains the phase of the modulation wave of the inverter based on the first real-time output voltage and the first real-time bridge arm current, until a timing value of the timer reaches the preset duration. In this way, when the timing value of the timer reaches the preset duration, the phases of the respective output voltages of the multiple inverters are the same. Each controller adjusts the amplitude of the modulation wave of the inverter connected to the controller based on the second real-time output voltage and the rated voltage such that the output voltage of the inverter is equal to the rated voltage. In this way, the multiple inverters in the parallel power-supply system are activated synchronously without network communication among the multiple controllers, effectively reducing the complexity of the system for controlling the parallel power-supply system, effectively reducing the dependence of the system for controlling the parallel power-supply system on the network, and effectively improving the starting capability of the parallel power-supply system with directly-connected loads.

[0042] In an embodiment of the present disclosure, step S14 includes: steps S141 and S142.

[0043] In step S141, based on the first real-time output voltage, the first real-time bridge arm current, and a formula for calculating an active power, the active power of the inverter is acquired.

[0044] In this embodiment, the first real-time output voltage is a three-phase voltage, and the first real-time output voltage includes the first real-time output voltage of phase a, the first real-time output voltage of phase b, and the first real-time output voltage of phase c, which are as follows.

[0045] $u_a = U\sin(\theta + \omega t)$;

[0046] $u_b = U\sin(\theta + \omega t - \frac{2\pi}{3})$;

[0047] $u_c = U\sin(\theta + \omega t + \frac{2\pi}{3})$.

[0048] Where, u_a represents the first real-time output voltage of phase a, u_b represents the first real-time output voltage of phase b, and u_c represents the first real-time output voltage of phase c.

[0049] The first real-time bridge arm current is a three-phase current, and the first real-time bridge arm current includes a first real-time bridge arm current of phase a, the first real-time bridge arm current of phase b, and the first real-time bridge arm current of phase c, which are as follows.

[0050] $i_a = I\sin(\theta + \omega t - \varphi)$;

[0051] $i_b = I\sin(\theta + \omega t - \frac{2\pi}{3} - \varphi)$;

[0052] $i_c = I\sin(\theta + \omega t + \frac{2\pi}{3} - \varphi)$.

[0053] Where, i_a represents the first real-time bridge arm current of phase a, i_b represents the first real-time bridge arm current of phase b, and i_c represents the first real-time bridge arm current of phase c.

[0054] The effective value U of the first real-time output voltage, the effective value I of the first real-time bridge arm current, and a phase difference φ between the phase of the first real-time output voltage and the phase of the first real-time bridge arm current are substituted into the formula for calculating an active power, to obtain the active power of the inverter. The formula for calculating an active power is:

[0055] P=UIcosφ.

[0056] Where, P represents the active power of the inverter, U represents the effective value of the first real-time output voltage, I represents the effective value of the first real-time bridge arm current, and φ represents the phase difference between the phase of the first real-time output

voltage and the phase of the first real-time bridge arm current.

[0057] In step S142, the phase of the modulation wave of the inverter is adjusted or maintained based on the active power, until the timing value of the timer reaches the preset duration.

[0058] In this embodiment, each inverter of one or more inverters with an active power greater than 0 adjusts the phase of the modulation wave of the inverter at a respective rate of change based on the active power P corresponding to the inverter. That is, the phase of the modulation wave of each inverter of the one or more inverters with an active power greater than 0 changes at a respective rate based on the difference among active powers P of the one or more inverters. Each inverter of one or more inverters with an active power of 0 controls the phase of the modulation wave of the inverter to be unchanged, such that when the timing value of the timer reaches the preset duration, the active power of each inverter is 0, the phases of the respective modulation waves of the one or more inverters are the same, and the phase is stopped changing, achieving phase synchronization.

[0059] In an embodiment, for each inverter of one or more inverters with an active power greater than 0, the active power corresponding to the inverter is substituted into a preset formula for an initial phase of the modulation wave, to calculate an adjusted phase of the modulation wave of the inverter. The preset formula is as follows.

[0060] In this embodiment, the preset formula is:

[0061] $\theta = \omega_0 - \int k \times P$.

[0062] Where, θ represents the adjusted phase of the modulation wave of the inverter, ω_0 represents the initial phase of the modulation wave of the inverter, k is a constant, and P represents the active power of the inverter.

[0063] k may be 0.001. For each inverter of t one or more inverters with an active power greater than 0, the integral of the constant k and the active power P corresponding to the inverter is determined as a phase-adjustment rate, and the phase of the modulation wave of the inverter is adjusted at the phase-adjustment rate. Each inverter of the one or more inverters with an active power of 0 controls the phase of the modulation wave of the inverter to be unchanged, such that when the timing value of the timer reaches the preset duration, the active power of each inverter is 0, and the phases of the respective modulation waves of the one or more

inverters are the same.

[0064] In an embodiment of the present disclosure, the method executed by each of the multiple controllers further includes: steps S21 to S24.

[0065] In step S21, a third real-time output voltage of the inverter collected by the voltage sensor, and a second real-time bridge arm current of the inverter collected by the current sensor are acquired.

[0066] In step S22, a voltage error is acquired based on the third real-time output voltage and the rated voltage.

[0067] In this embodiment, the third real-time output voltage is subtracted from the rated voltage to obtain the voltage error.

[0068] In step S23, based on the third real-time output voltage, the second real-time bridge arm current, and a formula for calculating a reactive power, the reactive power of the inverter is acquired.

[0069] In this embodiment, the effective value of the third real-time output voltage, the effective value of the second real-time bridge arm current, and a phase difference between the phase of the third real-time output voltage and the phase of the second real-time bridge arm current are substituted into the formula for calculating a reactive power, to obtain the reactive power of the inverter. The formula for calculating a reactive power is known by those skilled in the art, and thus is not repeated here.

[0070] In step S24, the amplitude of the modulation wave of the inverter is adjusted or maintained based on the voltage error and the reactive power.

[0071] In this embodiment, the output reactive power of the inverter is proportional to the amplitude of the output voltage of the inverter, and the amplitude of the output voltage of the inverter is proportional to the amplitude of the modulation wave of the inverter. Thus, the difference among the amplitudes of the respective modulation waves of the multiple inverters are reflected by the difference among the reactive powers of the multiple inverters.

[0072] The rated output voltage U_{ref} of each inverter is constant at 380V. By subtracting the rated voltage from the third real-time output voltage U_f, a voltage error is obtained. The voltage error signal is transmitted to an adaptive voltage controller. Through error-weighted control of the controller, two coefficients Ke and Kc of the controller are adjusted in real time

based on the current reactive power of the inverter, to control the amplitude of the modulation wave of the inverter. In this way, the bus voltage outputted by the parallel power supply of multiple inverters is dynamically constant at the rated voltage or within an acceptable error range of the rated voltage.

[0073] In an embodiment, when the third real-time output voltage U_f is lower than the rated voltage U_{ref}, an inverter with a smaller reactive power among the multiple inverters exhibits larger Ke and Kc during adaptive adjustment, leading to a higher target voltage. When the third real-time output voltage U_f is higher than the rated voltage U_{ref}, an inverter with a smaller reactive power among the multiple inverters exhibits smaller Ke and Kc during adaptive adjustment, leading to a higher target voltage. In this way, after the amplitudes of the respective modulation waves of the multiple inverters are dynamically adjusted, the bus voltage outputted by the parallel power supply of the multiple inverters is dynamically constant at the rated voltage or within an acceptable error range of the rated voltage (for example, the bus voltage error is within ±1% of the rated voltage), thereby effectively improving the accuracy of the output voltages of the inverters in a parallel power-supply system.

[0074] In an embodiment of the present disclosure, before step S11, the method further includes: steps S31 to S33.

[0075] In step S31, a first controller of the multiple controllers controls the contactor connected to the first controller to be turned on, acquires a second bus voltage collected by the voltage sensor connected to the first controller, and samples the acquired second bus voltage to obtain a first sampling value.

[0076] In this embodiment, the first controller controls the contactor connected to the first controller to be turned on, acquires the second bus voltage collected by the voltage sensor connected to the first controller, and samples the acquired second bus voltage to obtain a first sampling value.

[0077] In step S32, a remaining controller other than the first controller among the multiple controllers acquires a third bus voltage collected by the voltage sensor connected to the remaining controller, samples the third bus voltage to obtain a second sampling value, and adjusts, in response to the second sampling value being not equal to the first sampling value, a voltage sampling coefficient such that a real-time sampling value obtained based on the adjusted voltage sampling coefficient is equal to the first sampling value.

[0078] In this embodiment, the multiple controllers are N controllers, where N is a positive integer greater than 1. The N-1 controller other than the first controller acquires the third bus voltage with the number of N-1 collected by the voltage sensor connected to the N-1 controller, and samples the third bus voltage with the number of N-1 to obtain the second sampling value with the number of N-1. If one or more second sampling value of the N-1 second sampling value is not equal to the first sampling value, one or more voltage sampling coefficient corresponding to the one or more second sampling value is adjusted, such that one or more real-time sampling value obtained based on the adjusted one or more voltage sampling coefficient is equal to the first sampling value. In this way, the one or more voltage sampling coefficient are effectively corrected, reducing the risk of circulating current and uneven power distribution in the system due to differences in respective device parameters of the inverters or differences in sensor accuracy.

[0079] In step S33, the first controller controls the contactor connected to the first controller to be turned off.

[0080] In an embodiment of the present disclosure, the method executed by each of the multiple controllers further includes: steps S41 to S45.

[0081] In step S41, a fourth real-time output voltage of the inverter collected by the voltage sensor, and a third real-time bridge arm current of the inverter collected by the current sensor are acquired.

[0082] In step S42, a phase and an amplitude of a specific-order harmonic voltage and an amplitude of a specific-order harmonic current are acquired based on the fourth real-time output voltage and the third real-time bridge arm current.

[0083] In this embodiment, a specific-order harmonic is extracted from the fourth real-time output voltage to obtain the phase and the amplitude of the specific-order harmonic voltage, and a specific-order harmonic is extracted from the third real-time bridge arm current to obtain the amplitude of the specific-order harmonic current. The specific-order harmonic may be a fifth-order harmonic or a seventh-order harmonic.

[0084] In step S43, a harmonic suppression-calculation amplitude is acquired based on the amplitude of the specific-order harmonic voltage and a preset harmonic amplitude.

[0085] In this embodiment, the preset harmonic amplitude is set in advance, and the preset

harmonic amplitude may be 0. The harmonic suppression-calculation amplitude is calculated by using the amplitude of the specific-order harmonic voltage and the preset harmonic amplitude.

[0086] In step S44, whether the amplitude of the specific-order harmonic current is greater than or equal to a preset current threshold is determined. In response to the amplitude of the specific-order harmonic current being less than the preset current threshold, the harmonic suppression-calculation amplitude is determined as a target harmonic-suppression amplitude. In response to the amplitude of the specific-order harmonic current being greater than or equal to the preset current threshold, a current harmonic-suppression amplitude is determined as the target harmonic-suppression amplitude.

[0087] In this embodiment, the preset current threshold is set in advance. It is determined whether the amplitude of the specific-order harmonic current is greater than or equal to the preset current threshold. If the amplitude of the specific-order harmonic current is less than the preset current threshold, the harmonic suppression-calculation amplitude is determined as the target harmonic-suppression amplitude. If the amplitude of the specific-order harmonic current is greater than or equal to the preset current threshold, the current harmonic-suppression amplitude is determined as the target harmonic-suppression amplitude.

[0088] In step S45, a harmonic suppression wave is acquired based on the phase of the specific-order harmonic voltage and the target harmonic-suppression amplitude, and the modulation wave of the inverter is adjusted based on the harmonic suppression wave.

[0089] In this embodiment, the harmonic suppression wave is obtained based on the phase of the specific-order harmonic voltage and the target harmonic-suppression amplitude, and the modulation wave of the inverter is adjusted based on the harmonic suppression wave, effectively suppressing harmonics and effectively reducing the risk of inverter faults caused by harmonic issues.

[0090] According to the present disclosure, a system for controlling a parallel power-supply system is further provided. As shown in FIG. 2, the parallel power-supply system includes: multiple inverters 100, multiple contactors 200, and an alternating-current bus. The multiple inverters 100 are connected in parallel to the alternating-current bus via the multiple contactors 200. Each of multiple voltage sensors 300 is provided between a respective contactor of the multiple contactors 200 and the alternating-current bus. Each of multiple current sensors 400 is

provided on a bridge arm of a respective inverter of the multiple inverters 100. The multiple voltage sensors 300 and the multiple current sensors 400 are not shown in FIG. 2. As shown in FIG. 3, the system for controlling the parallel power-supply system includes multiple controllers 500. As shown in FIG. 4, each controller 500 of the multiple controllers 500 is connected to the respective inverter 100 of the multiple inverters 100, the respective contactor 200 of the multiple contactors 200, a respective voltage sensor 300 of the multiple voltage sensors 300, and a respective current sensor 400 of the multiple current sensors 400. Each controller of the multiple controllers is configured to: acquire a first bus voltage collected by the voltage sensor which is connected to the controller; in response to the acquired first bus voltage being less than a first preset voltage, control the contactor connected to the controller to be turned on, control a timer to start timing, and control an output voltage of the inverter connected to the controller to remain at a second preset voltage within a preset duration; acquire a first real-time output voltage of the inverter collected by the voltage sensor, and a first real-time bridge arm current of the inverter collected by the current sensor connected to the controller; adjust or maintain a phase of a modulation wave of the inverter based on the first real-time output voltage and the first real-time bridge arm current, until a timing value of the timer reaches the preset duration; acquire a second real-time output voltage of the inverter collected by the voltage sensor; and adjust an amplitude of the modulation wave of the inverter based on the second real-time output voltage and a rated voltage such that the output voltage of the inverter is equal to the rated voltage.

[0091] In an embodiment of the present disclosure, each controller of the multiple controllers, when adjusting or maintaining a phase of a modulation wave of the inverter based on the first real-time output voltage and the first real-time bridge arm current, until a timing value of the timer reaches the preset duration, is further configured to: acquire, based on the first real-time output voltage, the first real-time bridge arm current, and a formula for calculating an active power, the active power of the inverter; and adjust or maintain the phase of the modulation wave of the inverter based on the active power, until the timing value of the timer reaches the preset duration.

[0092] In an embodiment of the present disclosure, each controller of the multiple controllers is further configured to: acquire a third real-time output voltage of the inverter collected by the voltage sensor, and a second real-time bridge arm current of the inverter collected by the current sensor; acquire a voltage error based on the third real-time output voltage and the rated voltage;

acquire, based on the third real-time output voltage, the second real-time bridge arm current, and a formula for calculating a reactive power, the reactive power of the inverter; and adjust or maintain the amplitude of the modulation wave of the inverter based on the voltage error and the reactive power.

[0093] In an embodiment of the present disclosure, a first controller of the multiple controllers is further configured to control the contactor connected to the first controller to be turned on, acquire a second bus voltage collected by the voltage sensor connected to the first controller, and sample the acquired second bus voltage to obtain a first sampling value. A remaining controller other than the first controller among the multiple controllers is further configured to acquire a third bus voltage collected by the voltage sensor connected to the remaining controller, sample the third bus voltage to obtain a second sampling value, and adjust, in response to the second sampling value being not equal to the first sampling value, a voltage sampling coefficient such that a real-time sampling value obtained based on the adjusted voltage sampling coefficient is equal to the first sampling value. The first controller is further configured to control the contactor connected to the first controller to be turned off.

[0094] In an embodiment of the present disclosure, each controller of the multiple controllers is further configured to: acquire a fourth real-time output voltage of the inverter collected by the voltage sensor, and a third real-time bridge arm current of the inverter collected by the current sensor; acquire a phase and an amplitude of a specific-order harmonic voltage and an amplitude of a specific-order harmonic current based on the fourth real-time output voltage and the third real-time bridge arm current; acquire a harmonic suppression-calculation amplitude based on the amplitude of the specific-order harmonic voltage and a preset harmonic amplitude; determine whether the amplitude of the specific-order harmonic current is greater than or equal to a preset current threshold, determine, in response to the amplitude of the specific-order harmonic current being less than the preset current threshold, the harmonic suppression-calculation amplitude as a target harmonic-suppression amplitude, and determine, in response to the amplitude of the specific-order harmonic current being greater than or equal to the preset current threshold, a current harmonic-suppression amplitude as the target harmonic-suppression amplitude; and acquire a harmonic suppression wave based on the phase of the specific-order harmonic voltage and the target harmonic-suppression amplitude, and adjust the modulation wave of the inverter based on the harmonic suppression wave.

[0095] As shown in FIG. 5, an electronic device is further provided according to an embodiment of the present disclosure. The electronic device includes: a processor 600, a memory 700, and a communication bus 800.

[0096] The communication bus 800 is configured to implement connection and communication between the processor 600 and the memory 700.

[0097] The processor 600 is configured to execute a control processing program for a parallel power-supply system stored in the memory 700, to implement the method for controlling a parallel power-supply system according to any one of the above embodiments.

[0098] According to an embodiment of the present disclosure, a computer-readable storage medium is further provided. The computer-readable storage medium stores computer-executable instructions. The computer-executable instructions, when loaded and executed by a processor, are configured to implement the method for controlling a parallel power-supply system according to any one of the above embodiments.

[0099] According to an embodiment of the present disclosure, a computer program product is further provided. The computer program product includes computer-executable instructions. The computer-executable instructions, when loaded and executed by a processor, are configured to implement the method for controlling a parallel power-supply system according to any one of the above embodiments.

[0100] It should be understood that if terms such as “system,” “apparatus,” “unit,” and/or “module” are used in the present disclosure, it is merely an approach for distinguishing different components, elements, parts, portions or assembly at different levels. However, if other expressions can realize the same purpose, these expressions may be replaced by other expressions.

[0101] The various embodiments in this specification are described in a progressive manner, and each embodiment focuses on the differences from other embodiments. Same or similar parts among the various embodiments can be referred to each other.

[0102] The above description of the disclosed embodiments enables those skilled in the art to implement or use the present disclosure. Various modifications to these embodiments are apparent to those skilled in the art. The general principles defined herein may be implemented in other embodiments without departing from the spirit or scope of the present disclosure.

Therefore, the present disclosure should not be limited to the embodiments shown herein, but is to accord with the widest scope consistent with the principles and novel features disclosed herein.

CLAIMS

1. A method for controlling a parallel power-supply system, applied to a system for controlling the parallel power-supply system, wherein the parallel power-supply system comprises: a plurality of inverters, a plurality of contactors, and an alternating-current bus, wherein the plurality of inverters are connected in parallel to the alternating-current bus via the plurality of contactors, each of a plurality of voltage sensors is provided between a respective contactor of the plurality of contactors and the alternating-current bus, each of a plurality of current sensors is provided on a bridge arm of a respective inverter of the plurality of inverters, the system for controlling the parallel power-supply system comprises a plurality of controllers, each controller of the plurality of controllers is connected to the respective inverter of the plurality of inverters, the respective contactor of the plurality of contactors, a respective voltage sensor of the plurality of voltage sensors, and a respective current sensor of the plurality of current sensors, the method is executed by each of the plurality of controllers, and the method comprises:

for each controller of the plurality of controllers:

acquiring a first bus voltage collected by the voltage sensor which is connected to the controller;

in response to the acquired first bus voltage being less than a first preset voltage, controlling the contactor connected to the controller to be turned on, controlling a timer to start timing, and controlling an output voltage of the inverter connected to the controller to remain at a second preset voltage within a preset duration;

acquiring a first real-time output voltage of the inverter collected by the voltage sensor, and a first real-time bridge arm current of the inverter collected by the current sensor connected to the controller;

adjusting or maintaining a phase of a modulation wave of the inverter based on the first real-time output voltage and the first real-time bridge arm current, until a timing value of the timer reaches the preset duration;

acquiring a second real-time output voltage of the inverter collected by the voltage sensor; and

adjusting an amplitude of the modulation wave of the inverter based on the second real-time output voltage and a rated voltage such that the output voltage of the inverter is equal to the rated voltage.

2. The method according to claim 1, wherein the adjusting or maintaining a phase of a modulation wave of the inverter based on the first real-time output voltage and the first real-time bridge arm current, until a timing value of the timer reaches the preset duration comprises:

acquiring, based on the first real-time output voltage, the first real-time bridge arm current, and a formula for calculating an active power, the active power of the inverter; and

adjusting or maintaining the phase of the modulation wave of the inverter based on the active power, until the timing value of the timer reaches the preset duration.

3. The method according to claim 2, wherein the method executed by each of the plurality of controllers further comprises:

acquiring a third real-time output voltage of the inverter collected by the voltage sensor, and a second real-time bridge arm current of the inverter collected by the current sensor;

acquiring a voltage error based on the third real-time output voltage and the rated voltage;

acquiring, based on the third real-time output voltage, the second real-time bridge arm current, and a formula for calculating a reactive power, the reactive power of the inverter; and

adjusting or maintaining the amplitude of the modulation wave of the inverter based on the voltage error and the reactive power.

4. The method according to claim 3, wherein before the acquiring a first bus voltage collected by the voltage sensor which is connected to the controller, the method further comprises:

controlling, by a first controller of the plurality of controllers, the contactor connected to the first controller to be turned on; acquiring, by the first controller, a second bus voltage collected by the voltage sensor connected to the first controller; and sampling, by the first controller, the acquired second bus voltage to obtain a first sampling value;

acquiring, by a remaining controller other than the first controller among the plurality of controllers, a third bus voltage collected by the voltage sensor connected to the remaining controller; sampling, by the remaining controller, the third bus voltage to obtain a second

sampling value; and adjusting, in response to the second sampling value being not equal to the first sampling value, a voltage sampling coefficient such that a real-time sampling value obtained based on the adjusted voltage sampling coefficient is equal to the first sampling value; and

controlling, by the first controller, the contactor connected to the first controller to be turned off.

5. The method according to any one of claims 1 to 4, wherein the method executed by each of the plurality of controllers further comprises:

acquiring a fourth real-time output voltage of the inverter collected by the voltage sensor, and a third real-time bridge arm current of the inverter collected by the current sensor;

acquiring a phase and an amplitude of a specific-order harmonic voltage and an amplitude of a specific-order harmonic current based on the fourth real-time output voltage and the third real-time bridge arm current;

acquiring a harmonic suppression-calculation amplitude based on the amplitude of the specific-order harmonic voltage and a preset harmonic amplitude;

determining whether the amplitude of the specific-order harmonic current is greater than or equal to a preset current threshold, determining, in response to the amplitude of the specific-order harmonic current being less than the preset current threshold, the harmonic suppression-calculation amplitude as a target harmonic-suppression amplitude, and determining, in response to the amplitude of the specific-order harmonic current being greater than or equal to the preset current threshold, a current harmonic-suppression amplitude as the target harmonic-suppression amplitude; and

acquiring a harmonic suppression wave based on the phase of the specific-order harmonic voltage and the target harmonic-suppression amplitude, and adjusting the modulation wave of the inverter based on the harmonic suppression wave.

6. A system for controlling a parallel power-supply system, wherein the parallel power-supply system comprises: a plurality of inverters, a plurality of contactors, and an alternating-current bus, wherein the plurality of inverters are connected in parallel to the alternating-current bus via the plurality of contactors, each of a plurality of voltage sensors is provided between a respective contactor of the plurality of contactors and the alternating-current bus, each of a

plurality of current sensors is provided on a bridge arm of a respective inverter of the plurality of inverters,

the system for controlling the parallel power-supply system comprises a plurality of controllers, each controller of the plurality of controllers is connected to the respective inverter of the plurality of inverters, the respective contactor of the plurality of contactors, a respective voltage sensor of the plurality of voltage sensors, and a respective current sensor of the plurality of current sensors, and each controller of the plurality of controllers is configured to:

acquire a first bus voltage collected by the voltage sensor which is connected to the controller;

in response to the acquired first bus voltage being less than a first preset voltage in amplitude, control the contactor connected to the controller to be turned on, control a timer to start timing, and control an output voltage of the inverter connected to the controller to remain at a second preset voltage within a preset duration;

acquire a first real-time output voltage of the inverter collected by the voltage sensor, and a first real-time bridge arm current of the inverter collected by the current sensor connected to the controller;

adjust or maintain a phase of a modulation wave of the inverter based on the first real-time output voltage and the first real-time bridge arm current, until a timing value of the timer reaches the preset duration;

acquire a second real-time output voltage of the inverter collected by the voltage sensor; and

adjust an amplitude of the modulation wave of the inverter based on the second real-time output voltage and a rated voltage such that the output voltage of the inverter is equal to the rated voltage.

7. The system according to claim 6, wherein each controller of the plurality of controllers, when adjusting or maintaining a phase of a modulation wave of the inverter to be adjusted or unchanged based on the first real-time output voltage and the first real-time bridge arm current, until a timing value of the timer reaches the preset duration, is further configured to:

acquire, based on the first real-time output voltage, the first real-time bridge arm current, and a formula for calculating an active power, the active power of the inverter; and

adjust or maintain the phase of the modulation wave of the inverter based on the active power, until the timing value of the timer reaches the preset duration.

8. The system according to claim 7, wherein each controller of the plurality of controllers is further configured to:

acquire a third real-time output voltage of the inverter collected by the voltage sensor, and a second real-time bridge arm current of the inverter collected by the current sensor;

acquire a voltage error based on the third real-time output voltage and the rated voltage;

acquire, based on the third real-time output voltage, the second real-time bridge arm current, and a formula for calculating a reactive power, the reactive power of the inverter; and

adjust or maintain the amplitude of the modulation wave of the inverter based on the voltage error and the reactive power.

9. The system according to claim 8, wherein

a first controller of the plurality of controllers is further configured to control the contactor connected to the first controller to be turned on, acquire a second bus voltage collected by the voltage sensor connected to the first controller, and sample the acquired second bus voltage to obtain a first sampling value;

a remaining controller other than the first controller among the plurality of controllers is further configured to acquire a third bus voltage collected by the voltage sensor connected to the remaining controller, sample the third bus voltage to obtain a second sampling value, and adjust, in response to the second sampling value being not equal to the first sampling value, a voltage sampling coefficient such that a real-time sampling value obtained based on the adjusted voltage sampling coefficient is equal to the first sampling value; and

the first controller is further configured to control the contactor connected to the first controller to be turned off.

10. The system according to any one of claims 6 to 9, each controller of the plurality of controllers is further configured to:

acquire a fourth real-time output voltage of the inverter collected by the voltage sensor, and a third real-time bridge arm current of the inverter collected by the current sensor;

acquire a phase and an amplitude of a specific-order harmonic voltage and an amplitude

of a specific-order harmonic current based on the fourth real-time output voltage and the third real-time bridge arm current;

acquire a harmonic suppression-calculation amplitude based on the amplitude of the specific-order harmonic voltage and a preset harmonic amplitude;

determine whether the amplitude of the specific-order harmonic current is greater than or equal to a preset current threshold, determine, in response to the amplitude of the specific-order harmonic current being less than the preset current threshold, the harmonic suppression-calculation amplitude as a target harmonic-suppression amplitude, and determine, in response to the amplitude of the specific-order harmonic current being greater than or equal to the preset current threshold, a current harmonic-suppression amplitude as the target harmonic-suppression amplitude; and

acquire a harmonic suppression wave based on the phase of the specific-order harmonic voltage and the target harmonic-suppression amplitude, and adjust the modulation wave of the inverter based on the harmonic suppression wave.

11. An electronic device, comprising: a processor, a memory, and a communication bus, wherein

the communication bus is configured to implement connection and communication between the processor and the memory, and

the processor is configured to execute a control processing program for a parallel power-supply system stored in the memory, to implement the method for controlling the parallel power-supply system according to any one of claims 1 to 5.

12. A computer-readable storage medium, storing computer-executable instructions, wherein the computer-executable instructions, when loaded and executed by a processor, are configured to implement the method for controlling a parallel power-supply system according to any one of claims 1 to 5.

13. A computer program product, comprising computer-executable instructions, wherein the computer-executable instructions, when loaded and executed by a processor, are configured to implement the method for controlling a parallel power-supply system according to any one of claims 1 to 5.