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DUAL INVERTER SYSTEM

Abstract

The dual inverter system includes a first inverter connected to one end of a stator coil of the motor and a second inverter connected to the other end. The controller can execute a dual mode in which the motor is driven by two inverters and a single mode in which the motor is driven by only one inverter. The controller closes the upper SW elements of all of the first and second inverters, opens all the lower SW elements, and closes the connection switch when the voltage at the DC end of the first inverter exceeds the threshold voltage. Alternatively, the controllers close all the lower SW elements of the first and second inverters to open all the upper SW elements and close the connection switches.

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Background/Summary

CROSS-REFERENCE TO RELATED APPLICATION

[0001] This application claims priority to Japanese Patent Application No. 2024-022372 filed on Feb. 16, 2024, incorporated herein by reference in its entirety.

BACKGROUND

1. Technical Field

[0002] The technology disclosed by the present specification relates to a dual inverter system that includes two inverters and one open winding motor.

2. Description of Related Art

[0003] Japanese Unexamined Patent Application Publication No. 2018-014829 (JP 2018-014829 A) discloses an example of a dual inverter system. In the dual inverter system, an alternating current (AC) end of a first inverter is connected to one end of a stator coil of a motor, and an AC end of a second inverter is connected to the other end of the stator coil. When switching elements of the first inverter and the second inverter are synchronously turned ON and OFF, since a voltage twice as high can be applied to the motor as compared to when the motor is driven by one inverter, a high torque can be obtained by the motor. When a high torque is not necessary, the other end of the stator coil is interconnected to create a neutral point, and the motor is driven by only the first inverter. In the present specification, for convenience, the motor being driven by two inverters will be called a dual mode, and the motor being driven by only one inverter will be called a single mode.

[0004] Moreover, when a voltage at a direct current (DC) end of the inverter exceeds a predetermined threshold voltage or the like, a protection control is executed that consumes a current generated by an induced electromotive force of the stator coil while the motor inertially rotates. An example of a protection control is disclosed in Japanese Unexamined Patent Application Publication No. 2016-025776 (JP 2016-025776 A). The device disclosed in JP 2016-025776 A is a device that drives a motor by one inverter. JP 2016-025776 A discloses a protection control in which one of an upper switching element and a lower switching element is turned OFF and the other is turned ON after a predetermined standby time. A control that returns a current generated by an induced electromotive force of the stator coil by closing one of the upper switching element and the lower switching element is called an active short circuit control (or a zero vector control) (JP 2016-025776 A). In the specification, for convenience of explanation, a control that returns a current generated by an induced electromotive force of the stator coil by closing one of the upper switching element and the lower switching element will be abbreviated as an active short circuit (ASC) control.

SUMMARY

[0005] In the dual inverter system, a short circuit of the battery must be avoided when shifting from a single mode or a dual mode to an ASC control. The present specification provides technology, in a dual inverter system, that can shift to an ASC control (current is recirculated to a stator coil and consumed) while avoiding a short circuit of a battery in the same procedure, in either state of a single mode or a dual mode.

[0006] The dual inverter system disclosed by the present specification includes a first inverter, a second inverter, a motor, a connection switch, and a controller. A DC end of the first inverter is connected to a battery, and a plurality of AC ends is connected to respective ends of a plurality of stator coils of the motor on one side. A plurality of AC ends of the second inverter is connected to respective ends of the stator coils on another end. The connection switch connects a DC end of the second inverter to the battery and disconnects the DC end of the second inverter from the battery. The controller is capable of executing a dual mode in which the motor is driven by the first inverter

and the second inverter by closing the connection switch, and a single mode in which the motor is driven by only the first inverter by opening the connection switch.
[0007] As is well known, an inverter includes a plurality of series circuits in which an upper switching element and a lower switching element are connected in series. The series circuits are connected in parallel between a positive electrode and a negative electrode of the DC end of the inverter. A midpoint of each series circuit is connected to each of the AC ends of the inverter. When a voltage of the DC end of the first inverter exceeds a predetermined threshold voltage, the controller executes one of the following upper short circuit control and lower short circuit control. In the upper short circuit control, the controller closes the connection switch along with closing all of the upper switching elements of the first and second inverters and opening all of the lower switching elements of the first and second inverters. In the lower short circuit control, the controller closes the connection switch along with closing all of the lower switching elements of the first and second inverters and opening all of the upper switching elements of the first and second inverters.
[0008] In the upper short circuit control, a current generated by an induced electromotive force of the stator coil is recirculated through the upper switching elements of the first and second inverters. In the lower short circuit control, a current generated by an induced electromotive force of the stator coil is recirculated through the lower switching elements of the first and second inverters. In either the dual mode or the single mode, a current can be consumed by recirculation to the stator coil, without the battery being short circuited, by shifting to the upper short circuit control (or the lower short circuit control).
[0009] The controller executes the upper short circuit control when a load of the upper switching element is less than a load of the lower switching element, and executes the lower short circuit control when a load of the lower switching element is less than a load of the upper switching element. A cumulative load of the upper switching element and the lower switching element is leveled, by separately using the upper short circuit control and the lower short circuit control.
[0010] The controller may return a current by the following procedures, as a protection control: (1) the controller opens the connection switch; (2) the controller closes upper switching elements and opens lower switching elements that are connected to respective ends of at least one stator coil, and opens upper switching elements and closes lower switching elements that are connected to respective ends of remaining stator coils; and (3) the controller closes the connection switch.
[0011] According to the above procedures, the current is recirculated by a loop in which the upper switching elements are closed, and the current is recirculated by a loop in which the lower switching elements are closed. A power loss in the stator coil becomes larger than a power loss in the upper short circuit control and lower short circuit control, and the current is rapidly attenuated.
[0012] Details of the technique disclosed in the present specification and further modifications will be described in the “DETAILED DESCRIPTION OF EMBODIMENTS” below.

Description

BRIEF DESCRIPTION OF THE DRAWINGS
[0013] Features, advantages, and technical and industrial significance of exemplary embodiments of the disclosure will be described below with reference to the accompanying drawings, in which like signs denote like elements, and wherein:
[0014] FIG. **1** is a circuit diagram of a dual inverter system according to a first embodiment;
[0015] FIG. **2** is a circuit diagram showing the current flow during the upper short circuit control;
[0016] FIG. **3** is a schematic diagram showing the current flow during the lower short circuit control; and
[0017] FIG. **4** is a diagram illustrating a flow of a return current in the dual inverter system of the second embodiment.

DETAILED DESCRIPTION OF EMBODIMENTS

First Embodiment

[0018] The dual inverter system **2** of the first embodiment will be described with reference to FIGS. **1-3**. Hereinafter, for convenience of explanation, "dual inverter system" may be abbreviated as "DI system". FIG. **1** is a schematic diagram of a DI device **2**. DI device **2** includes a battery **3**, a first inverter **10**, a second inverter **20**, a motor **30**, connection switches **40***p*, **40***n*, and controller **50**. DI device **2** is mounted on, for example, a battery electric vehicle, and a motor **30** drives an axle.

[0019] The first inverter **10** includes a DC end (positive electrode **10***p* and negative electrode **10***n*) and AC ends **10***u*, **10***v*, **10***w*. The DC end is connected to the battery **3**, and the AC end is connected to the motor **30**.

[0020] The first inverter **10** includes three sets of series circuits **11***u*, **11***v*, **11***w*. The series circuit **11***u* includes a series-connected circuit of the upper switching element **12***u* and the lower switching element **13***u*. Hereinafter, for convenience of explanation, the "switching element" may be abbreviated as a SW element. The upper SW element **12** and the lower SW element **13** are connected in anti-parallel. The hardware of the diode may be a separate element from SW element or may be incorporated in the board of SW element.

[0021] The series circuit **11***u* is connected between the positive electrode **10***p* and the negative electrode **10***n* of the DC end of the first inverter **10**. The upper SW element **12***u* is connected to the positive electrode **10***p*, and the lower SW element **13***u* is connected to the negative electrode **10***n*. The midpoint of the series circuit **11***u*, that is, the midpoint of the series-connected circuit of the upper SW element **12***u* and the lower SW element **13***u* is connected to the AC end **10***u* of the first inverter **10**.

[0022] The series circuit **11***v* is composed of a series-connected circuit of an upper SW element **12***v* and a lower SW element **13***v*. The series circuit **11***w* is composed of a series-connected circuit of an upper SW element **12***w* and a lower SW element **13***w*. The series circuit **11***v*, **11***w* has the same construction as the series circuit **11***u*. Hereinafter, the upper SW elements **12***u*, **12***v*, **12***w* may be collectively referred to as the upper SW element **12**, and the lower SW elements **13***u*, **13***v*, **13***w* device may be collectively referred to as the lower SW element **13**.

[0023] Each upper SW element **12** is associated with a temperature sensor **14**, and each lower SW element **13** is associated with a temperature sensor **15**. A system main relay **4** is connected between the DC ends **10***p*, **10***n* of the first inverter **10** and the battery **3**. When the system main relay **4** is closed, the first inverter **10** (and the second inverter **20**) is connected to the battery **3**. When the system main relay **4** is opened, the first inverter **10** (and the second inverter **20**) is disconnected from the battery **3**. A capacitor **5** is connected between the positive electrode **10***p* of the DC end of the first inverter **10** and the negative electrode **10***n*, and a voltage sensor **6** for measuring the voltage across the capacitor **5** (the voltage at the DC end of the first inverter **10**) is provided.

[0024] For convenience of explanation, three sets of series circuit **11***u*, **11***v*, **11***w* may be collectively referred to as a series circuit **11**. Three series circuits **11** are connected **25** in parallel between the positive electrode **10***p* and the negative electrode **10***n* of the DC end of the first inverter **10**. A midpoint of each of the three sets of series circuits **11** is connected to each of the AC ends **10***u*, **10***v*, **10***w*. The upper SW element **12** and the lower SW element **13** are driven by the controller **50**. When the controller **50** alternately turns on and off the upper SW element **12** and the lower SW element **13** at a predetermined duty cycle, an alternating current flows through each of the three AC ends **10***u*, **10***v*, **10***w*.

[0025] The second inverter **20** has the same configuration as the first inverter **10**, and includes three series circuits **21***u*, **21***v*, **21***w*. The second inverter **20** also uses a generic name similar to that of the first inverter **10**. For example, three sets of series circuit **21***u*, **21***v*, **21***w* are collectively referred to below as series circuits **21**. The same generic term is used for the upper SW elements **22***u*, **22***v*, **22***w* and the lower SW elements **23***u*, **23***v*, **23***w*.

[0026] Three series circuits **21** are connected in parallel between the positive electrode **20***p* and the negative electrode **20***n* of the DC end of the second inverter **20**. Each of the series circuits **21** includes a series-connected circuit including an upper SW element **22** and a lower SW element **23**. The upper SW element **22** and the lower SW element **23** are connected in anti-parallel. The upper SW element **22** is connected to the positive electrode **20***p*, and the lower SW element **23** is connected to the negative electrode **20***n*. The midpoint of the series-connected circuitry of the upper SW element **22** and the lower SW element **23** is connected to the AC end. The midpoint of the series circuit **21***u* (**21***v*, **21***w*) is connected to the AC end **20***u* (**20***v*, **20***w*).

[0027] Each of the plurality of upper SW elements **22** is associated with a temperature sensor **24**, and each of the plurality of lower SW elements **23** is associated with a temperature sensor **25**.

[0028] The motor **30** includes three stator coils **31***u*, **31***v*, **31***w*. One end of each of the three stator coils **31***u*, **31***v*, **31***w* (the left end of the stator coil in FIG. **1**) is connected to each of the three AC ends **10***u*, **10***v*, **10***w* of the first inverter **10**. The other end of each of the three stator coils **31***u*, **31***v*, **31***w* (the right end of the stator coil in FIG. **1**) is connected to each of the three AC ends **20***u*, **20***v*, **20***w* of the second inverter **20**. Hereinafter, the stator coils **31***u*, **31***v*, **31***w* may be collectively referred to as the stator coil **31**.

[0029] The motor **30** is a three-phase AC motor. The suffix “u” /“v” /“w” of the symbol means each phase (u-phase, v-phase, w-phase) of three-phase alternating current. SW elements **12***u*, **13***u*, **22***u*, **23***u* are connected to the stator coil **31***u*. Similarly, SW elements **12***v*, **13***v*, **22***v*, **23***v* are connected to the stator coil **31***v*, and SW elements **12***w*, **13***w*, **22***w*, **23***w* are connected to the stator coil **31***w*.

[0030] In a normal motor, one end of each of the plurality of stator coils is connected to each of the plurality of AC ends of the inverter, and the other ends of the plurality of stator coils are connected to each other. A portion where the other ends of the plurality of stator coils are connected to each other is called a neutral point. In the motor **30**, one end of the plurality of stator coils **31** is connected to the AC ends **10***u*, **10***v*, **10***w* of the first inverter **10**, and the other end is connected to the AC ends **20***u*, **20***v*, **20***w* of the second inverter **20**. The motor **30** having no neutral point is called an open winding type.

[0031] The DC ends **20***p*, **20***n* of the second inverter **20** are connected to the battery **3** via connection switches **40***p*, **40***n*. Specifically, the positive electrode **20***p* is connected to the positive electrode **3***p* of the battery **3** via the connection switch **40***p*, and the negative electrode **20***n* is connected to the negative electrode **3***n* of the battery **3** via the connection switch **40***n*. When the connection switches **40***p*, **40***n* are closed, the second inverter **20** is connected to the battery **3**, and when at least one of the connection switches **40***p*, **40***n* are opened, the second inverter **20** is disconnected from the battery **3**.

[0032] The controller **50** may drive the motor **30** using both the first inverter **10** and the second inverter **20**. Specifically, the controller **50** closes the connection switches **40***p*, **40***n*. The upper SW element **12***u* and the lower SW element **13***u* of the series circuit **11***u* are alternately turned on and off. The upper SW element **22***u* of the series circuit **21***u* is turned on and off in a phase opposite to the upper SW element **12***u*, and the lower SW element **23***u* is turned on and off in a phase opposite to the lower SW element **13***u*. The same applies to other series circuits **11***v*/**21***v* (**11***w*/**21***w*). The controller **50** interlocks SW elements of the first inverter **10** with SW elements of the second inverter **20** to turn them on and off.

[0033] When SW elements of the first inverter **10** and the second inverter **20** are driven in opposite phases as described above, the stator coil **31** can be energized twice as much as when the motor is driven by one inverter. That is, when the motor **30** is driven by two inverters (the first inverter **10** and the second inverter **20**), a high torque is obtained. Driving the motor **30** by the first inverter **10** and the second inverter **20** by closing the connection switches **40***p*, **40***n* is hereinafter referred to as a dual mode.

[0034] The controller **50** may open the connection switches **40***p*, **40***n* and drive the motor **30** only by the first inverter **10**. At this time, a neutral point is created in the second inverter **20**. The controller **50** opens the connection switch **40***p*, closes all the upper SW elements **22** of the second inverter **20**, and opens all the lower SW elements **23**. Then, the other ends of the plurality of stator coils **31** (the right end of the stator coil **31** in FIG. **1**) are short-circuited via the upper SW elements **22**. That is, the other ends of the plurality of stator coils **31** are connected to the neutral point. The controller **50** turns on and off SW elements of the first inverter **10** as appropriate. The motor **30** is driven as a normal motor having a neutral point. The controller **50** using the second inverter **20** to create a neutral point and driving the motor **30** only by the first inverter **10** is hereinafter referred to as a single mode.

[0035] The controller **50** can create a neutral point in two ways: First, as described above, the controller **50** closes all the upper SW elements **22** of the second inverter **20** and opens all the lower SW elements **23**. In another way, the controller **50** closes all the lower SW elements **23** of the second inverter **20** and open all the upper SW elements **22**. The right ends of the stator coils **31** are short-circuited via the lower SW elements **23**. In the single mode, the controller **50** opens the connection switches **40***p*, **40***n*.

[0036] When any problem occurs in the first inverter **10** or the second inverter, the voltage at the DC end of the first inverter **10** (the voltage between the positive electrode **10***p* and the negative electrode **10***n*) may be higher than the battery voltage. A capacitor **5** is connected to the DC end (positive electrode **10***p* and negative electrode **10***n*). When the DC end is in an overvoltage condition, the capacitor **5** and SW elements are damaged. In such a case, the controller **50** implements protection control. In the present specification, the protective control means a control in which a current generated by the induced electromotive force of the stator coil **31** is consumed while being recirculated to the stator coil through SW elements of the inverters. When shifting from the dual mode or the single mode to the protective control, the positive electrode **3***p* and the negative electrode **3***n* of the battery **3** must not be short-circuited.

[0037] When the voltage at the DC end of the first inverter **10** exceeds a predetermined threshold voltage, the controller **50** performs one of the following upper short circuit control and lower short circuit control as the protection control. In the upper short circuit control, the controller **50** closes all the upper SW elements **12** and **22** of the first inverter **10** and the second inverter **20**, opens all the lower SW elements **13** and **23**, and closes the connection switches **40***p*, **40***n*. In the lower short circuit control, the controller **50** closes all the lower SW elements **13**, **23** of the first inverter **10** and the second inverter **20** to open all the upper SW elements **12**, **22** and close the connection switches **40***p*, **40***n*.

[0038] FIG. **2** shows the current flow during the upper short circuit control. The current generated by the induced electromotive force of the stator coil **31** flows back to the stator coil **31** through the connection switch **40***p* with the upper SW elements **12** and **22**. The current decays over time. Consequently, the voltage at the DC end (the voltage between the positive electrode **10***p* and the negative electrode **10***n*) decreases.

[0039] FIG. **3** shows the current flow during the lower short circuit control. The current generated by the induced electromotive force of the stator coil **31** flows back to the stator coil **31** through the connection switch **40***n* with the lower SW elements **13** and **23**. The current decays over time. Consequently, the voltage at the DC end (the voltage between the positive electrode **10***p* and the negative electrode **10***n*) decreases.

[0040] As can be understood from FIG. **2** and FIG. **3**, neither the upper short circuit control nor the lower short circuit control short-circuits the positive electrode **3***p* and the negative electrode **3***n* of the battery **3**. In particular, when shifting from the dual mode to the up (down) short-circuit control and when shifting from the single mode to the up (down) short-circuit control, a short-circuit of the battery **3** is avoided in both cases.

[0041] The controller **50** may compare the loads of the upper SW elements **12** and **22** with the loads of the lower SW elements **13** and **23**, execute the upper short circuit control when the loads of the upper SW elements **12** and **22** are small, and execute the lower short circuit control when the loads of the lower SW elements **13** and **23** are small. The cumulative loads of the upper SW elements **12**, **22** and the lower SW elements **13**, **23** are leveled. The load of SW element is specified based on the temperature, the driving time, and the number of times of driving of SW element.

Second Embodiment

[0042] FIG. **4** is a circuit diagram of DI device **102** according to the second embodiment. The circuit configuration of DI system **102** is the same as the circuit configuration of DI system **2** shown in FIG. **1**. The reference numerals assigned to the respective components in FIG. **2** are the same except for the reference numerals of the controller. DI system **102** differs from the system **2** in that the protective control is DI. Therefore, the controllers of DI **102** are given the reference numeral **150**.

[0043] As described above, the circuit configuration of DI system **102** is the same as the circuit configuration of DI system **2**, and therefore, a description of the circuit is omitted.

[0044] When the voltage at the DC end of the first inverter **10** exceeds a predetermined threshold voltage, the controller **150** of DI system **102** performs the protective control in the following manner. (1) The controller **150** opens the connection switches **40***p*, **40***n*. (2) The controller **150** closes the upper SW elements **12**, **22** connected to the respective ends of the at least one stator coil **31**, opens the lower SW elements **13**, **23**, opens the upper SW elements **12**, **22** connected to the respective ends of the remaining stator coils **31**, and closes the lower SW elements **13**, **23**. (3) Controller **150** closes the connection switches **40***p*, **40***n*.

[0045] FIG. **4** illustrates an exemplary current flow in the protective control of DI device **102**. In FIG. **4**, the upper SW elements **12***u*, **12***v*, **22***u*, **22***v* connected to the respective ends of the stator coils **31***u*, **31***v* are closed, and the lower SW elements **13***u*, **13***v*, **23***u*, **23***v* are open. Further, the upper SW elements **12***w*, **22***w* connected to each end of the stator coil **31***w* is opened, and the lower SW elements **13***w*, **23***w* is closed. The current generated in the stator coils **31***u*, **31***v* is recirculated through the upper SW elements **12***u*, **12***v*, **22***u*, **22***v* and the connection switch **40***p*. On the other hand, the current generated in the stator coil **31***w* is recirculated through the lower SW elements **13***w*, **23***w* and the connection switch **40***n*.

[0046] According to the above-described steps, the current is recirculated in the loop in which the upper SW element is closed, and the current is recirculated in the loop in which the lower SW element is closed. The power dissipation in the connection switches **40***p*, **40***n* is larger than that in the above-described upper short circuit control and lower short circuit control, and the current is rapidly attenuated.

[0047] When the loads of the upper SW elements **12** and **22** are smaller than the loads of the lower SW elements **13** and **23**, the controller **150** closes the upper SW elements **12** and **22** and opens the lower SW elements **13** and **23**. When the loads of the upper SW elements **12** and **22** are larger than the loads of the lower SW elements **13** and **23**, the controller **150** opens the upper SW elements **12** and **22** and closes the lower SW elements **13** and **23**. The controller **150** performs this determination in each of the u-phase, the v-phase, and the w-phase. This process also equalizes the cumulative load of the upper SW element and the cumulative load of the lower SW element. As in the first embodiment, the loads of SW elements are determined based on the temperatures, the driving times, and the driving times of SW elements.

[0048] In the protective control of DI device **102** of the second embodiment, the connection switches **40***p*, **40***n* are opened prior to opening and closing SW elements. By this processing, it is possible to avoid a short circuit of the battery **3** when shifting from the dual mode or the single mode to the protection control.

[0049] In the protective control (upper short circuit control and lower short circuit control) of DI device **2** according to the first embodiment, the process of opening and closing SW elements and the process of closing the connection switches may be performed in any order. Short-circuiting of the battery **3** can be avoided even if the battery is performed in any order. In this respect, DI device **2** of the first embodiment is advantageous.

[0050] In addition, DI devices **2** and **102** can be switched to the protective control while avoiding a

short circuit of the battery in the same manner in both the dual mode and the single mode.
[0051] Points to be noted regarding the technique described in the embodiment will be described. When the DC end and the AC end of the first inverter **10** are referred to as a first DC end and a first AC end, and the DC end and the AC end of the second inverter **20** are referred to as a second DC end and a second AC end, respectively, the circuitry of DI device **2** of the embodiment can be expressed as follows.
[0052] DI device **2** includes a motor **30** including a plurality of stator coils **31**, a
[0053] first inverter **10**, a second inverter **20**, connection switches **40***p*, **40***n*, and a controller **50**. The first inverter **10** includes a first DC end and a plurality of first AC ends, the first DC end is connected to the battery **3**, and each of the plurality of first AC ends is connected to one end of each of the stator coils **31**. The second inverter **20** includes a second DC end and a plurality of second AC ends, the second DC end is connected to the battery **3**, and each of the plurality of second AC ends is connected to the other end of each of the stator coils **31**.
[0054] The connection switches **40***p*, **40***n* connect the second DC end to the battery **3** or disconnects the battery **3**. The controller **50** may execute a dual mode in which the connection switches **40***p*, **40***n* are closed and the motor **30** is driven by the first inverter **10** and the second inverter **20**, and a single mode in which the connection switches **40***p*, **40***n* are opened and the motor **30** is driven only by the first inverter **10**.
[0055] The first inverter **10** includes a plurality of series circuits **11** connected in parallel to the first DC end. Each series circuit **11** includes a series-connected circuit of upper SW elements **12** and lower SW elements **13**. A midpoint of the series connection circuit is connected to the second AC end.
[0056] The second inverter **20** includes a plurality of series circuits **21** connected in parallel to the second DC end. Each series circuit **21** includes a series-connected circuit of upper SW elements **22** and lower SW elements **23**. A midpoint of the series connection circuit is connected to the second AC end.
[0057] The configuration of the inverter is expressed by another expression as follows. Each of the first inverter **10** and the second inverter **20** includes a plurality of series circuits **11** (**21**) connected in parallel between the positive electrode **3***p* and the negative electrode **3***n* of the battery **3**. Each series circuit includes an upper SW element **12** (**22**) and a lower SW element **13** (**23**) connected in series between the positive electrode **3***p* and the negative electrode **3***n* of the battery **3**, and a midpoint of the series connection is connected to the AC end.
[0058] The controller **50** performs one of upper short circuit control in which all upper SW elements of the first and second inverters are closed to open all lower SW elements and the connection switch is closed, and lower short circuit control in which all lower SW elements of the first and second inverters are closed to open all upper SW elements and the connection switch is closed, as a protection control when a voltage of the first DC end exceeds a threshold voltage.
[0059] The protection control is intended to attenuate the current generated by the induced electromotive force of the stator coil while rotating the motor **30** with inertia. By performing the protective control, the components of DI device can be protected from damage.
[0060] The techniques disclosed herein are also applicable to DI having four or more series circuitry and four or more stator coils.
[0061] In the present specification, the expression "turning on the switching element" means to make both ends of the switching element conductive, and the expression "turning off the switching element" means to electrically disconnect both ends of the switching element. However, since the diode is connected in anti-parallel to the switching element, even if the switching element is turned off, the recirculation of the current through the diode is allowed.
[0062] The expression "turning on the switching element" is equivalent to the expression "closing the switching element", and the expression "turning off the switching element" is equivalent to the expression "opening the switching element".

[0063] Although the specific examples of the present disclosure have been described in detail above, these are merely examples and do not limit the scope of claims.
[0064] The techniques described in the claims include various modifications and alternations of the specific examples illustrated above. The technical elements described in the present specification or the drawings exhibit technical usefulness alone or in various combinations, and are not limited to the combinations described in the claims at the time of filing. In addition, the techniques illustrated in the present specification or drawings can achieve a plurality of objectives at the same time, and achieving one of the objectives itself has technical usefulness.

Claims

1. A dual inverter system comprising: a motor that includes a plurality of stator coils; a first inverter including a direct current end connected to a battery and a plurality of alternating current ends connected to respective ends of the stator coils on one side; a second inverter including a direct current end connected to the battery and a plurality of alternating current ends connected to respective ends of the stator coils on another side; a connection switch connected between the direct current end of the second inverter and the battery; and a controller that is able to execute a dual mode in which the motor is driven by the first inverter and the second inverter by closing the connection switch and a single mode in which the motor is driven by only the first inverter by opening the connection switch, wherein when a voltage at the direct current end of the first inverter exceeds a predetermined threshold voltage, the controller executes one of an upper short circuit control and a lower short circuit control, the upper short circuit control closing the connection switch along with closing all upper switching elements of the first inverter and the second inverter and opening all lower switching elements of the first inverter and the second inverter, and the lower short circuit control closing the connection switch along with closing all the lower switching elements of the first inverter and the second inverter and opening all the upper switching elements of the first inverter and the second inverter.
2. The dual inverter system according to claim 1, wherein the controller executes the upper short circuit control when a load of the upper switching element is less than a load of the lower switching element, and the controller executes the lower short circuit control when the load of the lower switching element is less than the load of the upper switching element.
3. A dual inverter system comprising: a motor that includes a plurality of stator coils; a first inverter including a direct current end connected to a battery and a plurality of alternating current ends connected to respective ends of the stator coils on one side; a second inverter including a direct current end connected to the battery and a plurality of alternating current ends connected to respective ends of the stator coils on another side; a connection switch connected between the direct current end of the second inverter and the battery; and a controller that is able to execute a dual mode in which the motor is driven by the first inverter and the second inverter by closing the connection switch and a single mode in which the motor is driven by only the first inverter by opening the connection switch, wherein when a voltage at the direct current end of the first inverter exceeds a predetermined threshold voltage, the controller is configured to: (1) open the connection switch; (2) close upper switching elements and open lower switching elements that are connected to respective ends of at least one of the stator coils, and open upper switching elements and close lower switching elements that are connected to respective ends of remaining stator coils; and (3) close the connection switch.