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POWER SUPPLY SYSTEM AND PROGRAM PRODUCT

Abstract

A power supply system is connected to both (i) a high-side power supply line connected to a high-voltage load and (ii) a low-side power supply line connected to a low-voltage load. The power supply system includes a plurality of power storages, a switch unit for connection-mode switching of the power storages, and a switch controller configured to control the switch unit to set a connection mode of the power storages to one of (i) a first connection mode in which a part or all of the power storages is connected between the high-side power supply line and a low-side ground line, and (ii) a third connection mode in which power supply between the high-side ground line and a low-side ground line is cut off and a part of the power storages is connected between the low-side power supply line and the low-side ground line.

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Background/Summary

CROSS REFERENCE TO RELATED APPLICATION [0001] This application is a bypass continuation-in-part application of currently pending international application No. PCT/JP2023/37034 filed on Oct. 12, 2023 designating the United States of America, the entire disclosure of which is incorporated herein by reference, the international application being based on and claiming the benefit of priority from Japanese Patent Application No. 2022-177698 filed on Nov. 4, 2022, the disclosure of which is incorporated in its entirety herein by reference.

TECHNICAL FIELD
[0002] The present disclosure relates to power supply systems and program products.
BACKGROUND
[0003] Known vehicular power supply apparatuses, one of which is disclosed in patent literature 1, include a power storage unit comprised of a plurality of power storages. Such a vehicular power supply apparatus is configured to cut off power transmission between a high-voltage side of the power storage unit and a low-voltage side of the power storage unit in response to determination that there is an anomaly in the high-voltage side of the power storage unit, and supply power to one or more low-voltage loads from one or more power storages in the low-voltage side of the power storage unit. This reliably maintains power supply to the one or more low-voltage loads.
CROSS-REFERENCES
[0004] Patent Literature 1 Japanese Patent Application Publication No. 2018-148733
SUMMARY
[0005] Unfortunately, the circuit configuration of the power conversion apparatus disclosed in patent literature 1 may not perform (i) cutoff of power transmission between the high- and low-voltage sides of the power storage unit, and supply power to the one or more low-voltage loads from the one or more power storages in the low-voltage side of the power storage unit while supplying power to one or more high-voltage loads from one or more power storages in the high-voltage side of the power storage unit.
[0006] From the above viewpoint, the present disclosure seeks to provide power supply systems and program products, each of which is capable of flexibly selecting at least one of power sources to be used.
[0007] A first exemplary aspect of the present disclosure provides a power supply system connected to both (i) a high-side power supply line connected to a high-voltage load and (ii) a low-side power supply line connected to a low-voltage load. The power supply system includes a plurality of power storages, a switch unit for connection-mode switching of the power storages, and a switch controller configured to control the switch unit to set a connection mode of the power storages to one of (I) a first connection mode in which a part or all of the power storages is connected between the high-side power supply line and a low-side ground line, and (II) a third

connection mode in which power supply between the high-side ground line and a low-side ground line is cut off and a part of the power storages is connected between the low-side power supply line and the low-side ground line.
[0008] This configuration of the power supply system makes it possible to flexibly select at least one of power sources to be used.
[0009] A second exemplary aspect of the present disclosure provides a program product applicable to a power supply system connected to both (i) a high-side power supply line connected to a high-voltage load and (ii) a low-side power supply line connected to a low-voltage load. The power supply system includes a control apparatus. The program product includes program instructions that cause the control apparatus to perform a switching routine that controls a switch unit for connection-mode switching of the power storages to accordingly set a connection mode of the power storages to one of (I) a first connection mode in which a part or all of the power storages is connected between the high-side power supply line and a low-side ground line, and (II) a third connection mode in which power supply between the high-side ground line and a low-side ground line is cut off and a part of the power storages is connected between the low-side power supply line and the low-side ground line.
[0010] This configuration of the program product makes it possible to flexibly select at least one of power sources to be used.

Description

BRIEF DESCRIPTION OF THE DRAWINGS
[0011] Other aspects of the present disclosure will become apparent from the following description of embodiments with reference to the accompanying drawings in which:
[0012] FIG. **1** is a structural diagram of a power supply system according to the first embodiment;
[0013] FIG. **2** is a circuit diagram illustrating a first series-connection mode of the power supply system;
[0014] FIG. **3** is a circuit diagram illustrating a first parallel-connection mode of the power supply system;
[0015] FIG. **4** is a circuit diagram illustrating a second connection mode of the power supply system;
[0016] FIG. **5** is a circuit diagram illustrating a third connection mode of the power supply system;
[0017] FIG. **6** is a flowchart illustrating a normal mode-switching routine;
[0018] FIG. **7** is a circuit diagram illustrating the second connection mode of the power supply system;
[0019] FIG. **8** is a circuit diagram illustrating the first series-connection mode of the power supply system;
[0020] FIG. **9** is a circuit diagram illustrating the first parallel-connection mode of the power supply system;
[0021] FIG. **10** is a flowchart illustrating a stop-state equalization routine;
[0022] FIG. **11** is a structural diagram of a power supply system according to the second embodiment;
[0023] FIG. **12** is a circuit diagram illustrating the first series-connection mode of the power supply system according to the second embodiment;
[0024] FIG. **13** is a circuit diagram illustrating the first parallel-connection mode of the power supply system according to the second embodiment;
[0025] FIG. **14** is a circuit diagram illustrating the second connection mode of the power supply system according to the second embodiment;
[0026] FIG. **15** is a structural diagram of a power supply system according to the third

embodiment;
[0027] FIG. **16** is a circuit diagram illustrating the first connection mode of the power supply system according to the third embodiment;
[0028] FIG. **17** is a circuit diagram illustrating the second connection mode of the power supply system according to the third embodiment;
[0029] FIG. **18** is a structural diagram of a power supply system according to the fourth embodiment;
[0030] FIG. **19** is a circuit diagram illustrating the first connection mode of the power supply system according to the fourth embodiment;
[0031] FIG. **20** is a circuit diagram illustrating the second connection mode of the power supply system according to the fourth embodiment;
[0032] FIG. **21** is a structural diagram of a power supply system according to the first modification;
[0033] FIG. **22** is a flowchart illustrating an anomaly mode-switching routine according to the first modification;
[0034] FIG. **23** is a circuit diagram illustrating the third connection mode of the power supply system according to the second modification;
[0035] FIG. **24** is a circuit diagram illustrating the second connection mode of the power supply system according to the second modification;
[0036] FIG. **25** is a flowchart illustrating an equalization routine according to the second modification;
[0037] FIG. **26** is a flowchart illustrating an equalization routine according to the third modification;
[0038] FIG. **27** is a structural diagram of a power supply system according to the fourth modification;
[0039] FIG. **28** is a structural diagram of the power supply system according to the fourth modification;
[0040] FIG. **29** is a flowchart illustrating an equalization routine according to the fourth modification;
[0041] FIG. **30** is a structural diagram of a power supply system according to the fifth modification;
[0042] FIG. **31** is a structural diagram of a power supply system according to the sixth modification;
[0043] FIG. **32** is a structural diagram of a power supply system according to the seventh modification;
[0044] FIG. **33** is a structural diagram of a power supply system according to the eighth modification;
[0045] FIG. **34** is a structural diagram of a power supply system according to another modification;
[0046] FIG. **35** is a structural diagram of a power supply system according to a further modification;
[0047] FIG. **36** is a structural diagram of a power supply system according to a still further modification;
[0048] FIG. **37** is a structural diagram of a power supply system according to a still further modification;
[0049] FIG. **38** is a structural diagram of a power supply system according to a still further modification;
[0050] FIG. **39** is a structural diagram of a power supply system according to a still further modification;
[0051] FIG. **40** is a structural diagram of a power supply system according to a still further modification;
[0052] FIG. **41** is a structural diagram of a power supply system according to a still further

modification;
[0053] FIG. **42** is a structural diagram of a power supply system according to a still further modification;
[0054] FIG. **43** is a structural diagram of a power supply system according to a still further modification;
[0055] FIG. **44** is a structural diagram of a power supply system according to a still further modification;
[0056] FIG. **45** is a structural diagram of a power supply system according to a still further modification;
[0057] FIG. **46** is a structural diagram of a power supply system according to a still further modification;
[0058] FIG. **47** is a structural diagram of a power supply system according to a still further modification;
[0059] FIG. **48** is a structural diagram of a power supply system according to a still further modification;
[0060] FIG. **49** is a structural diagram of a power supply system according to a still further modification;
[0061] FIG. **50** is a structural diagram of a power supply system according to a still further modification;
[0062] FIG. **51** is a structural diagram of a power supply system according to a still further modification;
[0063] FIG. **52** is a structural diagram of a power supply system according to a still further modification;
[0064] FIG. **53** is a structural diagram of a power supply system according to a still further modification;
[0065] FIG. **54** is a structural diagram of a power supply system according to a still further modification;
[0066] FIG. **55** is a structural diagram of a power supply system according to a still further modification;
[0067] FIG. **56** is a structural diagram of a power supply system according to a still further modification; and
[0068] FIG. **57** is a structural diagram of a power supply system according to a still further modification.

DETAILED DESCRIPTION OF EMBODIMENTS

[0069] The following describes plural embodiments with reference to the accompanying drawings. Parts of the embodiments functionally or structurally corresponding to each other or associated with each other will be denoted by the same reference numbers or by reference numbers which are different in the hundreds place from each other. The corresponding or associated parts can refer to the corresponding descriptions in the other embodiments.

First Embodiment

[0070] The following describes the first embodiment, which is created by implementing one of power supply systems according to the present disclosure, with reference to the accompanying drawings.
[0071] A power conversion system according to the first embodiment is installed in a vehicle, such as an electric vehicle or a hybrid vehicle, to constitute a vehicular system.
[0072] The vehicular system includes, as illustrated in FIG. **1**, a motor **10**, an inverter **20**, a high-side power supply line H**1**, a high-side ground line L**1**, a low-side power supply line H**2**, a low-side ground line L**2**, a power supply system **30**, and a direct-current (DC)-to-DC converter **70** that serves as a voltage converter.
[0073] The motor **10** includes a plurality of armature windings. Specifically, the motor **10** of the

first embodiment is configured as a three-phase synchronous machine, and includes an unillustrated rotor and three-phase (UVW-phase) armature windings **11** connected in star configuration. The UVW-phase armature windings **11** are arranged to have a phase difference of 120 electrical degrees from each other. The motor **10** is, for example, configured as a permanent magnet synchronous machine. The rotor of the motor **10** is configured to transmit and receive power to and from one or more driving wheels of the vehicle. This therefore enables the motor **10** to serve as a torque generator for generating torque that propels the vehicle.

[0074] The inverter **20** includes three-phase (UVW-phase) series-connected switch units for the respective three-phases of the motor **10**; the series-connected switch unit for each of the U-, V-, and W-phases is comprised of an upper-arm switch SWH and a lower-arm switch SWL connected in series to each other. An upper-arm diode DH, which serves as a free wheel diode, is connected in antiparallel to the upper-arm switch SWH of each phase, and a lower-arm diode DL, which serves as a free wheel diode, is connected in antiparallel to the lower-arm switch SWL of each phase. The first embodiment uses, as each of the upper- and lower-arm switches, an Insulated Gate Bipolar Transistor (IGBT).

[0075] The inverter **20** includes a smoothing capacitor **21** that has a high-side terminal and a low-side terminal. The high-side terminal of the smoothing capacitor **21** is connected to the high-side power supply line H**1**, and the low-side terminal of the smoothing capacitor **21** is connected to the high-side ground line L**1**. The smoothing capacitor **21** may be arranged outside the inverter **20**.

[0076] The emitter, which serves as a low-side terminal, of the upper-arm switch SWH of each phase is connected to the collector, which serves as a high-side terminal, of the lower-arm switch SWL of the corresponding phase. The connection point between the emitter of the upper-arm switch SWH of each phase and the collector of the lower-arm switch SWL of the corresponding phase is connected to a first end of the corresponding phase armature winding **11** through a conductor, such as a busbar, **23**. The second ends of the respective three-phase armature windings **11** are connected to a neutral point.

[0077] The number of turns of each phase armature winding **11** is set to a predetermined constant value, so that, for example, the inductance of each phase armature winding **11** is set to a predetermined constant value.

[0078] The collector of each-phase upper-arm switch SWH is connected to the high-side power supply line H**1**, and the emitter of each-phase lower-arm switch SWL is connected to the high-side ground line L**1**. The high-side ground line L**1** is connected to a frame ground FG, such as the body of the vehicle. This results in the motor **10** being connected to the high-side power supply line H**1** through the inverter **20**. Both the motor **10** and the inverter **10** or any one of the motor **10** and the inverter **10** may be included in the power supply system **30** or cannot be included in the power supply system **30**.

[0079] Various high-voltage loads **71** are connected between the high-side power supply line H**1** and the high-side ground line L**1**. The high-voltage loads, such as an air compressor, **71** are electrical loads having a request voltage with a high level. The motor **10** may be a type of the high-voltage loads **71**.

[0080] Various low-voltage loads **72** are connected between the low-side power supply line H**2** and the low-side ground line L**2**. The low-voltage loads, such as various control units, for example, various electronic control units (ECUs), are electrical loads having a request voltage with a low level lower than the level of the request voltage for the high-voltage loads **71**. The low-side ground line L**2** is connected to a signal ground SG. The signal ground SG is electrically isolated from the frame ground FG.

[0081] The DC-to-DC converter **70** is operative to perform voltage conversion of power inputted thereto. The DC-to-DC converter **70** is connected between the high-side power supply line H**1** and the high-side ground line L**1**. The DC-to-DC converter **70** is configured to step down a voltage of power inputted thereto from the high-side power supply line H**1** into a lower voltage, and supply the lower voltage of the inputted power through a power transmission line L**3** to, for example, the low-voltage loads **72** connected to the low-side power supply line H**2**. Additionally, the DC-to-DC converter **70** is configured to step up a voltage of power inputted thereto from the low-side power supply line H**2** through the power transmission line L**3** into a higher voltage, and supply the higher voltage of the inputted power to, for example, the high-voltage loads **71** connected to the high-side power supply line H**1**. The DC-to-DC converter **70** may be controlled by a control apparatus **100** described later. The DC-to-DC converter **70** may be included in the power supply system **30** or cannot be included in the power supply system **30**. The DC-to-DC converter **70** of the first embodiment may be configured not to perform the voltage step-up function set forth above.

[0082] Next, the following describes the power supply system **30**.

[0083] The power supply system **30** includes a first battery **31** serving as a first power storage, a second battery **32** serving as a second power storage, and a third battery **33** serving as a third power storage.

[0084] Each of the first to third batteries **31** to **33** serves as a power storage for rotatably driving the rotor of the motor **10**.

[0085] Each of the first to third batteries **31** to **33** is a battery pack configured as a series module comprised of a plurality of battery cells, i.e., unit cells, connected in series to each other. For example, a secondary battery cell, such as a lithium-ion cell, may be used as each battery cell.

[0086] Each of the first to third batteries **31** to **33** has an output voltage, and the output voltage of the first battery **31** is the highest in all the output voltage of the first to third batteries **31** to **33**. The output voltage of the first battery **31** is, for example, 400 V. The output voltage of the second battery **32**, which is lower than the output voltage of the first battery **31**, is, for example, 12 V. The output voltage of the third battery **33** has any voltage of, for example, 200 V. The terminal voltage across each of the first to third batteries **31** to **33** may be freely changed.

[0087] The power supply system **30** includes a first-A electrical path **1**A connecting between the positive terminal of the first battery **31** and the high-side power supply line H**1**. The power supply system **30** includes a first-A switch SW**1***a* mounted on the first-A electrical path **1**A. The first-A switch SW**1***a* is configured to switch between (i) electrical conduction through the first-A electrical path **1**A and (ii) electrical cutoff therethrough to be switched therebetween.

[0088] A series module comprised of a pre-charge switch Pre-P and a resistor R**1** connected in series to each other may be connected in parallel to the first-A switch SW**1***a*. The first-A switch SW**1***a* serves as a high-side system main relay switch.

[0089] The power supply system **30** includes a first-B electrical path **1**B connecting between the negative terminal of the first battery **31** and the high-side ground line L**1**. The power supply system **30** includes a first-B switch SW**1***b* mounted on the first-B electrical path **1**B. The first-B switch SW**1***b* enables (i) electrical conduction through the first-B electrical path **1**B and (ii) electrical cutoff therethrough to be switched therebetween.

[0090] The power supply system **30** includes a second-A electrical path **2**A connecting between the negative terminal of the first battery **31** and the positive terminal of a first series-connection module **40**; the first series-connection module **40** is comprised of the second battery **32** and the third battery **33** connected in series to each other. The power supply system **30** includes a second-A switch SW**2***a* mounted on the second-A electrical path **2**A. The second-A switch SW**2***a* enables (i) electrical conduction through the second-A electrical path **2**A and (ii) electrical cutoff therethrough to be switched therebetween. In other words, the second-A switch SW**2***a* enables one of (i) electrical connection between the negative terminal of the first battery **31** and the positive terminal of first series-connection module **40** and (ii) electrical cutoff therebetween to be switched to the other thereof.

[0091] The first series-connection module **40** is configured such that the negative terminal of the third battery **33** is connected in series to the positive terminal of the second battery **32**. The positive terminal of the first series-connection module **40** corresponds to the positive terminal of the third battery **33**, and the negative terminal of the first series-connection module **40** corresponds to the negative terminal of the second battery **32**.

[0092] The power supply system **30** includes a second-B electrical path **2**B connecting between the negative terminal of the first battery **31** and the high-side ground line L**1**. The power supply system **30** includes a second-B switch SW**2***b* mounted on the second-B electrical path **2**B. The second-B switch SW**2***b* enables (i) electrical conduction through the second-B electrical path **2**B and (ii) electrical cutoff therethrough to be switched therebetween. In other words, the second-B switch SW**2***b* enables one of (i) electrical connection between the negative terminal of the first battery **31** and the high-side ground line L**1** and (ii) electrical cutoff therebetween to be switched to the other thereof. The second-B switch SW**1***a* serves as a low-side system main relay switch.

[0093] The power supply system **30** includes a third-A electrical path **3**A connecting between the positive terminal of the second battery **32** and the low-side power supply line H**2**. The power supply system **30** includes a third-A switch SW**3***a* mounted on the third-A electrical path **3**A. The third-A switch SW**3***a* enables (i) electrical conduction through the third-A electrical path **3**A and (ii) electrical cutoff therethrough to be switched therebetween.

[0094] The power supply system **30** includes a third-B electrical path **3**B connecting between the negative terminal of the second battery **32** and the low-side ground line L**2**. The power supply system **30** includes a third-B switch SW**3***b* mounted on the third-B electrical path **3**B. The third-B switch SW**3***b* enables (i) electrical conduction through the third-B electrical path **3**B and (ii) electrical cutoff therethrough to be switched therebetween.

[0095] The power supply system **30** includes a bypass path **60** connecting between the neural point of the armature windings **11** of the motor **10** and the positive terminal of the first series-connection module **40**. The power supply switch **30** includes a fourth switch SW**4** mounted on the bypass path **60**. The bypass switch SW**4** enables (i) electrical conduction through the bypass path **60** and (ii) electrical cutoff therethrough to be switched therebetween. The power supply system **30** includes a switch RN mounted on the bypass switch SW**4** adjacently to the neutral point. The switch RN is controlled to be turned on when the fourth switch SW**4** is controlled to be turned on. The power supply system **30** includes a capacitor C**1** arranged between the bypass path **60** and the high-side ground line L**1**.

[0096] A mechanical relay is used as each of the switches SW**1***a*, SW**1***b*, SW**2***a*, SW**2***b*, SW**3***a*, SW**3***b*, and SW**4** according to the first embodiment. These switches will also be collectively referred to as switches SW. Each switch SW is configured to enable a current to bidirectionally pass therethrough when turned on, and each switch SW is configured to bidirectionally cut off the current therethrough when turned off. Each switch SW is not limited to such a mechanical relay. Specifically, a semiconductor switching device may be used as each switch SW. One or more of the switches SW**1***a*, SW**1***b*, SW**2***a*, SW**2***b*, SW**3***a*, SW**3***b*, and SW**4** serve as a switch unit.

[0097] The power supply system **30** includes a control apparatus **100**.

[0098] The control apparatus **100** is comprised mainly of a microcomputer **101** that includes, for example, a Central Processing Unit (CPU), at least one read-only memory (ROM), and at least one random access memory (RAM). Functions provided by the microcomputer **101** can be implemented by software stored in a non-transitory storage medium and one or more computers that runs the software, only software, only one or more hardware devices, or the combination of software and one or more hardware devices. For example, if the microcomputer **101** is comprised of electronic circuits as hardware devices, the functions of the microcomputer **101** can be implemented by digital circuits including many logic circuits or analog circuits. For example, the microcomputer **101** is configured to execute programs stored in a storage unit, such as a non-transitory tangible storage medium. The programs include processing programs illustrated in FIG. **6** and other figures described later. Execution of the programs stored in the storage unit enables methods corresponding to the programs to be carried out. The storage unit is for example comprised of a non-volatile memory device. The programs stored in the storage unit can be updated through communication networks, such as an Over-The-Air (OTA) network or the Internet.

[0099] Information items, such as measurements of various sensors SS, are inputted to the control apparatus **100**. The various sensors SS include, for example, voltage sensors, each of which is configured to measure a terminal voltage across a corresponding one of the first, second, and third batteries **31**, **32**, and **33**. The various sensors SS include, for example, current sensors, each of which is configured to measure a current flowing through a corresponding one of the first, second, and third batteries **31**, **32**, and **33**. The various sensors SS include, for example, a rotational angle sensor for measuring a rotational angle, such as a rotational electric angle, of the rotor of the motor **10**, and phase current sensors, each of which is configured to measure a current flowing through a corresponding one of the three-phase armature windings **11**.

[0100] The control apparatus **100** is configured to perform, based on measurements of the above various sensors SS and other information items, various tasks in accordance with programs stored therein. The various tasks include a task for controlling the inverter **20**. Specifically, the control apparatus **100** is configured to perform a switching control task for the switches SWH and SWL constituting the inverter **20** to accordingly control a controlled variable, such as torque, of the motor **10** to be fed back to a target value for the controlled variable. That is, the switching control task alternately turns on the upper- and lower-arm switches SWH and SWL for each phase to accordingly control the controlled variable, such as torque, of the motor **10** to be fed back to the target value for the controlled variable. The above feedback control task causes rotary power of the rotor of the motor **10** to be transmitted to the driving wheels of the vehicle, resulting in the vehicle traveling. That is, the control apparatus **100** serves as an inverter controller.

[0101] The control apparatus **100** is configured to control the DC-to-DC converter **70** to accordingly perform a voltage conversion task set forth above. Additionally, the control apparatus **100** is configured to determine whether power supply from a power supply unit **80** is successfully performed described later. For this reason, the control apparatus **100** serves as an anomaly determiner.

[0102] Additionally, the control apparatus **100** serves as a switch controller for performing on-off control operations of each switch SW of the power supply system **30**.

[0103] The following describes how the control apparatus **100** of the first embodiment performs on-off control of each switch SW of the power supply system **30**.

[0104] The control apparatus **100** is configured to set, as illustrated in FIGS. **2** and **3**, a connection mode of the power storages, i.e., the first to third batteries **31**, **32**, and **33**, to a first connection mode in which a part or all of the first to third batteries **31** to **33** included in the power supply system **30** is connected to only the high-side power supply line H**1**. That is, the control apparatus **100** according to the first embodiment is configured to connect all the first to third batteries **31** to **33** included in the power supply system **30** to the high-side power supply line H**1** to accordingly establish the first connection mode. In particular, the control apparatus **100** according to the first embodiment is configured to select, as the first connection mode, one of a first series-connection mode and a first parallel-connection mode, and establish the selected one of the first series-connection mode and the first parallel-connection mode.

[0105] The first series-connection mode represents a mode in which the first battery **31**, the third battery **33**, and the second battery **32** are connected in series to one another to constitute a second series-connection module **50**, and the second series-connection module **50** is connected to the high-side power supply line H**1**.

[0106] Specifically, the control apparatus **100** is configured to, as illustrated in FIG. **2**, turn off or maintain in the off state each of the first-B switch SW**1***b*, the third-A switch SW**3***a*, the third-B switch SW**3***b*, and the fourth switch SW**4** and turn on or maintain in the on state the first-A switch SW**1***a*, the second-A switch SW**2***a*, and the second-B switch SW**2***b* to accordingly establish the first series-connection mode as the first connection mode.

[0107] The first series-connection mode results in the second series-connection module **50** being connected between the high-side power supply line H**1** and the high-side ground line L**1**; the second series-connection module **50** is comprised of the first, third, and second batteries **31**, **33**, and **32** being connected in series to each other. That is, as illustrated by a dash-dotted line in FIG. **2**, high-voltage power having the sum of 400 V, 200 V, and 12 V is supplied from the second series-connection module **50** to the high-voltage loads **71** through the high-side power supply line H**1**. FIG. **2** clearly illustrates that no power is directly supplied from the second battery **32** to the low-voltage loads **72** through the low-side power supply line H**2**.

[0108] The first parallel-connection mode represents a mode in which the first battery **31** and the first series-connection module **40** are connected in parallel to the high-side power supply line H**1**.

[0109] Specifically, the control apparatus **100** is configured to, as illustrated in FIG. **3**, turn off or maintain in the off state each of the second-A switch SW**2***a*, the third-A switch SW**3***a*, and the third-B switch SW**3***b*, and turn on or maintain in the on state the first-A switch SW**1***a*, the first-B switch SW**1***b*, the second-B switch SW**2***b*, and the fourth switch SW**4** to accordingly establish the first parallel-connection mode as the first connection mode.

[0110] The first parallel-connection mode results in (i) the first battery **31** being connected between the high-side power supply line H**1** and the high-side ground line L**1** and (ii) the first series-connection module **40** being connected between the neutral point of the motor **10** and the high-side ground line L**1**. That is, the first battery **31** and the first series-connection module **40** are connected in parallel to the high-side power supply line H**1**, so that high-voltage power is supplied from the first battery **31** to the high-voltage loads **71** through the high-side power supply line H**1**, and high-voltage power is supplied from the first series-connection module **40** to the high-voltage loads **71** through the high-side power supply line H**1**.

[0111] The terminal voltage, which is the sum of 12 V and 200 V, across the first series-connection module **40** comprised of the second and third batteries **32** and **33** is lower than the terminal voltage of 400 V across the first battery **31**. The control apparatus **100** is configured to control on-off operations of the switches SWH and SWL of each phase of the inverter **20** to accordingly boost the terminal voltage across the first series-connection module **40** is boosted by the motor **10** and the inverter **20**, and thereafter the boosted voltage is supplied to the high-side power supply line H**1**.

[0112] The control apparatus **100** is configured to set, as illustrated in FIG. **4**, the connection mode of the batteries **31** to **33** to a second connection mode in which a part of the first to third batteries **31** to **33**, such as the second battery **32**, included in the power supply system **30** is connected to the low-side power supply line H**2** and a part or all of the remaining batteries, such as the first battery **31**, is connected to the high-side power supply line H**1**.

[0113] Specifically, the control apparatus **100** is configured to, as illustrated in FIG. **4**, turn off or maintain in the off state each of the second-A switch SW**2***a*, the second-B switch SW**2***b*, and the fourth switch SW**4**, and turn on or maintain in the on state the first-A switch SW**1***a*, the first-B switch SW**1***b*, the third-A switch SW**3***a*, and the third-B switch SW**3***b* to accordingly establish the second connection mode.

[0114] The second connection mode results in the first battery **31** being connected between the high-side power supply line H**1** and the high-side ground line L**1**, and the second battery **32** being connected between the low-side power supply line H**2** and the low-side ground line L**2**. In the second connection mode, the high-side ground line L**1** and the low-voltage ground line L**2** are electrically isolated from one another. This results in high-voltage power being supplied from the first battery **31** to the high-voltage loads **71** through the high-side power supply line H**1**, and low-voltage power being supplied from the second battery **32** to the low-voltage loads **72** through the low-side power supply line H**2**.

[0115] The control apparatus **100** is configured to set, as illustrated in FIG. **5**, the connection mode of the batteries **31** to **33** to a third connection mode in which a part of the first to third batteries **31** to **33**, such as the second battery **32**, included in the power supply system **30** is only connected to the low-side power supply line H**2**.

[0116] Specifically, the control apparatus **100** is configured to, as illustrated in FIG. **5**, turn off or maintain in the off state each of the first-A switch SW**1***a*, the first-B switch SW**1***b*, the second-A switch SW**2***a*, the second-B switch SW**2***b*, and the fourth switch SW**4**, and turn on or maintain in the on state the third-A switch SW**3***a* and the third-B switch SW**3***b* to accordingly establish the third connection mode. This results in, in the third connection mode, low-voltage power being supplied from the second battery **32** to the low-voltage loads **72** through the low-side power supply line H**2**. FIG. **5** shows that no power is supplied from the first battery **31** to the high-voltage loads **71** through the high-side power supply line H**1**.
[0117] In the second connection mode illustrated in FIG. **4**, power supply between the high-side ground line L**1** and the low-side ground line L**2** is cut off, and a part of the first to third batteries **31** to **33**, such as the second battery **32**, is connected between the low-side power supply line H**2** and the low-side ground line L**2**. For this reason, the second connection mode is one type of the third connection mode.
[0118] Hereinafter, the connection configuration illustrated in FIG. **5** will be referred to as the third connection mode, and the connection configuration illustrated in FIG. **4** will be referred to as the second connection mode.
[0119] Next, the following describes mode-switching routines carried out by the control apparatus **100** for switchably selecting one of the first to third connection modes as the connection mode of the batteries **31** to **33**.
[0120] First, the following describes a normal mode-switching routine, which is carried out in a normal situation with reference to FIG. **6**. The control apparatus **100** is programmed to execute the normal mode-switching routine every predetermined period.
[0121] Referring to FIG. **6**, when starting the normal mode-switching routine, the control apparatus **100** determines whether the vehicle is stopped, i.e., the vehicle is in an ignition-off period in which the ignition switch of the vehicle is in the off state in step S**101**.
[0122] Upon determination that the vehicle is stopped (YES in step S**101**), the control apparatus **100** sets the connection mode of the batteries **31** to **33** to the third connection mode in step S**102**. Specifically, if the connection mode of the batteries **31** to **33** has been the third connection mode before execution of the normal mode-switching routine, the control apparatus **100** continues the third connection mode. Otherwise, if the connection mode of the batteries **31** to **33** has not been the third connection mode, the control apparatus **100** changes the connection mode of the batteries **31** to **33** to the third connection mode.
[0123] Specifically, in step S**102**, the control apparatus **100** turns off or maintains in the off state each of the first-A switch SW**1***a*, the first-B switch SW**1***b*, the second-A switch SW**2***a*, the second-B switch SW**2***b*, and the fourth switch SW**4**, and turns on or maintains in the on state the third-A switch SW**3***a* and the third-B switch SW**3***b* to accordingly establish the third connection mode. This results in, in the third connection mode, low-voltage power being supplied from the second battery **32** to the low-voltage loads **72** through the low-side power supply line H**2**.
[0124] Next, the control apparatus **100** determines whether the vehicle has started so that the consumed power of the low-voltage loads **72** has exceeded a predetermined first power threshold in step S**103**. The first power threshold is set to any value determined based on a power level that can be outputted by the second battery **32**.
[0125] Upon determination that the consumed power of the low-voltage loads **72** has not increased over the predetermined first power threshold (NO in step S**103**), the control apparatus **100** terminates the normal mode-switching routine.
[0126] Otherwise, upon determination that the consumed power of the low-voltage loads **72** has increased over the predetermined first power threshold (YES in step S**103**), the control apparatus **100** changes the connection mode of the batteries **31** to **33** from the third connection mode to the second connection mode in step S**104**.
[0127] Specifically, in step S**104**, the control apparatus **100** turns off or maintains in the off state

each of the second-A switch SW**2***a*, the second-B switch SW**2***b*, and the fourth switch SW**4**, and turns on or maintains in the on state the first-A switch SW**1***a*, the first-B switch SW**1***b*, the third-A switch SW**3***a*, and the third-B switch SW**3***b* to accordingly establish the second connection mode.
[0128] The second connection mode results in (i) the first battery **31** being connected between the high-side power supply line H**1** and the high-side ground line L**1** and (ii) the second battery **32** being connected between the low-side power supply line H**2** and the low-side ground line L**2** while the high-side ground line L**1** and the low-voltage ground line L**2** are electrically isolated from one another.
[0129] This enables high-voltage power to be supplied from the first battery **31** to the DC-to-DC converter **70** through the high-side power supply line H**1**. Additionally, low-voltage power is supplied from the second battery **32** to the low-voltage loads **72** through the low-side power supply line H**2**.
[0130] Next, the control apparatus **100** instructs the DC-to-DC converter **70** to convert, i.e., step down, an input voltage inputted thereto from the first battery **31** through the high-side power supply line H**1** in step S**105**. This results in power with the stepped-down voltage being supplied from the DC-to-DC converter **70** to the low-voltage loads **72** through the power transmission line L**3**.
[0131] Following the operation in step S**105**, the control apparatus **100** changes the connection mode of the batteries **31** to **33** from the second connection mode to the first connection mode in step S**106**. Specifically, the control apparatus **100** changes the connection mode of the batteries **31** to **33** from a selected one of the first series-connection mode and the first parallel-connection mode as the first connection mode in step S**106**.
[0132] When selecting the first series-connection mode as the first connection mode, the control apparatus **100** turns off or maintains in the off state each of the first-B switch SW**1***b*, the third-A switch SW**3***a*, the third-B switch SW**3***b*, and the fourth switch SW**4** and turns on or maintains in the on state the first-A switch SW**1***a*, the second-A switch SW**2***a*, and the second-B switch SW**2***b* to accordingly establish the first series-connection mode as the first connection mode. The first series-connection mode results in, as illustrated in FIG. **8**, the second series-connection module **50** being connected between the high-side power supply line H**1** and the high-side ground line L**1**.
[0133] Alternatively, when selecting the first parallel connection mode as the first connection mode, the control apparatus **100** turns off or maintains in the off state each of the second-A switch SW**2***a*, the third-A switch SW**3***a*, and the third-B switch SW**3***b*, and turns on or maintains in the on state the first-A switch SW**1***a*, the first-B switch SW**1***b*, the second-B switch SW**2***b*, and the fourth switch SW**4** to accordingly establish the first parallel-connection mode as the first connection mode.
[0134] The first parallel-connection mode results in, as illustrated in FIG. **9**, the first battery **31** and the first series-connection module **40** being connected in parallel to the high-side power supply line H**1**.
[0135] As illustrated in each of FIGS. **8** and **9**, the first connection mode results in power being supplied from the first to third batteries **31** to **33** connected to the high-side power supply line H**1** to the DC-to-DC converter **70**. A voltage of the power supplied to the DC-to-DC converter **70** is stepped down by the DC-to-DC converter **70**, so that the stepped-down voltage is supplied to the low-voltage loads **72**. As described above, before execution of the switching operation in step S**106**, power is supplied from the first battery **31** to the low-voltage loads **72** through the DC-to-DC converter **70**. The above normal mode-switching routine therefore prevents power to the low-voltage loads **72** from being cut off due to switching of the connection mode of the batteries **31** to **33** from the second connection mode to the first connection mode. After completion of the operation in step S**106**, the control apparatus **100** terminates the normal mode-switching routine.
[0136] Otherwise, upon determination that the vehicle is not stopped, i.e., the vehicle is not in the ignition-off period (NO in step S**101**), the control apparatus **100** sets the connection mode of the

batteries **31** to **33** to the first connection mode, i.e., one of the first series-connection mode and the second parallel-connection mode, in step S**111**.
[0137] Selecting the first series-connection mode in step S**111** results in, as illustrated in FIG. **8**, the second series-connection module **50** being connected between the high-side power supply line H**1** and the high-side ground line L**1**. Alternatively, selecting the first parallel-connection mode in step S**111** results in, as illustrated in FIG. **9**, the first battery **31** and the first series-connection module **40** being connected in parallel to the high-side power supply line H**1**. During the first connection mode, the control apparatus **100** instructs the DC-to-DC converter **70** to step down high-voltage power supplied from the first to third batteries **31** to **33**, so that the stepped-down voltage is supplied to the low-voltage loads **72**.
[0138] Next, the control apparatus **100** determines whether the vehicle has been stopped so that the consumed power of the low-voltage loads **72** has decreased to be lower than or equal to a predetermined second power threshold in step S**112**. The second power threshold is set to any value, i.e., may be set to be identical to the first power threshold. The second power threshold may be determined based on power that causes a dark current to flow through the low-voltage loads **72**. The dark current is needed to activate the low-voltage loads **72** and/or maintain the functions of the low-voltage loads **72**. The control apparatus **100**, which performs the operation in step S**112**, serves as a power monitor. In response to determination that the consumed power of the low-voltage loads **72** has not decreased to be lower than or equal to the predetermined second power threshold (NO in step S**112**), the control apparatus **100** terminates the normal mode-switching routine.
[0139] Otherwise, in response to determination that the consumed power of the low-voltage loads **72** has decreased to be lower than or equal to the predetermined second power threshold (YES in step S**112**), the control apparatus **100** changes the connection mode of the batteries **31** to **33** from the first connection mode to the second connection mode in step S**113** (see FIG. **7**). This causes (i) high-voltage power to be supplied from the first battery **31** to the DC-to-DC converter **70** through the high-side power supply line H**1** and (ii) low-voltage power to be supplied from the second battery **32** to the low-voltage loads **72** through the low-side power supply line H**2**.
[0140] Next, the control apparatus **100** deactivates the DC-to-DC converter **70** in step S**114**.
[0141] Following the operation in step S**114**, the control apparatus **100** changes the connection mode of the batteries **31** to **33** from the second connection mode to the third connection mode in step S**115** as illustrated in FIG. **5**. This results in, in the third connection mode, low-voltage power being supplied from the second battery **32** to the low-voltage loads **72** through the low-side power supply line H**2**. Before execution of the switching operation in step S**115**, power is supplied from the second battery **32** to the low-voltage loads **72** through the low-side power supply line H**2**. This results in power supply to the low-voltage loads **72** being continued even if the DC-to-DC converter **70** is deactivated in step S**114**. This therefore leads to (i) less power consumption as compared with activation of the DC-to-DC converter **70** and (ii) reduction in loss of power due to voltage conversion. Thereafter, the control apparatus **100** terminates the normal mode-switching routine.
[0142] As described above, the supply of power from the second battery **32** to the low-voltage loads **72** during the vehicle being stopped may result in the power storage state, such as the state of charge (SOC), of the second battery **32** being likely to be smaller than the SOC of the third battery **33**. That is, the supply of power from the second battery **32** to the low-voltage loads **72** during the vehicle being stopped may result in imbalance among the SOCs of the first to third batteries **31** to **33**.
[0143] From this viewpoint, the control apparatus **100** according to the first embodiment is configured to execute a stop-state equalization routine for equalizing the SOCs of the first through third batteries **31** to **33** while the vehicle is in a stop state.
[0144] The following describes the stop-state equalization routine with reference to FIG. **10**.
[0145] The control apparatus **100** is programmed to execute the stop-state equalization routine

every predetermined period.

[0146] Referring to FIG. **10**, when starting the stop-state equalization routine, the control apparatus **100** determines whether the vehicle is stopped, i.e., the vehicle is in the ignition-off period in which the ignition switch of the vehicle is in the off state in step S**201**.

[0147] Upon determination that the vehicle is not stopped, i.e., the vehicle is not in the ignition-off period (NO in step S**201**), the control apparatus **100** terminates the stop-state equalization routine.

[0148] Otherwise, upon determination that the vehicle is stopped (YES in step S**201**), the control apparatus **100** serves as an estimation unit to estimate the power storage state, i.e., the SOC, of each of the first to third batteries **31** to **33** to accordingly determine whether there is a need to equalize the SOCs of the first to third batteries **31** through **33** in step S**202**. The control apparatus **100** estimates the SOC of each of the first to third batteries **31** to **33** using one of known estimation methods.

[0149] For example, when the SOC of the second battery **32** is determined to be smaller than or equal to a predetermined lower limit, the control apparatus **100** determines that there is a need to equalize the SOCs of the first to third batteries **31** to **33** (YES in step S**202**). Additionally, when the SOC of the second battery **32** is determined to be smaller than the SOC of the third battery **33** by a predetermined first equalization threshold or more, the control apparatus **100** determines that there is a need to equalize the SOCs of the first to third batteries **31** to **33** (YES in step S**202**).

[0150] Upon determination that there is not a need to equalize the SOCs of the first to third batteries **31** to **33** (NO in step S**202**), the control apparatus **100** sets the connection mode of the batteries **31** to **33** to the third connection mode in step S**211**. Specifically, if the connection mode of the batteries **31** to **33** has been the third connection mode before execution of the stop-state equalization routine, the control apparatus **100** continues the third connection mode. Otherwise, if the connection mode of the batteries **31** to **33** has not been the third connection mode, the control apparatus **100** changes the connection mode of the batteries **31** to **33** to the third connection mode.

[0151] Otherwise, upon determination that there is a need to equalize the SOCs of the first to third batteries **31** to **33** (YES in step S**202**), the control apparatus **100** sets the connection mode of the batteries **31** to **33** to the second connection mode in step S**203**. This enables high-voltage power to be supplied from the first battery **31** to the DC-to-DC converter **70** through the high-side power supply line H**1**. Additionally, during the second connection mode, low-voltage power is also supplied from the second battery **32** to the low-voltage loads **72** through the low-side power supply line H**2**.

[0152] Next, the control apparatus **100** instructs the DC-to-DC converter **70** to convert, i.e., step down, the input voltage inputted thereto from the first battery **31** through the high-side power supply line H**1** in step S**204**. This results in power with the stepped-down voltage being supplied from the DC-to-DC converter **70** to both the low-voltage loads **72** and the second battery **32** through the power transmission line L**3**, resulting in the second battery **32** being charged.

[0153] Following the operation in step S**204**, the control apparatus **100** estimate the power storage state, i.e., the SOC, of each of the first to third batteries **31** to **33** to accordingly determine whether there is a need to equalize the SOCs of the first to third batteries **31** to **33** in step S**205**, which is identical to the determination in step S**202**. The criteria for the determination in step S**205** is identical to that for determination in step S**202**, but the criteria for the determination in step S**205** may be different from that for determination in step S**202**.

[0154] For example, the control apparatus **100** may be programmed to determine whether the SOC of the second battery **32** is within a predetermined allowable range and the absolute difference in SOC between the second and third batteries **32** and **33** is within a predetermined allowable difference range. Then, the control apparatus **100** may be programmed to determine that there is not a need to equalize the SOCs of the first to third batteries **31** to **33** upon determination that the SOC of the second battery **32** is within the predetermined allowable range and the absolute difference in SOC between the second and third batteries **32** and **33** is within the predetermined allowable

difference range. Otherwise, the control apparatus **100** may be programmed to determine that there is a need to equalize the SOCs of the first to third batteries **31** to **33** upon determination that the SOC of the second battery **32** is not within the predetermined allowable range or the absolute difference in SOC between the second and third batteries **32** and **33** is not within the predetermined allowable difference range.
[0155] In response to determination that there is a need to equalize the SOCs of the first to third batteries **31** to **33** (YES in step S**205**), the control apparatus **100** iterates the determination in step S**205** after lapse of a predetermined time as long as the determination in step S**205** is NO.
[0156] That is, in response to determination that there is not a need to equalize the SOCs of the first to third batteries **31** to **33** (NO in step S**205**), the control apparatus **100** sets the connection mode of the batteries **31** to **33** to the third connection mode in step S**206**.
[0157] Specifically, in step S**206**, the control apparatus **100** turns off or maintains in the off state each of the first-A switch SW**1***a* and the first-B switch SW**1***b*, thus cutting off power supply from the first battery **31** to **10**) the second battery **32** and supplying low-voltage power from the second battery **32** to the low-voltage loads **72** (see FIG. **5**). Following the operation in step S**206**, the control apparatus **100** deactivates the DC-to-DC converter **70** in step S**207**, and thereafter terminates the stop-state equalization routine.
[0158] The first embodiment described above achieves the following advantageous benefits.
[0159] The power supply system **30** according to the first embodiment is configured to switchably select between (i) the first connection mode in which all the first to third batteries **31** to **33** are connected between the high-side power supply line H**1** and the high-side ground line L**1** and (ii) the second connection mode. In the second connection mode, power supply between the high-side ground line L**1** and the low-side ground line L**2** is cut off, the second battery **32** is connected between the low-side power supply line H**2** and the low-side ground line L**2**, and the first battery **31** included in the remaining first and third batteries **31** and **33** is connected between the high-side power supply line H**1** and the high-side ground line L**1**. This therefore makes it possible to flexibly select at least one of the power sources **31** to **33** to be used.
[0160] The power supply system **30** according to the first embodiment, which establishes the second connection mode, enables low-voltage power to be supplied to the low-voltage loads **72**. This eliminates the need of providing low power supplies, resulting in reduction in both the number of components of the power supply system **30** and the number of processes required to constitute the power supply system **30**.
[0161] Successive execution of the third connection mode enables equalization of the SOCs of the first to third batteries **31** to **33** even if there is an imbalance among the SOCs of the first to third batteries **31** to **33**. During the successive execution of the third connection mode, the connection mode of the batteries **31** to **33** is switched to the second connection mode, so that the input voltage from the first battery **31** is stepped down, resulting in the third battery **33** being charged based on the stepped-down voltage. This eliminates the need of providing additional battery chargers, resulting in the configuration of the power supply system **30** being more simplified.
[0162] When switching the connection mode of the batteries **31** to **33** from the third connection mode to the first connection mode, the control apparatus **30** is configured to temporarily switch the control mode of the power supply system **30** to the second connection mode to accordingly (i) instruct the DC-to-DC converter **70** to operate and (ii) supply low-voltage power from the second battery **32** to the low-voltage loads **72**. Thereafter, the control apparatus **30** is configured to switch the connection mode of the batteries **31** to **33** to the first connection mode. This therefore prevents power supply to the low-voltage loads **72** from being cut off during switching of the connection mode of the batteries **31** to **33** from the third connection mode to the first connection mode.
[0163] Similarly, when switching the connection mode of the batteries **31** to **33** from the first connection mode to the third connection mode, the control apparatus **30** is configured to temporarily switch the control mode of the power supply system **30** to the second connection mode

to accordingly supply low-voltage power from the second battery **32** to the low-voltage loads **72** and thereafter switch the connection mode of the batteries **31** to **33** to the third connection mode. Thereafter, the control apparatus **30** is configured to switch the connection mode of the batteries **31** to **33** to the first connection mode. This therefore prevents power supply to the low-voltage loads **72** from being cut off during switching of the connection mode of the batteries **31** to **33** from the first connection mode to the third connection mode.

[0164] The power supply system **30** is configured to select the first parallel-connection mode when being connected to a low-voltage charger, and the first series-connection mode when being connected to a high-voltage charger.

[0165] The power supply system **30** is configured to establish the third connection mode in which only the second battery **32** is connected between the low-side power supply line H**2** and the low-side ground line L**2**. This configuration eliminates the need of stepping down, using the DC-to-DC converter **70**, high-voltage power, such as high-voltage power supplied from the first battery **31** and supplying the stepped-down voltage to the low-voltage loads **72** while the vehicle is in the stop state. This configuration therefore reduces consumed power required to operate the DC-to-DC converter **70** and loss of voltage stepping-down process.

Second Embodiment

[0166] The following describes a power supply system **230** according to the second embodiment. A part of the power supply system **30** has been changed to constitute the power supply system **230**.

[0167] A bypass path of the power supply system **230** according to the second embodiment, to which reference character **160** is added, has both first and second ends. As illustrated in FIG. **11**, the first end of the bypass path **160** is connected to a portion of the first-A electrical path **1**A; the portion is located between the first-A switch SW**1***a* and the positive terminal of the first battery **31**. The second end of the bypass path **160** is connected to the positive terminal of the first series-connection module **40**. The first end of the bypass path **160** may be connected to the high-side power supply line H**1**, and the second end of the bypass path **160** may be connected to the positive terminal of the first series-connection module **40**.

[0168] The power supply system **230** includes a fourth switch SW**4** mounted on the bypass path **160**.

[0169] The terminal voltage across the third battery **33** is set to 388 V, which is different from that according to the first embodiment. That is, the terminal voltage across each of the second battery **32** and the third battery **33** is set such that the terminal voltage across the first series-connection module **40**, which is comprised of the second and third batteries **32** and **33** connected in series to each other, is substantially identical to the terminal voltage across the first battery **31**.

[0170] The following describes how the control apparatus **100** of the second embodiment performs on-off control of each switch SW of the power supply system **230**.

[0171] The control apparatus **100** of the second embodiment is configured to set the connection mode of the batteries **31** to **33** to the first connection mode in which a part or all of the first to third batteries **31** to **33** included in the power supply system **230** is connected to the high-side power supply line H**1**. That is, the control apparatus **100** according to the second embodiment is configured to connect all the first to third batteries **31** to **33** included in the power supply system **230** to the high-side power supply line H**1** to accordingly establish the first connection mode. In particular, the control apparatus **100** according to the second embodiment is configured to select, as the first connection mode, one of the first series-connection mode and the first parallel-connection mode, and establish the selected one of the first series-connection mode and the first parallel-connection mode.

[0172] The first series-connection mode represents a mode in which the first battery **31**, the third battery **33**, and the second battery **32** are connected in series to one another to constitute the second series-connection module **50**, and the second series-connection module **50** is connected to the high-side power supply line H**1**.

[0173] Specifically, the control apparatus **100** is configured to, as illustrated in FIG. **12**, turn off or maintain in the off state each of the first-B switch SW**1***b*, the third-A switch SW**3***a*, the third-B switch SW**3***b*, and the fourth switch SW**4** and turn on or maintain in the on state the first-A switch SW**1***a*, the second-A switch SW**2***a*, and the second-B switch SW**2***b* to accordingly establish the first series-connection mode as the first connection mode.
[0174] The first series-connection mode results in the second series-connection module **50** being connected between the high-side power supply line H**1** and the high-side ground line L**1**; the second series-connection module **50** is comprised of the first, third, and second batteries **31**, **33**, and **32** being connected in series to each other. That is, high-voltage power having the sum of 400 V, 388 V, and 12 V is supplied from the second series-connection module **50** to the high-voltage loads **71** through the high-side power supply line H**1**. In contrast, no power is supplied from the second battery **32** to the low-voltage loads **72** through the low-side power supply line H**2**. Like FIG. **8**, it is possible to step down the voltage across the second series-connection module **50** through the DC-to-DC converter **70**, and supply the stepped-down voltage to the low-voltage loads **72**.
[0175] The first parallel-connection mode represents a mode in which the first battery **31** and the first series-connection module **40** are connected in parallel to the high-side power supply line H**1**.
[0176] Specifically, the control apparatus **100** is configured to, as illustrated in FIG. **13**, turn off or maintain in the off state each of the second-A switch SW**2***a*, the third-A switch SW**3***a*, and the third-B switch SW**3***b*, and turn on or maintain in the on state the first-A switch SW**1***a*, the first-B switch SW**1***b*, the second-B switch SW**2***b*, and the fourth switch SW**4** to accordingly establish the first parallel-connection mode as the first connection mode.
[0177] The first parallel-connection mode results in the first battery **31** and the second series-connection module **50** being connected in parallel to between the high-side power supply line H**1** and the high-side ground line L**1**. No power is supplied from the second battery **32** to the low-voltage loads **72** through the low-side power supply line H**2**. Like FIG. **9**, it is possible to step down the voltage across the second series-connection module **50** through the DC-to-DC converter **70**, and supply the stepped-down voltage to the low-voltage loads **72**.
[0178] Additionally, the control apparatus **100** is configured to set the connection mode of the batteries **31** to **33** to the second connection mode in which a part of the first to third batteries **31** to **33**, such as the second battery **32**, included in the power supply system **230** is connected to the low-side power supply line H**2** and a part or all of the remaining batteries, such as the first battery **31**, is connected to the high-side power supply line H**1**.
[0179] Specifically, the control apparatus **100** is configured to, as illustrated in FIG. **14**, turn off or maintain in the off state each of the second-A switch SW**2***a*, the second-B switch SW**2***b*, and the fourth switch SW**4**, and turn on or maintain in the on state the first-A switch SW**1***a*, the first-B switch SW**1***b*, the third-A switch SW**3***a*, and the third-B switch SW**3***b* to accordingly establish the second connection mode.
[0180] The second connection mode results in the first battery **31** being connected between the high-side power supply line H**1** and the high-side ground line L**1**, and the second battery **32** being connected between the low-side power supply line H**2** and the low-side ground line L**2**. This results in high-voltage power being supplied from the first battery **31** to the high-voltage loads **71** through the high-side power supply line H**1**, and low-voltage power being supplied from the second battery **32** to the low-voltage loads **72** through the low-side power supply line H**2**. In the second connection mode, the high-side ground line L**1** and the low-voltage ground line L**2** are electrically isolated from one another. Like FIG. **7**, it is possible to step down the voltage across the first battery **31** through the DC-to-DC converter **70**, and supply the stepped-down voltage to the low-voltage loads **72** and/or charge the second battery **32**.
[0181] The control apparatus **100** is configured to set the connection mode of the batteries **31** to **33** to the third connection mode in which a part of the first to third batteries **31** to **33**, such as the

second battery **32**, included in the power supply system **30** is only connected to the low-side power supply line H**2**.
[0182] Specifically, the control apparatus **100** is configured to turn off or maintain in the off state each of the first-A switch SW**1***a*, the first-B switch SW**1***b*, the second-A switch SW**2***a*, the second-B switch SW**2***b*, and the fourth switch SW**4**, and turn on or maintain in the on state the third-A switch SW**3***a* and the third-B switch SW**3***b* to accordingly establish the third connection mode. This results in, in the third connection mode, low-voltage power being supplied from the second battery **32** to the low-voltage loads **72** through the low-side power supply line H**2**. No power is supplied from the first battery **31** to the high-voltage loads **71** through the high-side power supply line H**1**.
[0183] The normal mode-switching routine and the stop-state equalization routine according to the second embodiment are substantially identical to the respective normal mode-switching routine and stop-state equalization routine according to the first embodiment, and therefore descriptions of the normal mode-switching routine and the stop-state equalization routine according to the second embodiment are omitted.
[0184] Accordingly, the power supply system **230** of the second embodiment achieves the same advantageous benefits as those achieved by the power supply system **30** of the first embodiment.
Third Embodiment
[0185] The following describes a power supply system **330** according to the third embodiment. A part of the power supply system **30** has been changed to constitute the power supply system **330**.
[0186] The power supply system **330** of the third embodiment is configured such that, as illustrated in FIG. **15**, the first battery **31** and the first series-connection module **40** comprised of the second and third batteries **32** and **33** are connected in parallel to the high-side power supply line H**1**.
[0187] The following describes in detail the power supply system **330** with reference to FIG. **15**.
[0188] The terminal voltage across the third battery **33** according to the third embodiment is set to 388 V, which is different from that according to the first embodiment. That is, the terminal voltage across each of the second battery **32** and the third battery **33** is set such that the terminal voltage across the first series-connection module **40**, which is comprised of the second and third batteries **32** and **33** connected in series to each other, is substantially identical to the terminal voltage across the first battery **31**.
[0189] The power supply system **330** includes the first-A switch SW**1***a* mounted on the first-A electrical path **1**A that connects between the positive terminal of the first battery **31** and the high-side power supply line H**1**. The power supply system **330** also includes the first-B switch SW**1***b* mounted on the first-B electrical path **1**B that connects between the negative terminal of the first battery **31** and the high-side ground line L**1**. A series module comprised of a pre-charge switch Pre-P**2** and a resistor R**2** connected in series to each other is connected in parallel to the first-A switch SW**1***a*.
[0190] The power supply system **330** includes the second-A switch SW**2***a* mounted on the second-A electrical path **2**A connecting between the positive terminal of the first series-connection module **40** and the high-level power supply line H**1**. The power supply system **330** includes the second-B switch SW**2***b* mounted on the second-B electrical path **2**B that connects between the negative terminal of the first series-connection module **40** and the high-side ground line L**1**.
[0191] In the third embodiment, the third battery **33** and the second battery **32** are connected to one another in this order from the high-voltage power supply line H**1** to the high-side ground line L**1**. The positive terminal of the first series-connection module **40** according to the first embodiment corresponds to the positive terminal of the third battery **33**, and the negative terminal of the first series-connection module **40** corresponds to the negative terminal of the second battery **32**. A series-connection module, which is comprised of a pre-charge switch Pre-P**3** and a resistor R**3** connected in series to one another, is connected in parallel to the second-A switch SW**2***a*.
[0192] The power supply system **330** includes the third-A switch SW**3***a* mounted on the third-A

electrical path **3**A that connects between the positive terminal of the second battery **32** and the low-side power supply line H**2**. The power supply system **330** also includes the third-B switch SW**3***b* mounted on the third-B electrical path **3**B that connects between the negative terminal of the second battery **32** and the low-side ground line L**2**.

[0193] The following describes how the control apparatus **100** of the third embodiment performs on-off control of each switch SW of the power supply system **330**.

[0194] The control apparatus **100** of the third embodiment is configured to set the connection mode of the batteries **31** to **33** to the first connection mode in which a part or all of the first to third batteries **31** to **33** included in the power supply system **330** is connected to the high-side power supply line H**1**.

[0195] The first connection mode according to the third embodiment represents a mode in which the first battery **31** and the first series-connection module **40** are connected in parallel to the high-side power supply line H**1**.

[0196] Specifically, the control apparatus **100** is configured to, as illustrated in FIG. **16**, turn off or maintain in the off state each of the third-A switch SW**3***a* and the third-B switch SW**3***b*, and turn on or maintain in the on state the first-A switch SW**1***a*, the first-B switch SW**1***b*, the second-A switch SW**2***a*, and the second-B switch SW**2***b* to accordingly establish the first connection mode. As illustrated by the dashed line in FIG. **16**, the DC-to-DC converter **70** is capable of stepping down high-voltage power, and supply the stepped-down voltage to the low-voltage loads **72**.

[0197] Additionally, the control apparatus **100** is configured to set the connection mode of the batteries **31** to **33** to the second connection mode in which a part of the first to third batteries **31** to **33**, such as the second battery **32**, included in the power supply system **330** is connected to the low-side power supply line H**2** and a part or all of the remaining batteries, such as the first battery **31**, is connected to the **25** high-side power supply line H**1**.

[0198] Specifically, the control apparatus **100** is configured to, as illustrated in FIG. **17**, turn off or maintain in the off state each of the second-A switch SW**2***a* and the second-B switch SW**2***b*, and turn on or maintain in the on state the first-A switch SW**1***a*, the first-B switch SW**1***b*, the third-A switch SW**3***a*, and the third-B switch SW**3***b* to accordingly establish the second connection mode.

[0199] The second connection mode results in the first battery **31** being connected between the high-side power supply line H**1** and the high-side ground line L**1**, and the second battery **32** being connected between the low-side power supply line H**2** and the low-side ground line L**2** while the high-side ground line L**1** and the low-voltage ground line L**2** are electrically isolated from one another. This results in high-voltage power being supplied from the first battery **31** to the high-voltage loads **71** through the high-side power supply line H**1**, and low-voltage power being supplied from the second battery **32** to the low-voltage loads **72** through the low-side power supply line H**2**. Like the first connection mode, in the second connection mode, it is possible to step down the voltage across the first battery **31** through the DC-to-DC converter **70**, and supply the stepped-down voltage to the low-voltage loads **72** and/or charge the second battery **32**.

[0200] The control apparatus **100** is configured to set the connection mode of the batteries **31** to **33** to the third connection mode in which a part of the first to third batteries **31** to **33**, such as the second battery **32**, included in the power supply system **30** is only connected to the low-side power supply line H**2**.

[0201] Specifically, the control apparatus **100** is configured to turn off or maintain in the off state each of the first-A switch SW**1***a*, the first-B switch SW**1***b*, the second-A switch SW**2***a*, and the second-B switch SW**2***b*, and turn on or maintain in the on state the third-A switch SW**3***a* and the third-B switch SW**3***b* to accordingly establish the third connection mode. This results in, in the third connection mode, low-voltage power being supplied from the second battery **32** to the low-voltage loads **72** through the low-side power supply line H**2**. No power is supplied from the first battery **31** to the high-voltage loads **71** through the high-side power supply line H**1**.

[0202] The normal mode-switching routine and the stop-state equalization routine according to the third embodiment are substantially identical to the respective normal mode-switching routine and stop-state equalization routine according to the first embodiment, and therefore descriptions of the normal mode-switching routine and the stop-state equalization routine according to the third embodiment are omitted.

[0203] Accordingly, the power supply system **330** of the third embodiment achieves the same advantageous benefits as those achieved by the power supply system **30** of the first embodiment.

Fourth Embodiment

[0204] The following describes a power supply system **430** according to the fourth embodiment. A part of the power supply system **30** has been changed to constitute the power supply system **430**.

[0205] The power supply system **430** of the fourth embodiment includes, as illustrated in FIG. **18**, a first inverter **420***a* and a second inverter **420***b*.

[0206] The following describes in detail the power supply system **430** with reference to FIG. **18**.

[0207] The first inverter **420***a* includes, like the inverter **20** of the first embodiment, three-phase series-connected switch units; the series-connected switch unit for each phase is comprised of an upper-arm switch SWH and a lower-arm switch SWL connected in series to each other. The first inverter **420***a* includes, like the inverter **20** of the first embodiment, a smoothing capacitor **21***a*. The smoothing capacitor **21***a* may be arranged outside the first inverter **420***a*.

[0208] The first inverter **420***a* is connected to a first high-side power supply line H**401** and to a first high-level ground line L**401**. That is, the series-connected switch unit, which is comprised of the upper- and lower-arm switches SWH and SWL, of each phase of the first inverter **420***a* is connected between the first high-side power supply line H**401** and the first high-level ground line L**401**.

[0209] The emitter, which serves as the low-side terminal, of the upper-arm switch SWH of the first inverter **420***a* for each phase is connected to the collector, which serves as the high-side terminal, of the lower-arm switch SWL of the first inverter **420***a* for the corresponding phase. The connection point between the emitter of the upper-arm switch SWH and the collector of the lower-arm switch SWL of the first inverter **420***a* for each phase is connected to the first end of the corresponding phase armature winding **11** through the conductor, such as the busbar, **23**.

[0210] The second inverter **420***b* includes, like the inverter **20** of the first embodiment, three-phase series-connected switch units; the series-connected switch unit for each phase is comprised of an upper-arm switch SWH and a lower-arm switch SWL connected in series to each other. The second inverter **420***b* includes, like the inverter **20** of the first embodiment, a smoothing capacitor **21***b*. The smoothing capacitor **21***b* may be arranged outside the second inverter **420***b*.

[0211] The second inverter **420***b* is connected to a second high-side power supply line H**402** and to a second high-level ground line L**402**. That is, the series-connected switch unit, which is comprised of the upper- and lower-arm switches SWH and SWL, of each phase of the second inverter **420***b* is connected between the second high-side power supply line H**402** and the second high-level ground line L**402**.

[0212] The emitter, which serves as the low-side terminal, of the upper-arm switch SWH of the second inverter **420***b* for each phase is connected to the collector, which serves as the high-side terminal, of the lower-arm switch SWL of the second inverter **420***b* for the corresponding phase. The connection point between the emitter of the upper-arm switch SWH and the collector of the lower-arm switch SWL of the second inverter **420***b* for each phase is connected to the first end of the corresponding phase armature winding **11** through the conductor, such as the busbar, **23**.

[0213] Each of the second high-side power supply line H**402** and the second high-side ground line L**402** is connected through the armature windings **11** of the motor **10** to the corresponding one of the first high-side power supply line H**401** and the first high-side ground line L**401**.

[0214] The terminal voltage across the third battery **33** according to the fourth embodiment is set to 388 V, which is different from that according to the first embodiment. That is, the terminal voltage across each of the second battery **32** and the third battery **33** is set such that the terminal voltage across the first series-connection module **40**, which is comprised of the second and third batteries **32** and **33** connected in series to each other, is substantially identical to the terminal voltage across the first battery **31**. The terminal voltage across the first battery **31** according to the fourth embodiment may be identical to or may not be identical to the terminal voltage across the first battery **31**.

[0215] The power supply system **430** includes the first-A switch SW**1***a* mounted on the first-A electrical path **1**A that connects between the positive terminal of the first battery **31** and the first high-side power supply line H**401**. The power supply system **430** also includes the first-B switch SW**1***b* mounted on the first-B electrical path **1**B that connects between the negative terminal of the first battery **31** and the first high-side ground line L**401**. The first inverter **420***a* enables power to be transferred to and from the first battery **31** through the first high-side power supply line H**401** and the first ground line L**401**. The series module comprised of the pre-charge switch Pre-P**2** and the resistor R**2** connected in series to each other is connected in parallel to the first-A switch SW**1***a*.

[0216] The power supply system **430** includes the second-A switch SW**2***a* mounted on the second-A electrical path **2**A connecting between the positive terminal of the first series-connection module **40** and the second high-level power supply line H**402**. The power supply system **430** includes the second-B switch SW**2***b* mounted on the second-B electrical path **2**B that connects between the negative terminal of the first series-connection module **40** and the second high-side ground line L**402**. The series module comprised of the pre-charge switch Pre-P**3** and the resistor R**3** connected in series to each other is connected in parallel to the second-A switch SW**2***a*.

[0217] The power supply system **430** includes the third-A switch SW**3***a* mounted on the third-A electrical path **3**A that connects between the positive terminal of the second battery **32** and the low-side power supply line H**2**. The power supply system **430** also includes the third-B switch SW**3***b* mounted on the third-B electrical path **3**B that connects between the negative terminal of the second battery **32** and the low-side ground line L**2**.

[0218] The following describes how the control apparatus **100** of the fourth embodiment performs on-off controls of each switch SW of the power supply system **430**.

[0219] The control apparatus **100** of the fourth embodiment is configured to set the connection mode of the batteries **31** to **33** to the first connection mode in which a part or all of the first to third batteries **31** to **33** included in the power supply system **430** is connected to the high-side power supply line H**1** comprised of the first and second high-side power supply lines H**401** and H**402**.

[0220] The first connection mode according to the fourth embodiment represents a mode in which the first battery **31** is connected to the first high-side power supply line H**401**, and the first series-connection module **40** is connected to the second high-side power supply line H**402**.

[0221] Specifically, the control apparatus **100** is configured to, as illustrated in FIG. **19**, turn off or maintain in the off state each of the third-A switch SW**3***a* and the third-B switch SW**3***b*, and turn on or maintain in the on state the first-A switch SW**1***a*, the first-B switch SW**1***b*, the second-A switch SW**2***a*, and the second-B switch SW**2***b* to accordingly establish the first connection mode. The first connection mode results in the first battery **31** being connected between the first high-side power supply line H**401** and the first high-side ground line H**402** and the first series-connection module **40** being connected between the second high-side power supply line H**402** and the second high-side ground line L**402**. As illustrated by the dashed line in FIG. **19**, the DC-to-DC converter **70** is capable of stepping down high-voltage power, and supply the stepped-down voltage to the low-voltage loads **72**.

[0222] Additionally, the control apparatus **100** is configured to set the connection mode of the batteries **31** to **33** to the second connection mode in which a part of the first to third batteries **31** to **33**, such as the second battery **32**, included in the power supply system **430** is connected to the low-side power supply line H**2** and a part or all of the remaining batteries, such as the first battery **31**, is connected to the first high-side power supply line H**401**.

[0223] Specifically, the control apparatus **100** is configured to, as illustrated in FIG. **20**, turn off or maintain in the off state each of the second-A switch SW**2***a* and the second-B switch SW**2***b*, and turn on or maintain in the on state the first-A switch SW**1***a*, the first-B switch SW**1***b*, the third-A switch SW**3***a*, and the third-B switch SW**3***b* to accordingly establish the second connection mode.

[0224] The second connection mode results in the first battery **31** being connected between the first high-side power supply line H**401** and the first high-side ground line L**401**, and the second battery **32** being connected between the low-side power supply line H**2** and the low-side ground line L**2**. In the second connection mode, it is possible to step down the voltage across the first battery **31** through the DC-to-DC converter **70**, and supply the stepped-down voltage to the low-voltage loads **72**.

[0225] The control apparatus **100** is configured to set the connection mode of the batteries **31** to **33** to the third connection mode in which a part of the first to third batteries **31** to **33**, such as the second battery **32**, included in the power supply system **30** is only connected to the low-side power supply line H**2**.

[0226] Specifically, the control apparatus **100** is configured to turn off or maintain in the off state each of the first-A switch SW**1***a*, the first-B switch SW**1***b*, the second-A switch SW**2***a*, and the second-B switch SW**2***b*, and turn on or maintain in the on state the third-A switch SW**3***a* and the third-B switch SW**3***b* to accordingly establish the third connection mode. This results in, in the third connection mode, power supply between the first high-side power supply line H**401** and the first battery **31** being cut off, and the second battery **32** being connected between the low-side power supply line H**2** and the low-side ground line L**2**. This also results in power supply from the third battery **33** to the second high-side power supply line H**402** being cut off.

[0227] The normal mode-switching routine and the stop-state equalization routine according to the fourth embodiment are substantially identical to the respective normal mode-switching routine and stop-state equalization routine according to the first embodiment, and therefore descriptions of the normal mode-switching routine and the stop-state equalization routine according to the third embodiment are omitted.

[0228] Accordingly, the power supply system **430** of the fourth embodiment achieves the same advantageous benefits as those achieved by the power supply system **30** of the first embodiment.

MODIFICATIONS

[0229] The following describes modifications, each of which includes a modified configuration of at least part of the embodiments.

First Modification

[0230] Each of the power supply systems **30**, **230**, **330**, and **430** of the corresponding one of the embodiments may include a low-voltage power supply unit **80** that supplies low-voltage power, such as power with 12 V, to the low-voltage loads **72** through the low-side power supply line H**2**.

[0231] For example, as illustrated in FIG. **21**, such a low-voltage power supply unit **80** may be provided in the power supply system **30** of the first embodiment. The low-voltage power supply unit **80** is comprised of, for example, switches and a lead-acid storage battery. The control apparatus may be configured to control power supply from the low-voltage power supply unit **80**. Both of or any one of the DC-to-DC converter **70** and the low-voltage power supply unit **80** may be provided in the power supply system **30** or outside the power supply system **30**.

[0232] The configuration of the power supply system **30** including the low-voltage power supply unit **80** makes it possible to eliminate the need of supplying low-voltage power from the third battery **33** to the low-voltage loads **72** during normal stop periods. For example, in a case where there is an anomaly in the low-voltage power supply unit **80**, at least one of the first to third batteries **31** to **33**, such as the second battery **32**, can serve as a low-voltage power supply in such an anomaly situation. That is, each of the power supply systems **30**, **230**, **330**, and **430** can be configured to include redundancy.

[0233] The following describes an anomaly mode-switching routine carried out by the control apparatus **100** for switchably selecting one of the first to third connection modes as the connection mode of, for example, power supply system **30** in an anomaly situation according to the first modification in accordance with FIG. **22**. In the first modification, let us assume that the connection mode of the batteries **31** to **33** is set to the first connection mode during startup of the vehicle, so that power is supplied from at least one of the first to third batteries **31** to **33** to the high-voltage loads **71**, such as the motor **10**, and power is supplied from the low-voltage power supply unit **80** or the DC-to-DC converter **70** to the low-voltage loads **72**.

[0234] The control apparatus **100** is programmed to execute the anomaly mode-switching routine every predetermined period.

[0235] When starting the anomaly mode-switching routine, the control apparatus **100** determines whether the vehicle is operating, i.e., the ignition switch of the vehicle is in the on state in step S**301**. Upon determination that the vehicle is not operating (NO in step S**301**), the control apparatus **100** terminates the anomaly mode-switching routine.

[0236] Otherwise, upon determination that the vehicle is operating (YES in step S**301**), the control apparatus **100** sets the connection mode of the batteries **31** to **33** to the first connection mode in step S**302**. Specifically, if the connection mode of the batteries **31** to **33** has been the first connection mode before execution of the anomaly mode-switching routine, the control apparatus **100** continues the first connection mode. Otherwise, if the connection mode of the batteries **31** to **33** has not been the first connection mode, the control apparatus **100** changes the connection mode of the batteries **31** to **33** to the first connection mode. The first connection mode results in high-voltage power being supplied from the second series-connection module **50** to the high-voltage loads **71** through the high-side power supply line H**1** while no power is supplied from the second battery **32** to the low-voltage loads **72** through the low-side power supply line H**2**. That is, the first connection mode results in low-voltage power being supplied from the low-voltage power source **80** to the low-voltage loads **72**.

[0237] Following the operation in step S**302**, the control apparatus **100** serves as an anomaly determiner to determine whether there is an anomaly in power supply from the low-voltage power supply unit **80** to the low-voltage loads **72** in step S**303**. Specifically, the control apparatus **100** measures, for example, the amount of current outputted from the low-voltage power supply unit **80**, the voltage outputted from the low-voltage power supply unit **80** and/or the temperature of the low-voltage power supply unit **80** based on the measurements of the above various sensors SS, and determines whether there is an anomaly in power supply from the low-voltage power supply unit **80** to the low-voltage loads **72** in accordance with the measured amount of current, voltage, and/or temperature of the low-voltage power supply unit **80**.

[0238] Upon determination that there is no anomaly in power supply from the low-voltage power supply unit **80** to the low-voltage loads **72** (NO in step S**303**), the control apparatus **100** terminates the anomaly mode-switching routine.

[0239] Otherwise, upon determination that there is an anomaly in power supply from the low-voltage power supply unit **80** to the low-voltage loads **72** (YES in step S**303**), the control apparatus **100** serves as a load controller to control the high-voltage loads **71** to limit consumed power of the high-voltage loads **71** in step S**304**. For example, the control apparatus **100** controls the inverter **20** to lower output torque of the motor **10**.

[0240] Next, the control apparatus **100** changes the connection mode of the batteries **31** to **33** to the third connection mode in step S**305**. This results in, in the third connection mode, low-voltage power being supplied from the second battery **32** to the low-voltage loads **72** through the low-side power supply line H**2**. While no power is supplied from the first battery **31** to the high-voltage loads **71** through the high-side power supply line H**1**, power is supplied from the smoothing capacitor **21** to the high-voltage loads **71** for a while.

[0241] Following the operation in step S**305**, the control apparatus **100** serves as the inverter controller to control the inverter **20** to accordingly adjust a voltage across the smoothing capacitor **21** in step S**306**. Specifically, the control apparatus **100** adjusts the voltage across the smoothing capacitor **21** to cause the voltage across the smoothing capacitor **21** to be equal to the voltage across the first battery **31**. The voltage adjustment in step S**306** makes it possible to prevent, if the connection mode of the batteries **31** to **33** is changed to the second connection mode, the voltage across the smoothing capacitor **21** from becoming higher than the voltage across the first battery **31**.

[0242] After the voltage adjustment in step S**306**, the control apparatus **100** changes the connection mode of the batteries **31** to **33** to the second connection mode in step S**307**. This results in, in the second connection mode, high-voltage power being supplied from the first battery **31** to the high-voltage loads **71** through the high-side power supply line H**1** and low-voltage power being supplied from the second battery **32** to the low-voltage loads **72** through the low-side power supply line H**2**. This therefore enables the vehicle to travel in a limp-home mode for a while. After completion of the operation in step S**307**, the control apparatus **100** terminates the anomaly mode-switching routine.

[0243] Next, the following describes a mode-switching routine carried out by the control apparatus **100** in response to determination that there is an anomaly in the low-voltage power supply unit **80** while the vehicle is stopped. While the vehicle is stopped, no power is supplied from each of the first to third batteries **31** to **33** to the low-voltage loads **72**, but power is supplied from the low-voltage power supply unit **80** to the low-voltage loads **72**. For this reason, if it is determined that there is an anomaly in the low-voltage power supply unit **80**, the control apparatus **100** is configured to set the control mode of the power supply system **30** to the third control mode, resulting in low-voltage power being supplied from the second battery **32** to the low-voltage loads **72** through the low-side power supply line H**2**. While the vehicle is stopped, the vehicle does not have to travel in the limp-home mode. For this reason, the control apparatus **100** may be configured not to set the control mode of the power supply system **30** to the third control mode.

Second Modification

[0244] Each of the power supply systems **30**, **230**, **330**, and **430** of the corresponding one of the embodiments may be connected to a charging device for charging the second battery **32** while the vehicle is stopped. For example, as illustrated in FIG. **23**, the power supply system **30** may be connected to a charging device **500**. An external charging station or a solar power generator may be used as the charging device **500**. The charging device **500** may be connected to the second battery **32** through the low-side power supply line H**2** and the third-A electrical path **3**A, making it possible for the charging device **500** to charge the second battery **32** while the connection mode of the batteries **31** to **33** is set to the third connection mode.

[0245] As illustrated in FIG. **23**, charging only the second battery **32** may result in imbalance between the SOC of the second battery **32** and the SOC of the third battery **33**.

[0246] From this viewpoint, the control apparatus **100** according to the second modification may be configured to execute an equalization routine illustrated in FIG. **25** for equalizing the SOCs of the first to third batteries **31** to **33**.

[0247] The control apparatus **100** is programmed to execute the equalization routine illustrated in FIG. **25** every predetermined period while both the vehicle is in the stop state and the second battery **32** is charged.

[0248] When starting the equalization routine illustrated in FIG. **25**, the control apparatus **100** estimates the power storage state, i.e., the SOC, of each of the first to third batteries **31** to **33** to accordingly determine whether there is a need to equalize the SOCs of the first to third batteries **31** to **33** in step S**401**. The control apparatus **100** estimates the SOC of each of the first to third batteries **31** to **33** using one of the known estimation methods. For example, when the SOC of the second battery **32** is determined to be greater than or equal to a predetermined upper limit, the control apparatus **100** determines that there is a need to equalize the SOCs of the first to third batteries **31** to **33** (YES in step S**401**).

[0249] Additionally, when the SOC of the second battery **32** is determined to be greater than the

SOC of the third battery **33** by a predetermined second equalization threshold or more, the control apparatus **100** determines that there is a need to equalize the SOCs of the first to third batteries **31** to **33** (YES in step S**401**).

[0250] Upon determination that there is not a need to equalize the SOCs of the first to third batteries **31** to **33** (NO in step S**401**), the control apparatus **100** sets the connection mode of the batteries **31** to **33** to the third connection mode in step S**402**. Specifically, if the connection mode of the batteries **31** to **33** has been the third connection mode before execution of the equalization routine, the control apparatus **100** continues the third connection mode. Otherwise, if the connection mode of the batteries **31** to **33** has not been the third connection mode, the control apparatus **100** changes the connection mode of the batteries **31** to **33** to the third connection mode. This results in, as illustrated in FIG. **23**, power being supplied from the charging device **500** to the second battery **32**, so that the second battery **32** is charged. Thereafter, the control apparatus **100** terminates the equalization routine illustrated in FIG. **25**.

[0251] Otherwise, upon determination that there is a need to equalize the SOCs of the first to third batteries **31** to **33** (YES in step S**401**), the control apparatus **100** sets the connection mode of the batteries **31** to **33** to the second connection mode in step S**403**.

[0252] Following the operation in step S**403**, the control apparatus **100** instructs the DC-to-DC converter **70** to convert, i.e., boost, the input voltage inputted thereto from the second battery **32** through the power transmission line L**3** in step S**404**. This enables the boosted power by the DC-to-DC converter **70** being supplied to the high-voltage loads **71** and/or the first battery **31** through the high-side power supply line H**1**, resulting in the second battery **32** being discharged.

[0253] Following the operation in step S**404**, the control apparatus **100** estimates the power storage state, i.e., the SOC, of each of the first to third batteries **31** to **33** to accordingly determine whether there is a need to equalize the SOCs of the first to third batteries **31** to **33** in step S**405**, which is identical to the determination in step S**401**. The criteria for the determination in step S**405** is identical to that for determination in step S**401**, but the criteria for the determination in step S**405** may be different from that for determination in step S**401**.

[0254] For example, the control apparatus **100** may be programmed to determine whether the SOC of the second battery **32** is within the predetermined allowable range and the absolute difference in SOC between the second and third batteries **32** and **33** is within the predetermined allowable difference range. Then, the control apparatus **100** may be programmed to determine that there is not a need to equalize the SOCs of the first to third batteries **31** to **33** upon determination that the SOC of the second battery **32** is within the predetermined allowable range and the absolute difference in SOC between the second and third batteries **32** and **33** is within the predetermined allowable difference range. Otherwise, the control apparatus **100** may be programmed to determine that there is a need to equalize the SOCs of the first to third batteries **31** to **33** upon determination that the SOC of the second battery **32** is not within the predetermined allowable range or the absolute difference in SOC between the second and third batteries **32** and **33** is not within the predetermined allowable difference range.

[0255] In response to determination that there is a need to equalize the SOCs of the first to third batteries **31** to **33** (YES in step S**405**), the control apparatus **100** iterates the determination in step S**405** after lapse of a predetermined time as long as the determination in step S**405** is NO.

[0256] That is, in response to determination that there is not a need to equalize the SOCs of the first to third batteries **31** to **33** (NO in step S**405**), the control apparatus **100** sets the connection mode of the batteries **31** to **33** to the third connection mode in step S**406**.

[0257] Specifically, in step S**406**, the control apparatus **100** turns off or maintains in the off state each of the first-A switch SW**1***a* and the first-B switch SW**1***b*, thus stopping the discharging of the second battery **32** (see FIG. **23**). Following the operation in step S**406**, the control apparatus **100** deactivates the DC-to-DC converter **70** in step S**407**, and thereafter terminates the equalization routine illustrated in FIG. **25**. This enables the SOC of the second battery **32** to be equalized to the

SOC of the third battery **33**. Additionally, discharged power from the second battery **32** is configured to be supplied to the high-voltage loads **71** and/or the first battery **31**, making it possible to efficiently discharge, without power loss, the second battery **32** using a simpler power discharging configuration.

Third Modification

[0258] Each embodiment may be configured as the third modification to set the connection mode of the corresponding power supply system to the second connection mode independently of whether the corresponding power supply system includes the low-voltage power supply unit **80** during, for example, startup of the vehicle. Specifically, the control apparatus **100** of the third modification may be configured to supply high-voltage power from the first battery **31** to the high-voltage loads **71** through the high-side power supply line H**1** and supply low-voltage power from the second battery **32** to the low-voltage loads **72** through the low-side power supply line H**2** during startup of the vehicle.

[0259] The control apparatus **100** of the third modification, which continuously sets the connection mode of the batteries **31** to **33** to the second connection mode, may result in imbalance among the SOCs of the first to third batteries **31** to **33**.

[0260] From this viewpoint, the control apparatus **100** according to the third modification may be configured to execute an equalization routine illustrated in FIG. **26** for equalizing the SOCs of the first to third batteries **31** to **33**.

[0261] The control apparatus **100** is programmed to execute the stop-state equalization routine illustrated in FIG. **26** every predetermined period while connection mode of the batteries **31** to **33** is set to the second connection mode.

[0262] When starting the equalization routine illustrated in FIG. **26**, the control apparatus **100** determines whether the connection mode of the batteries **31** to **33** is set to the second connection mode in step S**501**. Upon determination that the connection mode of the batteries **31** to **33** is not set to the second connection mode (NO in step S**501**), the control apparatus **100** terminates the equalization routine illustrated in FIG. **26**.

[0263] Otherwise, upon determination that the connection mode of the batteries **31** to **33** is set to the second connection mode (YES in step S**501**), the control apparatus **100** estimates the power storage state, i.e., the SOC, of each of the first to third batteries **31** to **33** to accordingly determine whether there is a need to equalize the SOCs of the first to third batteries **31** to **33** in step S**502**. The control apparatus **100** estimates the SOC of each of the first to third batteries **31** to **33** using one of the known estimation methods.

[0264] For example, when the SOC of the second battery **32** is determined to be smaller than or equal to the predetermined lower limit, the control apparatus **100** determines that there is a need to equalize **20** the SOCs of the first to third batteries **31** to **33** (YES in step S**502**).

[0265] Additionally, when the absolute difference in SOC between any pair of the first to third batteries **31** to **33** is determined to be greater than or equal to than a predetermined third equalization threshold, the control apparatus **100** determines that there is a need to equalize the SOCs of the first to third batteries **31** to **33** (YES in step S**502**).

[0266] Upon determination that there is not a need to equalize the SOCs of the first to third batteries **31** to **33** to one another (NO in step S**502**), the control apparatus **100** terminates the equalization routine illustrated in FIG. **26**.

[0267] Otherwise, upon determination that there is a need to equalize the SOCs of the first to third batteries **31** to **33** (YES in step S**502**), the control apparatus **100** instructs the DC-to-DC converter **70** to convert, i.e., step down, the voltage of high-voltage power inputted thereto from the first battery **31**, thus charging the second battery **32** based on the stepped-down voltage in step S**503**. Alternatively, in step S**503**, the control apparatus **100** instructs the DC-to-DC converter **70** to increase the level of power supplied from the DC-to-DC converter **70**, thus increasing the amount of charge in the second battery **32**.

[0268] When a predetermined time has elapsed since completion of the operation in step S**503**, the control apparatus **100** estimates the SOC of each of the first to third batteries **31** to **33** to accordingly determine whether there is a need to equalize the SOCs of the first to third batteries **31** to **33** in step S**504**, which is identical to the determination in step S**502**. The criteria for the determination in step S**504** is identical to that for determination in step S**502**, but the criteria for the determination in step S**504** may be different from that for determination in step S**502**.
[0269] For example, the control apparatus **100** may be programmed to determine whether the SOC of the second battery **32** is within the predetermined allowable range and the absolute difference in SOC between each pair of the first to third batteries **31** to **33** is within the predetermined allowable difference range. Then, the control apparatus **100** may be programmed to determine that there is not a need to equalize the SOCs of the first to third batteries **31** to **33** upon determination that the SOC of the second battery **32** is within the predetermined allowable range and the absolute difference in SOC between each pair of the first to third batteries **31** to **33** is within the predetermined allowable difference range. Otherwise, the control apparatus **100** may be programmed to determine that there is a need to equalize the SOCs of the first to third batteries **31** to **33** upon determination that the SOC of the second battery **32** is not within the predetermined allowable range or the absolute difference in SOC between any pair of the first to third batteries **31** to **33** is not within the predetermined allowable difference range.
[0270] In response to determination that there is a need to equalize the SOCs of the first to third batteries **31** to **33** (YES in step S**504**), the control apparatus **100** iterates the determination in step S**504** after lapse of a predetermined time as long as the determination in step S**504** is NO.
[0271] That is, in response to determination that there is not a need to equalize the SOCs of the first to third batteries **31** to **33** (NO in step S**504**), the control apparatus **100** deactivates the DC-to-DC converter **70** in step S**505**. Alternatively, in step S**505**, the control apparatus **100** instructs the DC-to-DC converter **70** to decrease the level of power supplied from the DC-to-DC converter **70**, thus decreasing the amount of charge in the second battery **32**. After the operation in step S**505**, the control apparatus **100** terminates the equalization routine illustrated in FIG. **26**.
[0272] This therefore enables the SOCs of the first to third batteries **31** to **33** to be equalized even when the connection mode of the batteries **31** to **33** is continuously set to the second connection mode.
Fourth Modification
[0273] The control apparatus **100** of each power supply system **30**, **230**, **330**, **430** of the corresponding embodiment may be configured to set the connection mode of the batteries **31** to **33** to the second connection model while the power supply system **30**, **230**, **330**, **430** is connected to the charging device for charging the second battery **32**. For example, while the power supply system **30** of the first embodiment is connected to the charging device **500** set forth above, the control apparatus **100** may be configured to set the connection mode of the batteries **31** to **33** to the second connection mode. This enables the charging device **500** to charge the second battery **32** while the first battery **31** supplies power to the high-voltage loads **71**.
[0274] As described above, charging the second battery **32** in the second connection mode may result in imbalance among the SOCs of the first to third batteries **31** to **33**.
[0275] From this viewpoint, the control apparatus **100** according to the fourth modification may be configured to execute an equalization routine illustrated in FIG. **29** for equalizing the SOCs of the first to third batteries **31** to **33**.
[0276] The control apparatus **100** is programmed to execute the equalization routine illustrated in FIG. **29** every predetermined period while both the second battery **32** is charged by the charging device **500** and the second connection mode is set to the connection mode of the batteries **31** to **33**.
[0277] When starting the equalization routine illustrated in FIG. **29**, the control apparatus **100** determines whether the connection mode of the batteries **31** to **33** is set to the second connection mode and the second battery **32** is charged by the charging device **500** in step S**601**. Upon

determination that the connection mode of the batteries **31** to **33** is not set to the second connection mode or the second battery **32** is not charged by the charging device **500** (NO in step S**601**), the control apparatus **100** terminates the equalization routine illustrated in FIG. **29**.

[0278] Otherwise, upon determination that the connection mode of the batteries **31** to **33** is set to the second connection mode and the second battery **32** is charged by the charging device **500** (YES in step S**601**), the control apparatus **100** estimates the power storage state, i.e., the SOC, of each of the first to third batteries **31** to **33** to accordingly determine whether there is a need to equalize the SOCs of the first to third batteries **31** to **33** in step S**602**. The control apparatus **100** estimates the SOC of each of the first to third batteries **31** to **33** using one of the known estimation methods.

[0279] For example, when the SOC of the second battery **32** is determined to be greater than or equal to the predetermined upper limit, the control apparatus **100** determines that there is a need to equalize the SOCs of the first to third batteries **31** to **33** (YES in step S**602**).

[0280] Additionally, when the absolute difference in SOC between any pair of the first to third batteries **31** to **33** is determined to be greater than or equal to the SOC of the third battery **33** by a predetermined fourth equalization threshold, the control apparatus **100** determines that there is a need to equalize the SOCs of the first to third batteries **31** to **33** (YES in step S**602**).

[0281] Upon determination that there is not a need to equalize the SOCs of the first to third batteries **31** to **33** (NO in step S**602**), the control apparatus **100** terminates the equalization routine illustrated in FIG. **29**.

[0282] Otherwise, upon determination that there is a need to equalize the SOCs of the first to third batteries **31** to **33** (YES in step S**602**), the control apparatus **100** instructs the DC-to-DC converter **70** to (i) boost the voltage of low-voltage power inputted thereto from the second battery **32**, and (ii) supply the boosted power to, for example, the high-voltage loads **71**, thus discharging the second battery **32** in step S**603**. Alternatively, in step S**603**, when the DC-to-DC converter **70** is activated, the control apparatus **100** instructs the DC-to-DC converter **70** to increase the level of power inputted to the DC-to-DC converter **70**, thus increasing the amount of discharge from the second battery **32**.

[0283] When a predetermined time has elapsed since completion of the operation in step S**603**, the control apparatus **100** estimates the SOC of each of the first to third batteries **31** to **33** to accordingly determine whether there is a need to equalize the SOCs of the first to third batteries **31** to **33** in step S**604**, which is identical to the determination in step S**602**. The criteria for the determination in step S**604** is identical to that for determination in step S**602**, but the criteria for the determination in step S**604** may be different from that for determination in step S**602**.

[0284] For example, the control apparatus **100** may be programmed to determine whether the SOC of the second battery **32** is within the predetermined allowable range and the absolute difference in SOC between each pair of the first to third batteries **31** to **33** is within the predetermined allowable difference range. Then, the control apparatus **100** may be programmed to determine that there is not a need to equalize the SOCs of the first to third batteries **31** to **33** *r* upon determination that the SOC of the second battery **32** is within the predetermined allowable range and the absolute difference in SOC between each pair of the first to third batteries **31** to **33** is within the predetermined allowable difference range. Otherwise, the control apparatus **100** may be programmed to determine that there is a need to equalize the SOCs of the first to third batteries **31** to **33** upon determination that the SOC of the second battery **32** is not within the predetermined allowable range or the absolute difference in SOC between any pair of the first to third batteries **31** to **33** is not within the predetermined allowable difference range.

[0285] In response to determination that there is a need to equalize the SOCs of the first to third batteries **31** to **33** (YES in step S**604**), the control apparatus **100** iterates the determination in step S**604** after lapse of a predetermined time as long as the determination in step S**604** is NO.

[0286] That is, in response to determination that there is not a need to equalize the SOCs of the first to third batteries **31** to **33** (NO in step S**604**), the control apparatus **100** deactivates the DC-to-DC converter **70** in step S**605**. Alternatively, in step S**605**, the control apparatus **100** instructs the DC-to-DC converter **70** to decrease the level of power inputted to the DC-to-DC converter **70**, thus decreasing the amount of discharge from the second battery **32**. After the operation in step S**605**, the control apparatus **100** terminates the equalization routine illustrated in FIG. **29**.

[0287] This therefore enables the SOCs of the first to third batteries **31** to **33** to be equalized even when the connection mode of the batteries **31** to **33** is continuously set to the second connection mode.

Fifth Modification

[0288] A switch may be provided between the second battery **32** and the third battery **33** in each of the power supply systems **30**, **230**, **330**, and **430**; the switch is configured to switchably select one of electrical conduction between the second and third batteries **32** and **33** and electrical cutoff therebetween. For example, as illustrated in FIG. **30**, a switch SW**5** may be provided between the positive terminal of the second battery **32** and the negative terminal of the third battery **33** in the power supply system **30**; the switch SW**5** is configured to switchably select one of (i) electrical conduction between the second and third batteries **32** and **33** and (ii) electrical cutoff therebetween. The switch SW**5** may serve as such a second-A switch that enables (i) electrical conduction through the second-A electrical path **2**A and (ii) electrical cutoff therethrough to be switched therebetween.

Sixth Modification

[0289] The arrangement of the second and third batteries **32** and **33** in each of the power supply systems **30**, **230**, **330**, and **430** may be changed. For example, as illustrated in FIG. **31**, the first battery **31**, the second battery **32**, and the third battery **33** may be connected in series to one another in this order from the high-voltage power supply line H**1** to the high-side ground line L**1** in the power supply system **30** of the first embodiment. In the sixth modification, such a switch SW**5** may be provided between the negative terminal of the second battery **32** and the positive terminal of the third battery **33**.

Seventh Modification

[0290] The arrangement of the first to third batteries **31** to **33** in each of the power supply systems **30** and **230** may be changed. For example, as illustrated in FIG. **32**, the second battery **32**, the third battery **33**, and the first battery **31** may be connected to one another in this order from the high-voltage power supply line H**1** to the high-side ground line L**1** in the power supply system **30** of the first embodiment. The bypass path **60** according to this seventh modification may serve as a path connecting between the negative terminal of the first series-connection module **40**, i.e., the negative terminal of the third battery **33**, and the neutral point of the motor **10**. A series-connection module, which is comprised of a pre-charge switch Pre-G and the resistor R**1** connected in series to one another, may be connected in parallel to the second-A switch SW**1***b*.

Eighth Modification

[0291] The third battery **33** may be omitted in each of the power supply systems **30**, **230**, **330**, and **430**. For example, as illustrated in FIG. **33**, no third battery **33** may be provided in the power supply system **30** of the first embodiment. In the eighth modification of each of the power supply systems **230** and **330** of the second and third embodiments, which includes no third battery **33**, the terminal voltage across the second battery **32** should be substantially identical to the terminal voltage across the first battery **31**.

Other Modifications

[0292] In each of the embodiments and modifications, at least one series-connection module comprised of a pre-charge switch and a resistor is connected in parallel to a switch arranged to be closer to the high-side power supply line than to the low-side ground line. At least one additional series-connection module comprised of a pre-charge switch and a resistor may be provided to be connected in parallel to a switch arranged to be closer to the low-side power supply line than to the high-side ground line.

[0293] In each of the embodiments and modifications, the control apparatus is configured to determine whether there is a need to equalize the SOCs of the first to third batteries **31** to **33**. The control apparatus according to each of the embodiments and modifications may be configured to measure or estimate, as the power storage state, the remaining capacity of each of the first to third batteries **31** to **33** and determine whether there is a need to equalize the SOCs of the first to third batteries **31** to **33** using the measured or estimated remaining capacity of each of the first to third batteries **31** to **33**. Alternatively, the control apparatus according to each of the embodiments and modifications may be configured to measure or estimate, as the power storage state, the voltage across each of the first to third batteries **31** to **33** and determine whether there is a need to equalize the SOCs of the first to third batteries **31** to **33** using the measured or estimated voltage across each of the first to third batteries **31** to **33**.

[0294] The configuration of the power supply system **30** of the first embodiment can be modified to have any one of the following configurations illustrated in respective FIGS. **34** to **57**.

[0295] The modification of the power supply system **30** illustrated in each of FIGS. **34** to **57** shows only characteristic components thereof as compared with the power supply system **30** of the first embodiment, and therefore the other components are not illustrated in each of FIGS. **34** to **57**. Unlike FIG. **1**, each of FIGS. **34** to **57** shows the side of the inverter **20** on the left side of the corresponding drawing, and the side of the power supply system **30** on the right side of the corresponding drawing.

[0296] Like the eighth modification, the third battery **33** is omitted in the modification of the power supply system **30** illustrated in each of FIGS. **34** to **57**.

Modification in FIG. **34**

[0297] The power supply system **30** according to the modification illustrated in FIG. **34** includes the second-A switch SW**2***a* and the switch SW**5** mounted on the second-A electrical path **2**A that connects between the negative terminal of the first battery **31** and the positive terminal of the second battery **32**. The second-A switch SW**2***a* and the switch SW**5** are connected in series to one another.

[0298] Specifically, the switch SW**5** is connected to the negative terminal of the first battery **31**, and the second-A switch SW**2***a* is connected to the switch SW**5**. The positive terminal of the second battery **32** is connected to the second-A switch SW**2***a*.

[0299] The fourth switch SW**4** and the switch RN are omitted from the bypass path **60** that connects between the neural point of the armature windings **11** of the motor **10** and the connection point between the second-A switch SW**2***a* and the switch SW**5**.

[0300] In the power supply system **30** according to the modification illustrated in FIG. **34**, on-off control of the switch SW**5**, which is carried out by the control apparatus **100**, enables switching between (i) electrical conduction between the negative terminal of the first battery **31** and the neutral point of the armature windings **11** of the motor **10** and (ii) electrical cutoff therebetween. On-off control of the second-A switch SW**2***a*, which is carried out by the control apparatus **100**, enables switching between (i) electrical conduction between the positive terminal of the second battery **32** and the neutral point of the armature windings **11** of the motor **10** and (ii) electrical cutoff therebetween.

[0301] Specifically, in the first series-connection mode (see FIG. **2**) of the power supply system **30** according to the modification illustrated in FIG. **34**, the first-A switch SW**1***a*, the switch SW**5**, the second-A switch SW**2***a*, and the second-B switch **2***b* are turned on, and the first-B switch SW**1***b* is turned off. In the first parallel-connection mode (see FIG. **3**) of the power supply system **30** according to the modification illustrated in FIG. **34**, the switch SW**5** is turned off, and the second-A switch SW**2***a*, the second-B switch SW**2***b*, the first-A switch SW**1***a*, and the first-B switch SW**1***b* are turned on.

[0302] In the second connection mode (see FIG. **4**) of the power supply system **30** according to the modification illustrated in FIG. **34**, the switch SW**5**, the second-A switch SW**2***a*, and the second-B switch SW**2***b* are turned off, and the first-A switch SW**1***a* and the first-B switch SW**1***b* are turned on.

[0303] In the third connection mode (see FIG. **5**) of the power supply system **30** according to the modification illustrated in FIG. **34**, the switch SW**5**, the second-A switch SW**2***a*, the second-B switch SW**2***b*, the first-A switch SW**1***a*, and the first-B switch SW**1***b* are turned off. The other configuration of the modification of the power supply system **30** illustrated in FIG. **34** is substantially identical to that of the power supply system **30** illustrated in FIG. **1**.

Modification in FIG. **35**

[0304] As compared with the power supply system **30** according to the eighth modification illustrated in FIG. **33**, the switch RN is omitted from the bypass path **60** of the modification of the power supply system **30** illustrated in FIG. **35**. The other configuration of the power supply system **30** according to the modification illustrated in FIG. **35** is substantially identical to that of the power supply system **30** according to the eighth modification illustrated in FIG. **33**.

Modification in FIG. **36**

[0305] In the power supply system **30** according to the modification illustrated in FIG. **36**, the bypass route **60** is connected between the neutral point of the armature windings **11** of the motor **10** and the connection point on the second-A electrical path **2**A between the negative terminal of the first battery **31** and the second-A switch SW**2***a*. The fourth switch SW**4** and the switch RN are omitted from the bypass path **60** of the modification of the power supply system **30** illustrated in FIG. **36**. The other configuration of the power supply system **30** according to the modification illustrated in FIG. **36** is substantially identical to that of the power supply system **30** according to the eighth modification illustrated in FIG. **33**.

Modification in FIG. **37**

[0306] In the power supply system **30** according to the modification illustrated in FIG. **37**, the bypass route **60** is connected between the neutral point of the armature windings **11** of the motor **10** and the connection point on the second-A electrical path **2**A between the negative terminal of the first battery **31** and the second-A switch SW**2***a*. The switch RN is omitted from the bypass path **60**. The other configuration of the power supply system **30** according to the modification illustrated in FIG. **37** is substantially identical to that of the power supply system **30** according to the eighth modification illustrated in FIG. **33**.

[0307] Specifically, in the first series-connection mode (see FIG. **2**) of the power supply system **30** according to the modification illustrated in FIG. **37**, the first-A switch SW**1***a*, the second-A switch SW**2***a*, and the second-B switch **2***b* are turned on, and the first-B switch SW**1***b* and the fourth switch SW**4** are turned off.

[0308] In the second connection mode (see FIG. **4**) of the power supply system **30** according to the modification illustrated in FIG. **37**, the fourth switch SW**4**, the second-A switch SW**2***a*, and the second-B switch SW**2***b* are turned off, and the first-A switch SW**1***a* and the first-B switch SW**1***b* are turned on.

[0309] In the third connection mode (see FIG. **5**) of the power supply system **30** according to the modification illustrated in FIG. **37**, the fourth switch SW**4**, the second-A switch SW**2***a*, the second-B switch SW**2***b*, the first-A switch SW**1***a*, and the first-B switch SW**1***b* are turned off. The other configuration of the power supply system **30** according to the modification illustrated in FIG. **37** is substantially identical to that of the power supply system **30** illustrated in FIG. **1**.

Modification in FIG. **38**

[0310] The power supply system **30** according to the modification illustrated in FIG. **38** includes the second-A switch SW**2***a* and the switch SW**5** mounted on the second-A electrical path **2**A that connects between the negative terminal of the first battery **31** and the positive terminal of the second battery **32**. The second-A switch SW**2***a* and the switch SW**5** are connected in series to one another.

[0311] Specifically, the switch SW**5** is connected to the negative terminal of the first battery **31**, and the second-A switch SW**2***a* is connected to the switch SW**5**. The positive terminal of the second battery **32** is connected to the second-A switch SW**2***a*.

[0312] The bypass path **60** of the power supply system **30** according to the modification illustrated in FIG. **38** has a first end and a second end, and the first end of the bypass path **60** is connected to the neutral point of the armature windings **11** of the motor **10**. A connection line connected to the second end of the bypass path **60** branches into first and second branch lines. The first branch line is connected to the connection point on the second-A electrical path **2**A between the negative terminal of the first battery **31** and the second-A switch SW**2***a*. The second branch line is connected to the connection point between the switch SW**5** and the second-A electrical path **2**A.

[0313] Specifically, in the first series-connection mode (see FIG. **2**) of the power supply system **30** according to the modification illustrated in FIG. **38**, the first-A switch SW**1***a*, the second-A switch SW**2***a*, the second-B switch **2***b*, and the switch SW**5** are turned on, and the first-B switch SW**1***b* is turned off.

[0314] In the second connection mode (see FIG. **4**) of the power supply system **30** according to the modification illustrated in FIG. **38**, the switch SW**5**, the second-A switch SW**2***a*, and the second-B switch SW**2***b* are turned off, and the first-A switch SW**1***a* and the first-B switch SW**1***b* are turned on.

[0315] In the third connection mode (see FIG. **5**) of the power supply system **30** according to the modification illustrated in FIG. **38**, the switch SW**5**, the second-A switch SW**2***a*, the second-B switch SW**2***b*, the first-A switch SW**1***a*, and the first-B switch SW**1***b* are turned off. The other configuration of the power supply system **30** according to the modification illustrated in FIG. **38** is substantially identical to that of the power supply system **30** illustrated in FIG. **1**.

Modification in FIG. **39**

[0316] As compared with the power supply system **30** according to the modification illustrated in FIG. **38**, the power supply system **30** according to the modification illustrated in FIG. **39** includes the fourth switch SW**4** mounted on the first branch line.

[0317] Specifically, in the first series-connection mode (see FIG. **2**) of the power supply system **30** according to the modification illustrated in FIG. **39**, the first-A switch SW**1***a*, the second-A switch SW**2***a*, the second-B switch **2***b*, and the switch SW**5** are turned on, and the first-B switch SW**1***b* and the fourth switch SW**4** are turned off.

[0318] In the first parallel-connection mode (see FIG. **3**) of the power supply system **30** according to the modification illustrated in FIG. **39**, the second-A switch SW**2***a*, the second-B switch SW**2***b*, the first-A switch SW**1***a*, and the first-B switch SW**1***b* are turned on, and the fourth switch and the switch SW**5** are turned off.

[0319] In the second connection mode (see FIG. **4**) of the power supply system **30** according to the modification illustrated in FIG. **39**, the switch SW**5**, the fourth switch SW**4**, the second-A switch SW**2***a*, and the second-B switch SW**2***b* are turned off, and the first-A switch SW**1***a* and the first-B switch SW**1***b* are turned on.

[0320] In the third connection mode (see FIG. **5**) of the power supply system **30** according to the modification illustrated in FIG. **39**, the switch SW**5**, the fourth switch SW**4**, the second-A switch SW**2***a*, the second-B switch SW**2***b*, the first-A switch SW**1***a*, and the first-B switch SW**1***b* are turned off. The other configuration of the power supply system **30** according to the modification illustrated in FIG. **39** is substantially identical to that of the power supply system **30** illustrated in FIG. **1**.

Modification in FIG. **40**

[0321] In the power supply system **30** according to the modification illustrated in FIG. **40**, the second-A switch SW**2***a* is mounted on the second-A electrical path **2**A that connects between the negative terminal of the first battery **31** and the positive terminal of the second battery **32**. The second-A switch SW**2***a* is connected to the negative of the first battery **31** and the positive terminal of the second battery **32**.

[0322] The bypass path **60** of the power supply system **30** according to the modification illustrated in FIG. **40** has a first end and a second end, and the first end of the bypass path **60** is connected to the neutral point of the armature windings **11** of the motor **10**. A connection line connected to the second end of the bypass path **60** branches into first and second branch lines. The first branch line is connected to the connection point on the second-A electrical path **2**A between the negative terminal of the first battery **31** and the second-A switch SW**2***a*. The second branch line is connected to the second-A switch SW**2***a* and the positive terminal of the second batter **32**.

[0323] Specifically, in the first series-connection mode (see FIG. **2**) of the modification illustrated in FIG. **40**, the first-A switch SW**1***a*, the second-A switch SW**2***a*, and the second-B switch **2***b* are turned on, and the first-B switch SW**1***b* and the fourth switch SW**4** are turned off.

[0324] In the second connection mode (see FIG. **4**) of the power supply system **30** according to the modification illustrated in FIG. **40**, the fourth switch SW**4**, the second-A switch SW**2***a*, and the second-B switch SW**2***b* are turned off, and the first-A switch SW**1***a* and the first-B switch SW**1***b* are turned on.

[0325] In the third connection mode (see FIG. **5**) of the power supply system **30** according to the modification illustrated in FIG. **40**, the fourth switch SW**4**, the second-A switch SW**2***a*, the second-B switch SW**2***b*, the first-A switch SW**1***a*, and the first-B switch SW**1***b* are turned off. The other configuration of the power supply system **30** according to the modification illustrated in FIG. **40** is substantially identical to that of the power supply system **30** illustrated in FIG. **1**.

Modification in FIG. **41**

[0326] As compared with the power supply system **30** according to the modification illustrated in FIG. **38**, a switch SW**41** is additionally mounted on the first branch line, and a switch SW**42** is additionally mounted on the second branch line.

[0327] Specifically, in the first series-connection mode (see FIG. **2**) of the power supply system **30** according to the modification illustrated in FIG. **41**, the first-A switch SW**1***a* and the second-A switch SW**2***a* are turned on, and the first-B switch SW**1***b*, the fourth switch SW**4**, and the switch SW**41** are turned off.

[0328] In the second connection mode (see FIG. **4**) of the power supply system **30** according to the modification illustrated in FIG. **41**, the switch SW**41**, the fourth switch SW**4**, and the second-A switch SW**2***a* are turned off, and the first-A switch SW**1***a* and the first-B switch SW**1***b* are turned on.

[0329] In the third connection mode (see FIG. **5**) of the power supply system **30** according to the modification illustrated in FIG. **41**, the switch SW**41**, the fourth switch SW**41**, the second-A switch SW**2***a*, the second-B switch SW**2***b*, the first-A switch SW**1***a*, and the first-B switch SW**1***b* are turned off. The other configuration of the power supply system **30** according to the modification illustrated in FIG. **41** is substantially identical to that of the power supply system **30** illustrated in FIG. **1**.

Modification in FIG. **42**

[0330] In the power supply system according to the modification illustrated in FIG. **42**, the second-A electrical path **2**A, which connects the positive terminal of the second battery **32** and the negative terminal of the first battery **31**, includes a first-B electrical path **1**B that connects between the negative terminal of the first battery **31** and the high-side ground line L**1**. The first battery **31** is mounted on the second-B electrical path **2**B that connects between the negative terminal of the second battery **32** and the high-side ground line L**1**.

[0331] The bypass path **60** of the power supply system according to the modification illustrated in FIG. **42** is connected between (i) the neutral point of the armature windings **11** of the motor **10** and (ii) the connection point on the second-B electrical path **2**B between the positive terminal of the first battery **31** and the second-B switch SW**2***b*. No switch RN is mounted on the bypass path **60**. The other configuration of the power supply system **30** according to the modification illustrated in FIG. **42** is substantially identical to that of the power supply system **30** according to the eighth modification illustrated in FIG. **33**.

[0332] Specifically, in the first series-connection mode (see FIG. **2**) of the power supply system **30** according to the modification illustrated in FIG. **42**, the first-B switch SW**1***b*, the second-A switch SW**2***a*, and the second-B switch **2***b* are turned on, and the first-A switch SW**1***a* is turned off.
[0333] In the second connection mode (see FIG. **4**) of the power supply system **30** according to the modification illustrated in FIG. **42**, the second-A switch SW**2***a* and the second-B switch SW**2***b* are turned off, and the first-A switch SW**1***a* and the first-B switch SW**1***b* are turned on.
[0334] In the third connection mode (see FIG. **5**) of the power supply system **30** according to the modification illustrated in FIG. **42**, the first-A switch SW**1***a*, the first-B switch SW**1***b*, the second-A switch SW**2***a*, and the second-B switch SW**2***b* are turned off. The other configuration of the power supply system **30** according to the modification illustrated in FIG. **42** is substantially identical to that of the power supply system **30** illustrated in FIG. **1**.
Modification in FIG. **43**
[0335] As compared with the power supply system **30** according to the modification illustrated in FIG. **42**, the fourth switch SW**4** is mounted on the bypass path **60** in the power supply system according to the modification illustrated in FIG. **43**.
[0336] Specifically, in the first series-connection mode (see FIG. **2**) of the power supply system **30** according to the modification illustrated in FIG. **43**, the first-B switch SW**1***b*, the second-A switch SW**2***a*, and the second-B switch **2***b* are turned on, and the first-A switch SW**1***a* and the fourth switch SW**4** are turned off.
[0337] In the second connection mode (see FIG. **4**) of the power supply system **30** according to the modification illustrated in FIG. **43**, the second-A switch SW**2***a*, the second-B switch SW**2***b*, and the fourth switch SW**4** are turned off, and the first-A switch SW**1***a* and the first-B switch SW**1***b* are turned on.
[0338] In the third connection mode (see FIG. **5**) of the power supply system **30** according to the modification illustrated in FIG. **43**, the first-A switch SW**1***a*, the first-B switch SW**1***b*, the second-A switch SW**2***a*, the second-B switch SW**2***b*, and the fourth switch SW**4** are turned off. The other configuration of the power supply system **30** according to the modification illustrated in FIG. **43** is substantially identical to that of the power supply system **30** illustrated in FIG. **1**.
Modification in FIG. **44**
[0339] As compared with the power supply system **30** according to the modification illustrated in FIG. **43**, the switch SW**5** is mounted on the second-B electrical path **2**B between the second-B switch SW**2***b* and the positive terminal of the first battery **31**. The bypass path **60** is connected between the neutral point of the armature windings **11** of the motor **10** and the connection point on the second-B electrical path **2**B between the second-B switch SW**2***b* and the switch SW**5**.
[0340] Specifically, in the first series-connection mode (see FIG. **2**) of the power supply system **30** according to the modification illustrated in FIG. **44**, the first-B switch SW**1***b*, the second-A switch SW**2***a*, the second-B switch **2***b*, and the switch SW**5** are turned on, and the first-A switch SW**1***a* is turned off.
[0341] In the first parallel-connection mode (see FIG. **3**) of the power supply system **30** according to the modification illustrated in FIG. **44**, the first-A switch SW**1***a*, the first-B switch SW**1***b*, the second-A switch SW**2***a*, and the second-B switch SW**2***b* are turned on, and the switch SW**5** is turned off.
[0342] In the second connection mode (see FIG. **4**) of the power supply system **30** according to the modification illustrated in FIG. **44**, the **20**) second-A switch SW**2***a*, the second-B switch SW**2***b*, and the switch SW**5** are turned off, and the first-A switch SW**1***a* and the first-B switch SW**1***b* are turned on.
[0343] In the third connection mode (see FIG. **5**) of the power supply system **30** according to the modification illustrated in FIG. **44**, the first-A switch SW**1***a*, the first-B switch SW**1***b*, the second-A switch SW**2***a*, the second-B switch SW**2***b*, and the switch SW**5** are turned off. The other configuration of the power supply system **30** according to the modification illustrated in FIG. **44** is

substantially identical to that of the power supply system **30** illustrated in FIG. **1**.

Modification in FIG. **45**

[0344] As compared with the power supply system **30** according to the modification illustrated in FIG. **43**, the bypass path **60** is connected between the neutral point of the armature windings **11** of the motor **10** and the connection point on the second-B electrical path **2**B between the negative terminal of the second battery **32** and the second-B switch SW**2***b*.

[0345] Specifically, in the first series-connection mode (see FIG. **2**) of the power supply system **30** according to the modification illustrated in FIG. **45**, the first-B switch SW**1***b*, the second-A switch SW**2***a*, and the second-B switch **2***b* are turned on, and the first-A switch SW**1***a* and the fourth switch SW**4** are turned off.

[0346] In the first parallel-connection mode (see FIG. **3**) of the power supply system **30** according to the modification illustrated in FIG. **45**, the first-A switch SW**1***a*, the first-B switch SW**1***b*, the second-A switch SW**2***a*, and the fourth switch SW**4** are turned on, and the second-B switch SW**2***b* is turned off.

[0347] In the second connection mode (see FIG. **4**) of the power supply system **30** according to the modification illustrated in FIG. **45**, the second-A switch SW**2***a*, the second-B switch SW**2***b*, and the fourth switch SW**4** are turned off, and the first-A switch SW**1***a* and the first-B switch SW**1***b* are turned on.

[0348] In the third connection mode (see FIG. **5**) of the power supply system **30** according to the modification illustrated in FIG. **45**, the first-A switch SW**1***a*, the first-B switch SW**1***b*, the second-A switch SW**2***a*, the second-B switch SW**2***b*, and the fourth switch SW**4** are turned off. The other configuration of the power supply system **30** according to the modification illustrated in FIG. **45** is substantially identical to that of the power supply system **30** illustrated in FIG. **1**.

Modification in FIG. **46**

[0349] The bypass path **60** of the power supply system **30** according to the modification illustrated in FIG. **46** has a first end and a second end, and the first end of the bypass path **60** is connected to the neutral point of the armature windings **11** of the motor **10**. As compared with the power supply system **30** according to the modification illustrated in FIG. **44**, a connection line connected to the second end of the bypass path **60** branches into a first branch line and a second branch line. The first branch line is connected to the connection point on the second-B electrical path **2**B between the second-B switch SW**2***b* and the switch SW**5**. The second branch line is connected to the connection point between the switch SW**5** and the positive terminal of the first battery **31**.

[0350] Specifically, in the first series-connection mode (see FIG. **2**) of the power supply system **30** according to the modification illustrated in FIG. **46**, the first-B switch SW**1***b*, the second-A switch SW**2***a*, the second-B switch **2***b*, and the switch SW**5** are turned on, and the first-A switch SW**1***a* is turned off.

[0351] In the second connection mode (see FIG. **4**) of the power supply system **30** according to the modification illustrated in FIG. **46**, the second-A switch SW**2***a*, the second-B switch SW**2***b*, and the switch SW**5** are turned off, and the first-A switch SW**1***a* and the first-B switch SW**1***b* are turned on.

[0352] In the third connection mode (see FIG. **5**) of the power supply system **30** according to the modification illustrated in FIG. **46**, the first-A switch SW**1***a*, the first-B switch SW**1***b*, the second-A switch SW**2***a*, the second-B switch SW**2***b*, and the switch SW**5** are turned off. The other configuration of the power supply system **30** according to the modification illustrated in FIG. **46** is substantially identical to that of the power supply system **30** illustrated in FIG. **1**.

Modification in FIG. **47**

[0353] The bypass path **60** of the power supply system **30** according to the modification illustrated in FIG. **47** has a first end and a second end, and the first end of the bypass path **60** is connected to the neutral point of the armature windings **11** of the motor **10**. As compared with the power supply system **30** according to the modification illustrated in FIG. **45**, a connection line connected to the second end of the bypass path **60** branches into a first branch line and a second branch line. The first branch line is connected to the connection point on the second-B electrical path **2**B between the negative terminal of the second battery **32** and the second-B switch SW**2***b*. The second branch line is connected to the connection point on the second-B electrical path **2**B between the second-B switch SW**2***b* and the positive terminal of the first battery **31**. The fourth switch SW**4** is mounted on the first branch line.

[0354] Specifically, in the first series-connection mode (see FIG. **2**) of the power supply system **30** according to the modification illustrated in FIG. **47**, the first-B switch SW**1***b*, the second-A switch SW**2***a*, and the second-B switch **2***b* are turned on, and the first-A switch SW**1***a* and the fourth switch SW**4** are turned off.

[0355] In the second connection mode (see FIG. **4**) of the power supply system **30** according to the modification illustrated in FIG. **47**, the second-A switch SW**2***a*, the second-B switch SW**2***b*, and the fourth switch SW**4** are turned off, and the first-A switch SW**1***a* and the first-B switch SW**1***b* are turned on.

[0356] In the third connection mode (see FIG. **5**) of the power supply system **30** according to the modification illustrated in FIG. **47**, the first-A switch SW**1***a*, the first-B switch SW**1***b*, the second-A switch SW**2***a*, the second-B switch SW**2***b*, and the fourth switch SW**4** are turned off. The other configuration of the power supply system **30** according to the modification illustrated in FIG. **47** is substantially identical to that of the power supply system **30** illustrated in FIG. **1**.

Modification in FIG. **48**

[0357] As compared with the power supply system **30** according to the modification illustrated in FIG. **47**, the fourth switch SW**4** of the power supply system **30** according to the modification illustrated in FIG. **48** is not mounted on the first branch line but mounted on the second branch line.

[0358] Specifically, in the first series-connection mode (see FIG. **2**) of the power supply system **30** according to the modification illustrated in FIG. **48**, the first-B switch SW**1***b*, the second-A switch SW**2***a*, and the second-B switch **2***b* are turned on, and the first-A switch SW**1***a* and the fourth switch SW**4** are turned off.

[0359] In the first parallel-connection mode (see FIG. **3**) of the power supply system **30** according to the modification illustrated in FIG. **48**, the first-A switch SW**1***a*, the first-B switch SW**1***b*, and the second-A switch SW**2***a* are turned on, and the second-B switch SW**2***b* and the fourth switch SW**4** are turned off.

[0360] In the second connection mode (see FIG. **4**) of the power supply system **30** according to the modification illustrated in FIG. **48**, the second-A switch SW**2***a*, the second-B switch SW**2***b*, and the fourth switch SW**4** are turned off, and the first-A switch SW**1***a* and the first-B switch SW**1***b* are turned on.

[0361] In the third connection mode (see FIG. **5**) of the power supply system **30** according to the modification illustrated in FIG. **48**, the first-A switch SW**1***a*, the first-B switch SW**1***b*, the second-A switch SW**2***a*, the second-B switch SW**2***b*, and the fourth switch SW**4** are turned off. The other configuration of the power supply system **30** according to the modification illustrated in FIG. **48** is substantially identical to that of the power supply system **30** illustrated in FIG. **1**.

Modification in FIG. **49**

[0362] As compared with the power supply system **30** according to the modification illustrated in FIG. **47**, the switch SW**41** of the power supply system **30** according to the modification illustrated in FIG. **49** is mounted on the first branch line in place of the fourth switch SW**4**, and the switch SW**42** of the power supply system **30** according to the modification illustrated in FIG. **49** is mounted on the second branch.

[0363] Specifically, in the first series-connection mode (see FIG. **2**) of the power supply system **30** according to the modification illustrated in FIG. **49**, the first-B switch SW**1***b*, the second-A switch SW**2***a*, and the second-B switch **2***b* are turned on, and the first-A switch SW**1***a*, the switch SW**41**, and the switch SW**42** are turned off.

[0364] In the first parallel-connection mode (see FIG. **3**) of the power supply system **30** according to the modification illustrated in FIG. **49**, the first-A switch SW**1**_a_, the first-B switch SW**1**_b_, and the switch SW**41** are turned on, and the second-B switch SW**2**_b_ and the switch SW**41** are turned off.

[0365] In the second connection mode (see FIG. **4**) of the power supply system **30** according to the modification illustrated in FIG. **49**, the second-A switch SW**2**_a_, the second-B switch SW**2**_b_, the switch SW**41**, and the switch SW**42** are turned off, and the first-A switch SW**1**_a_ and the first-B switch SW**1**_b_ are turned on.

[0366] In the third connection mode (see FIG. **5**) of the power supply system **30** according to the modification illustrated in FIG. **49**, the first-A switch SW**1**_a_, the first-B switch SW**1**_b_, the second-A switch SW**2**_a_, the second-B switch SW**2**_b_, the switch SW**41**, and the switch SW**42** are turned off. The other configuration of the power supply system **30** according to the modification illustrated in FIG. **49** is substantially identical to that of the power supply system **30** illustrated in FIG. **1**.

Modification in FIG. **50**

[0367] As compared with the power supply system **30** according to the modification illustrated in FIG. **34**, the power supply system **30** according to the modification illustrated in FIG. **50** includes a bypass path **61** connecting between (i) the connection point between the switches SW**5** and the second-A switch SW**2**_a_ and (ii) the connection portion of the high-side power supply line H**1**, which connects the inverter **20** and the first-A switch SW**1**_a_. A switch SW**7** is mounted on the bypass path **61**.

[0368] Specifically, in the first series-connection mode (see FIG. **2**) of the power supply system **30** according to the modification illustrated in FIG. **50**, the first-A switch SW**1**_a_, the switch SW**5**, the second-A switch SW**2**_a_, and the second-B switch **2**_b_ are turned on, and the first-B switch SW**1**_b_ and the switch SW**7** are turned off.

[0369] In the first parallel-connection mode (see FIG. **3**) of the power supply system **30** according to the modification illustrated in FIG. **50**, the switch SW**5** is turned off, and the second-A switch SW**2**_a_, the second-B switch SW**2**_b_, the first-A switch SW**1**_a_, the first-B switch SW**1**_b_, and the switch SW**7** are turned on. That is, in the first parallel-connection mode, the first battery **31** is connected between the high-side power supply line H**1** and the high-side ground line L**1** through the first-B switch SW**1**_b_, and the second battery **32** is connected between the high-side power supply line H**1** and the high-side ground line L**1** through the second-B switch SW**2**_b_, the bypass path **61**, and the switch SW**7**.

[0370] In the second connection mode (see FIG. **4**) of the power supply system **30** according to the modification illustrated in FIG. **50**, the switch SW**5**, the switch SW**7**, the second-A switch SW**2**_a_, and the second-B switch SW**2**_b_ are turned off, and the first-A switch SW**1**_a_ and the first-B switch SW**1**_b_ are turned on.

[0371] In the third connection mode (see FIG. **5**) of the power supply system **30** according to the modification illustrated in FIG. **50**, the switch SW**5**, the switch SW**7**, the second-A switch SW**2**_a_, the second-B switch SW**2**_b_, the first-A switch SW**1**_a_, and the first-B switch SW**1**_b_ are turned off. The other configuration of the modification of the power supply system **30** illustrated in FIG. **50** is substantially identical to that of the power supply system **30** illustrated in FIG. **1**.

Modification in FIG. **51**

[0372] As compared with the power supply system **30** according to the modification illustrated in FIG. **50**, no switch SW**5** is provided in the power supply system **30** according to the modification illustrated in FIG. **51**. Additionally, the bypass path **60** connects between (i) the neutral point of the armature windings **11** of the motor **10** and (ii) the connection point between the second-A switch SW**2**_a_ and the positive terminal of the second battery **32**. The fourth switch SW**4** is mounted on the bypass path **60**.

[0373] Specifically, in the first series-connection mode (see FIG. **2**) of the power supply system **30** according to the modification illustrated in FIG. **51**, the first-A switch SW**1**_a_, the switch SW**5**, the second-A switch SW**2**_a_, and the second-B switch **2**_b_ are turned on, and the first-B switch SW**1**_b_, the switch SW**7**, and the fourth switch SW**4** are turned off.

[0374] The first parallel-connection mode (see FIG. **3**) of the power supply system **30** according to the modification illustrated in FIG. **51** includes a first configuration and a second configuration.

[0375] In the first configuration, the switch SW**7** and the second-A switch SW**2***a* are turned off, and the second-B switch SW**2***b*, the first-A switch SW**1***a*, the first-B switch SW**1***b*, and the fourth switch SW**4** are turned on. This results in, in the first configuration, the first battery **31** being connected between the high-side power supply line H**1** and the high-side ground line L**1** through the first-B switch SW**1***b* and the second battery **32** being connected between the neutral point of the armature windings **11** of the motor **10** and the high-side ground line L**1**.

[0376] In the second configuration, the second-A switch SW**2***a* and the fourth switch SW**4** are turned off, and the second-B switch SW**2***b*, the first-A switch SW**1***a*, the first-B switch SW**1***b*, and the switch SW**7** are turned on. This results in, in the second configuration, the first battery **31** being connected between the high-side power supply line H**1** and the high-side ground line L**1** through the first-B switch SW**1***b* and the second battery **32** being connected between the high-side power supply line H**1** and the high-side ground line L**1** through the second-B switch SW**2***b*, the bypass path **61**, and the switch SW**7**.

[0377] In the second connection mode (see FIG. **4**) of the power supply system **30** according to the modification illustrated in FIG. **51**, the fourth switch SW**4**, the switch SW**7**, the second-A switch SW**2***a*, and the second-B switch SW**2***b* are turned off, and the first-A switch SW**1***a* and the first-B switch SW**1***b* are turned on.

[0378] In the third connection mode (see FIG. **5**) of the power supply system **30** according to the modification illustrated in FIG. **51**, the fourth switch SW**4**, the switch SW**7**, the second-A switch SW**2***a*, the second-B **20**) switch SW**2***b*, the first-A switch SW**1***a*, and the first-B switch SW**1***b* are turned off. The other configuration of the modification of the power supply system **30** illustrated in FIG. **51** is substantially identical to that of the power supply system **30** illustrated in FIG. **1**.

Modification in FIG. **52**

[0379] As compared with the power supply system **30** according to the modification illustrated in FIG. **51**, the bypass path **60** connects between (i) the neutral point of the armature windings **11** of the motor **10** and (ii) the connection point between the second-A switch SW**2***a* and the negative terminal of the first battery **31**. No fourth switch SW**4** is mounted on the bypass path **60**.

[0380] Specifically, in the first series-connection mode (see FIG. **2**) of the power supply system **30** according to the modification illustrated in FIG. **52**, the first-A switch SW**1***a*, the second-A switch SW**2***a*, and the second-B switch **2***b* are turned on, and the first-B switch SW**1***b* and the switch SW**7** are turned off.

[0381] In the first parallel-connection mode (see FIG. **3**) of the power supply system **30** according to the modification illustrated in FIG. **52**, the second-A switch SW**2***a* is turned off, and the second-B switch SW**2***b*, the first-A switch SW**1***a*, the first-B switch SW**1***b*, and the switch SW**7** are turned on. That is, in the first parallel-connection mode, the first battery **31** is connected between the high-side power supply line H**1** and the high-side ground line L**1** through the first-B switch SW**1***b*, and the second battery **32** is connected between the high-side power supply line H**1** and the high-side ground line L**1** through the second-B switch SW**2***b*, the bypass path **61**, and the switch SW**7**.

[0382] In the second connection mode (see FIG. **4**) of the power supply system **30** according to the modification illustrated in FIG. **52**, the switch SW**7**, the second-A switch SW**2***a*, and the second-B switch SW**2***b* are turned off, and the first-A switch SW**1***a* and the first-B switch SW**1***b* are turned on.

[0383] In the third connection mode (see FIG. **5**) of the power supply system **30** according to the modification illustrated in FIG. **52**, the switch SW**7**, the second-A switch SW**2***a*, the second-B switch SW**2***b*, the first-A switch SW**1***a*, and the first-B switch SW**1***b* are turned off. The other configuration of the modification of the power supply system **30** illustrated in FIG. **52** is substantially identical to that of the power supply system **30** illustrated in FIG. **1**.

Modification in FIG. **53**

[0384] As compared with the power supply system **30** according to the modification illustrated in FIG. **52**, the switch SW**4** is mounted on the bypass path **60**.

[0385] Specifically, in the first series-connection mode (see FIG. **2**) of the power supply system **30** according to the modification illustrated in FIG. **53**, the first-A switch SW**1***a*, the second-A switch SW**2***a*, and the second-B switch **2***b* are turned on, and the first-B switch SW**1***b*, the fourth switch SW**4**, and the switch SW**7** are turned off.

[0386] In the first parallel-connection mode (see FIG. **3**) of the power supply system **30** according to the modification illustrated in FIG. **53**, the second-A switch SW**2***a* and the fourth switch SW**4** are turned off, and the second-B switch SW**2***b*, the first-A switch SW**1***a*, the first-B switch SW**1***b*, and the switch SW**7** are turned on. That is, in the first parallel-connection mode, the first battery **31** is connected between the high-side power supply line H**1** and the high-side ground line L**1** through the first-B switch SW**1***b*, and the second battery **32** is connected between the high-side power supply line H**1** and the high-side ground line L**1** through the second-B switch SW**2***b*, the bypass path **61**, and the switch SW**7**.

[0387] In the second connection mode (see FIG. **4**) of the power supply system **30** according to the modification illustrated in FIG. **53**, the switch SW**7**, the second-A switch SW**2***a*, the second-B switch SW**2***b*, and the fourth switch SW**4** are turned off, and the first-A switch SW**1***a* and the first-B switch SW**1***b* are turned on.

[0388] In the third connection mode (see FIG. **5**) of the power supply system **30** according to the modification illustrated in FIG. **53**, the switch SW**7**, the second-A switch SW**2***a*, the second-B switch SW**2***b*, the first-A switch SW**1***a*, the first-B switch SW**1***b*, and the fourth switch SW**7** are turned off. The other configuration of the modification of the power supply system **30** illustrated in FIG. **53** is substantially identical to that of the power supply system **30** illustrated in FIG. **1**.

Modification in FIG. **54**

[0389] The bypass path **60** of the power supply system **30** according to the modification illustrated in FIG. **54** has a first end and a second end, and the first end of the bypass path **60** is connected to the neutral point of the armature windings **11** of the motor **10**. A connection line connected to the second end of the bypass path **60** branches into first and second branch lines. The first branch line is connected to the connection point between the negative terminal of the first battery **31** and the switch SW**5**. The second branch line is connected to the connection point between the switch SW**5** and the second-A electrical path **2**A.

[0390] Specifically, in the first series-connection mode (see FIG. **2**) of the power supply system **30** according to the modification illustrated in FIG. **54**, the first-A switch SW**1***a*, the switch SW**5**, the second-A switch SW**2***a*, and the second-B switch **2***b* are turned on, and the first-B switch SW**1***b* and the switch SW**7** are turned off.

[0391] In the first parallel-connection mode (see FIG. **3**) of the power supply system **30** according to the modification illustrated in FIG. **54**, the switch SW**5** is turned off, and the second-A switch SW**2***a*, the second-B switch SW**2***b*, the first-A switch SW**1***a*, the first-B switch SW**1***b*, and the switch SW**7** are turned on. That is, in the first parallel-connection mode, the first battery **31** is connected between the high-side power supply line H**1** and the high-side ground line L**1** through the first-B switch SW**1***b*, and the second battery **32** is connected between the high-side power supply line H**1** and the high-side ground line L**1** through the second-B switch SW**2***b*, the bypass path **61**, and the switch SW**7**.

[0392] In the second connection mode (see FIG. **4**) of the power supply system **30** according to the modification illustrated in FIG. **54**, the switch SW**5**, the switch SW**7**, the second-A switch SW**2***a*, and the second-B switch SW**2***b* are turned off, and the first-A switch SW**1***a* and the first-B switch SW**1***b* are turned on.

[0393] In the third connection mode (see FIG. **5**) of the power supply system **30** according to the modification illustrated in FIG. **54**, the switch SW**5**, the switch SW**7**, the second-A switch SW**2***a*, the second-B switch SW**2***b*, the first-A switch SW**1***a*, and the first-B switch SW**1***b* are turned off. The other configuration of the modification of the power supply system **30** illustrated in FIG. **54** is substantially identical to that of the power supply system **30** illustrated in FIG. **1**.

Modification in FIG. **55**

[0394] As compared with the power supply system **30** according to the modification illustrated in FIG. **54**, the fourth switch SW**4** is mounted on the first branch line of the bypass path **60** in the power supply system **30** according to the modification illustrated in FIG. **55**.

[0395] Specifically, in the first series-connection mode (see FIG. **2**) of the power supply system **30** according to the modification illustrated in FIG. **55**, the first-A switch SW**1***a*, the switch SW**5**, the second-A switch SW**2***a*, and the second-B switch **2***b* are turned on, and the first-B switch SW**1***b*, the fourth switch SW**4**, and the switch SW**7** are turned off.

[0396] The first parallel-connection mode (see FIG. **3**) of the power supply system **30** according to the modification illustrated in FIG. **55** includes a first configuration and a second configuration.

[0397] In the first configuration, the switch SW**7**, the switch SW**5**, and the fourth switch SW**4** are turned off, and the second-A switch SW**2***a*, the second-B switch SW**2***b*, the first-A switch SW**1***a*, and the first-B switch SW**1***b* are turned on. This results in, in the first configuration, the first battery **31** being connected between the high-side power supply line H**1** and the high-side ground line L**1** through the first-B switch SW**1***b* and the second battery **32** being connected between the neutral point of the armature windings **11** of the motor **10** and the high-side ground line L**1**.

[0398] In the second configuration, the switch SW**5** and the fourth switch SW**4** are turned off, and the second-A switch SW**2***a*, the second-B switch SW**2***b*, the first-A switch SW**1***a*, the first-B switch SW**1***b*, and the switch SW**7** are turned on. This results in, in the second configuration, the first battery **31** being connected between the high-side power supply line H**1** and the high-side ground line L**1** through the first-B switch SW**1***b* and the second battery **32** being connected between the high-side power supply line H**1** and the high-side ground line L**1** through the second-B switch SW**2***b*, the bypass path **61**, and the switch SW**7**.

[0399] In the second connection mode (see FIG. **4**) of the power supply system **30** according to the modification illustrated in FIG. **55**, the switch SW**5**, the switch SW**7**, the second-A switch SW**2***a*, the second-B switch SW**2***b*, and the fourth switch SW**4** are turned off, and the first-A switch SW**1***a* and the first-B switch SW**1***b* are turned on.

[0400] In the third connection mode (see FIG. **5**) of the power supply system **30** according to the modification illustrated in FIG. **55**, the switch SW**5**, the switch SW**7**, the second-A switch SW**2***a*, the second-B switch SW**2***b*, the first-A switch SW**1***a*, the first-B switch SW**1***b*, and the fourth switch SW**4** are turned off. The other configuration of the modification of the power supply system **30** illustrated in FIG. **55** is substantially identical to that of the power supply system **30** illustrated in FIG. **1**.

Modification in FIG. **56**

[0401] As compared with the power supply system **30** according to the modification illustrated in FIG. **55**, the switch SW**5** is replaced with the second-A switch SW**2***a*, and the fourth switch SW**4** is not mounted on the first branch line but mounted on the second branch line in the power supply system **30** according to the modification illustrated in FIG. **56**.

[0402] Specifically, in the first series-connection mode (see FIG. **2**) of the power supply system **30** according to the modification illustrated in FIG. **56**, the first-A switch SW**1***a*, the second-A switch SW**2***a*, and the second-B switch **2***b* are turned on, and the first-B switch SW**1***b*, the fourth switch SW**4**, and the switch SW**7** are turned off.

[0403] In the first parallel-connection mode (see FIG. **3**) of the power supply system **30** according to the modification illustrated in FIG. **56**, the second-A switch SW**2***a* and the fourth switch SW**4** are turned off, and the second-B switch SW**2***b*, the first-A switch SW**1***a*, the first-B switch SW**1***b*, and the switch SW**7** are turned on. That is, in the first parallel-connection mode, the first battery **31** is connected between the high-side power supply line H**1** and the high-side ground line L**1** through the first-B switch SW**1***b*, and the second battery **32** is connected between the high-side power supply line H**1** and the high-side ground line L**1** through the second-B switch SW**2***b*, the bypass path **61**, and the switch SW**7**.

[0404] In the second connection mode (see FIG. **4**) of the power supply system **30** according to the modification illustrated in FIG. **56**, the switch SW**7**, the second-A switch SW**2***a*, the second-B switch SW**2***b*, and the fourth switch SW**4** are turned off, and the first-A switch SW**1***a* and the first-B switch SW**1***b* are turned on.

[0405] In the third connection mode (see FIG. **5**) of the power supply system **30** according to the modification illustrated in FIG. **56**, the switch SW**7**, the second-A switch SW**2***a*, the second-B switch SW**2***b*, the first-A switch SW**1***a*, the first-B switch SW**1***b*, and the fourth switch SW**4** are turned off. The other configuration of the modification of the power supply system **30** illustrated in FIG. **56** is substantially identical to that of the power supply system **30** illustrated in FIG. **1**.

Modification in FIG. **57**

[0406] As compared with the power supply system **30** according to the modification illustrated in FIG. **56**, the switch SW**41** is mounted on the first branch line of the bypass path **60** in the power supply system **30** according to the modification illustrated in FIG. **57**.

[0407] Specifically, in the first series-connection mode (see FIG. **2**) of the power supply system **30** according to the modification illustrated in FIG. **57**, the first-A switch SW**1***a*, the second-A switch SW**2***a*, and the second-B switch **2***b* are turned on, and the first-B switch SW**1***b*, the fourth switch SW**4**, the switch SW**7**, and the switch SW**41** are turned off.

[0408] The first parallel-connection mode (see FIG. **3**) of the power supply system **30** according to the modification illustrated in FIG. **57** includes a first configuration and a second configuration.

[0409] In the first configuration, the switch SW**7**, the second-A switch SW**2***a*, and the switch SW**41** are turned off, and the second-B switch SW**2***b*, the first-A switch SW**1***a*, the first-B switch SW**1***b*, and the fourth switch SW**4** are turned on. This results in, in the first configuration, the first battery **31** being connected between the high-side power supply line H**1** and the high-side ground line L**1** through the first-B switch SW**1***b* and the second battery **32** being connected between the neutral point of the armature windings **11** of the motor **10** and the high-side ground line L**1**.

[0410] In the second configuration, the second-A switch SW**2***a*, the fourth switch SW**4**, and the switch SW**41** are turned off, and the second-B switch SW**2***b*, the first-A switch SW**1***a*, the first-B switch SW**1***b*, and the switch SW**7** are turned on. This results in, in the second configuration, the first battery **31** being connected between the high-side power supply line H**1** and the high-side ground line L**1** through the first-B switch SW**1***b* and the second battery **32** being connected between the high-side power supply line H**1** and the high-side ground line L**1** through the second-B switch SW**2***b*, the bypass path **61**, and the switch SW**7**.

[0411] In the second connection mode (see FIG. **4**) of the power supply system **30** according to the modification illustrated in FIG. **57**, the switch SW**7**, the second-A switch SW**2***a*, the second-B switch SW**2***b*, the fourth switch SW**4**, and the switch SW**41** are turned off, and the first-A switch SW**1***a* and the first-B switch SW**1***b* are turned on.

[0412] In the third connection mode (see FIG. **5**) of the power supply system **30** according to the modification illustrated in FIG. **57**, the switch SW**7**, the second-A switch SW**2***a*, the second-B switch SW**2***b*, the fourth switch SW**4**, the switch SW**41**, the first-A switch SW**1***a*, and the first-B switch SW**1***b* are turned off. The other configuration of the modification of the power supply system **30** illustrated in FIG. **57** is substantially identical to that of the power supply system **30** illustrated in FIG. **1**.

[0413] The control apparatus of each of the embodiments and modifications may be configured to determine that there is an anomaly in power supply from the low-voltage power supply unit **80** to the low-voltage loads **72** in, for example, step S**303** upon detecting at least one of (i) a failure in the low-voltage power supply unit **80**, (ii) a failure in the DC-to-DC converter **70**, (iii) a ground fault of the power supply line L**3** or the low-side power supply line H**2**, and (iv) a failure in one of the batteries **31** to **33** that is supplying power to the DC-to-DC converter **70**.

[0414] The control apparatus of the fourth embodiment may be configured to instruct only the first inverter **420***a* to operate when changing the connection mode of the batteries **31** to **33** from the first connection mode to the second connection mode. This modification prevents a failure in the switches of the second inverter **420***b* when cutting off power supply between the second inverter **420***b* and the second and third batteries **32** and **33** while reducing torque fluctuations due to the power-supply cutoff.

[0415] Each switch SW according to each of the embodiments and modifications is not limited to a single switch, and may be comprised of a series module of plural switches connected in series to each other or a parallel module of plural switches connected in parallel to each other.

[0416] Each of the upper- and lower-arm switches of each of the inverters **20**, **420***a*, and **420***b* is not limited to an IGBT. Specifically, an N-channel MOSFET having an intrinsic diode may be used as each of the upper- and lower-arm switches of each of the inverters **20**, **420***a*, and **420***b*.

[0417] The connection configuration of the armature windings **11** of the motor **10** is not limited to the star configuration. Specifically, delta configuration may be used as the connection configuration of the armature windings **11** of the motor **10**. The motor **10** may be configured as a two-phase motor or a four or more-phase motor, and each inverter may be configured as a two-phase inverter or a four or more-phase inverter.

[0418] The motor **10** is not limited to a permanent magnet synchronous machine that includes permanent magnets as field poles mounted to the rotor thereof. Specifically, the motor **10** may be configured as a wound field synchronous machine that includes field windings as field poles mounted to the rotor thereof. Such a wound field synchronous motor may include both permanent magnets and field windings mounted to the rotor thereof. The motor **10** may not be limited to a synchronous machine, and may be configured as an induction machine.

[0419] In each of the embodiments and modifications, the power storages are not limited to batteries. Specifically, electrical double layer capacitors with, for example, high capacity may be used as the power storages. Additionally, a set of a battery and an electrical double layer capacitor may be used as each power storage.

[0420] In each of the embodiments and modifications, the third battery **33** is more heavily used as compared with the other batteries. For this reason, a battery having more excellent durability, more excellent safety, and high capacity may be used as the third battery **33**.

[0421] Each power supply system disclosed in the embodiments and the modifications is not limited being installed in a vehicle. Specifically, each power supply system according to the present disclosure may be installed in mobile objects, such as aircraft or ships, or stationary objects.

[0422] The control apparatuses and their methods according to the present disclosure may be implemented by a dedicated computer including a memory and a processor programmed to perform one or more functions embodied by one or more computer programs.

[0423] The control apparatuses and their methods according to the present disclosure may also be implemented by a dedicated computer including a processor comprised of one or more dedicated hardware logic circuits.

[0424] The control apparatuses and their methods according to the present disclosure may further be implemented by a processor system comprised of a memory, a processor programmed to perform one or more functions embodied by one or more computer programs, and one or more hardware logic circuits.

[0425] The one or more programs may be stored in a computer-readable non-transitory storage medium as instructions to be carried out by a computer or a processor.

[0426] The following describes features extracted from the above embodiments.

Feature 1

[0427] A power supply system (**30**, **230**, **330**, **430**) according to the feature 1 is connected to both (i) a high-side power supply line (H**1**) connected to a high-voltage load (**71**) and (ii) a low-side power supply line (H**2**) connected to a low-voltage load (**72**).

[0428] The power supply system includes a plurality of power storages (**31**, **32**, **33**), a switch unit (SWs) for connection-mode switching of the power storages, and a switch controller (**100**) configured to control the switch unit to set a connection mode of the power storages to one of (i) a first connection mode in which a part or all of the power storages is connected between the high-side power supply line and a low-side ground line (L**1**), and (ii) a third connection mode in which power supply between the high-side ground line and a low-side ground line (L**2**) is cut off and a part of the power storages is connected between the low-side power supply line and the low-side ground line.

Feature 2

[0429] In the power supply system of the feature 2, which depends from the feature 1, the switch controller is configured to selectably set, as the first switching mode, the connection mode of the power storages to one of (i) a first series-connection mode in which the power storages are connected in series to the high-side power supply line, and (ii) a first parallel-connection mode in which the power storages are connected in parallel to the high-side power supply line.

Feature 3

[0430] In the power supply system of the feature 3, which depends from the feature 1 or 2, the switch controller is configured to control the switch unit to set the connection mode of the power storages to a second connection mode in which at least one power storage of the power storages is connected between the low-side power supply line and the low-side ground line and at least one remaining power storage of the power storages is connected between the high-side power supply line and the high-side ground line, so that the high-side ground line and the low-side ground line are electrically isolated from one another.

Feature 4

[0431] In the power supply system of the feature 4, which depends from the feature 3, the power storages include a first power storage (**31**), a second power storage (**32**) lower in voltage than the first power storage, and a third power storage (**33**) connected in series to the second power storage, each of the first, second, and third power storages having a positive terminal and a negative terminal. The switch unit includes a first-A switch (SW**1***a*) mounted on a first-A electrical path (**1**A) connecting between the positive terminal of the first power storage and the high-side power supply line, and a first-B switch (SW**1***b*) mounted on a first-B electrical path (**1**B) connecting between the negative terminal of the first power storage and the high-side ground line, the second power storage and the third power storage being connected in series to one another to constitute a first series-connection module (**40**) that has a positive terminal and a negative terminal. The switch unit includes a second-A switch (SW**2***a*, SW**5**) configured to switch between electrical connection and electrical cutoff of a second-A electrical path (**2**A), the second-A electrical path (**2**A) connecting between the positive terminal of the first series-connection module and the negative terminal of the first power storage, and a second-B switch (SW**2***b*) mounted on a second-B electrical path (**2**B) connecting between the negative terminal of the first series-connection module and the high-side ground line. The switch unit includes a third-A switch (SW**3***a*) mounted on a third-A electrical path (**3**A) connecting between the positive terminal of the second power storage and the low-side power supply line, and a third-B switch (SW**3***b*) mounted on a third-B electrical path (**3**B) connecting between the negative terminal of the second power storage and the low-side ground line. The switch controller is configured to turn off or maintain in an off state each of the first-B switch, the third-A switch, and the third-B switch and turn on or maintain in an on state each of the first-A switch, the second-A switch, and the second-B switch to set the connection mode of the power storages to the first connection mode, and turn off or maintain in the off state each of the second-A switch and the second-B switch and turn on or maintain in the on state each of the first-A switch, the first-B switch, the third-A switch, and the third-B switch to set the connection mode of the power storages to the second connection mode.

Feature 5

[0432] The power supply system of the feature 5, which depends from the feature 4, is connected to an inverter (**20**) through the high-side power supply line and the high-side ground line, the inverter being connected to a motor (**10**) that includes one or more armature windings (**11**) that have a neutral point. The switch unit includes a fourth switch (SW**4**) mounted on a bypass path (**60**) connecting between the neutral point of the one or more armature windings of the motor and the positive terminal of the first series-connection module. The switch controller is configured to selectably set, as the first switching mode, the connection mode of the power storages to one of (i) a first series-connection mode in which the power storages are connected in series to the high-side power supply line, and (ii) a first parallel-connection mode in which the power storages are connected in parallel to the high-side power supply line. The switch controller is configured to turn off or maintain in the off state each of the first-B switch, the third-A switch, the third-B switch, and the fourth switch and turn on or maintain in the on state each of the first-A switch, the second-A switch, and the second-B switch to set the connection mode of the power storages to the first series-connection mode. The switch controller is configured to turn off or maintain in the off state each of the second-A switch, the third-A switch, and the third-B switch and turn on or maintain in the on state each of the first-A switch, the first-B switch, the second-B switch, and the fourth switch to set the connection mode of the power storages to the first parallel-connection mode.

Feature 6

[0433] In the power supply system of the feature 6, which depends from the feature 4, the switch unit includes a fourth switch (SW**4**) mounted on a bypass path (**160**) connecting between the positive terminal of the first series-connection module and the high-side power supply line. The switch controller is configured to selectably set, as the first switching mode, the connection mode of the power storages to one of (i) a first series-connection mode in which the power storages are connected in series to the high-side power supply line, and (ii) a first parallel-connection mode in which the power storages are connected in parallel to the high-side power supply line. The switch controller is configured to turn off or maintain in the off state each of the first-B switch, the third-A switch, the third-B switch, and the fourth switch and turn on or maintain in the on state each of the first-A switch, the second-A switch, and the second-B switch to set the connection mode of the power storages to the first series-connection mode. The switch controller is configured to turn off or maintain in the off state each of the second-A switch, the third-A switch, and the third-B switch and turn on or maintain in the on state each of the first-A switch, the first-B switch, the second-B switch, and the fourth switch to set the connection mode of the power storages to the first parallel-connection mode.

Feature 7

[0434] In the power supply system of the feature 7, which depends from the feature 3, the power storages include a first power storage (**31**), a second power storage (**32**) lower in voltage than the first power storage, and a third power storage (**33**) connected in series to the second power storage, each of the first, second, and third power storages having a positive terminal and a negative terminal. The switch unit includes (i) a first-A switch (SW**1***a*) mounted on a first-A electrical path (**1**A) connecting between the positive terminal of the first power storage and the high-side power supply line, (ii) a first-B switch (SW**1***b*) mounted on a first-B electrical path (**1**B) connecting between the negative terminal of the first power storage and the high-side ground line, the second power storage and the third power storage being connected in series to one another to constitute a first series-connection module (**40**) that has a positive terminal and a negative terminal, (iii) a second-A switch (SW**2***a*, SW**5**) configured to switch between electrical connection and electrical cutoff of a second-A electrical path (**2**A), the second-A electrical path (**2**A) connecting between the positive terminal of the first series-connection module and the high-side power supply line, (iv) a second-B switch (SW**2***b*) mounted on a second-B electrical path (**2**B) connecting between the negative terminal of the first series-connection module and the positive terminal of the first power storage, (v) a third-A switch (SW**3***a*) mounted on a third-A electrical path (**3**A) connecting between the positive terminal of the second power storage and the low-side power supply line, and (vi) a third-B switch (SW**3***b*) mounted on a third-B electrical path (**3**B) connecting between the negative terminal of the second power storage and the low-side ground line. The switch controller is configured to turn off or maintain in an off state each of the first-A switch, the third-A switch, and the third-B switch and turn on or maintain in an on state each of the first-B switch, the second-A switch, and the second-B switch to set the connection mode of the power storages to the first connection mode. The switch controller is configured to turn off or maintain in the off state each of the second-A switch and the second-B switch and turn on or maintain in the on state each of the first-A switch, the first-B switch, the third-A switch, and the third-B switch to set the connection mode of the power storages to the second connection mode.

Feature 8

[0435] The power supply system of the feature 8, which depends from the feature 7, is connected to an inverter (**20**) through the high-side power supply line and the high-side ground line, the inverter being connected to a motor (**10**) that includes one or more armature windings (**11**) that have a neutral point. The switch unit includes a fourth switch (SW**4**) mounted on a bypass path (**60**) connecting between the neutral point of the one or more armature windings of the motor and the negative terminal of the first series-connection module. The switch controller is configured to selectably set, as the first switching mode, the connection mode of the power storages to one of (i) a first series-connection mode in which the power storages are connected in series to the high-side power supply line, and (ii) a first parallel-connection mode in which the power storages are connected in parallel to the high-side power supply line. The switch controller is configured to turn off or maintain in the off state each of the first-A switch, the third-A switch, the third-B switch, and the fourth switch and turn on or maintain in the on state each of the first-B switch, the second-A switch, and the second-B switch to set the connection mode of the power storages to the first series-connection mode. The switch controller is configured to turn off or maintain in the off state each of the second-B switch, the third-A switch, and the third-B switch and turn on or maintain in the on state each of the first-A switch, the first-B switch, the second-A switch, and the fourth switch to set the connection mode of the power storages to the first parallel-connection mode.

Feature 9

[0436] In the power supply system of the feature 8, which depends from the feature 7, the switch unit includes a fourth switch (SW**4**) mounted on a bypass path (**160**) connecting between the negative terminal of the first series-connection module and the high-side ground line. The switch controller is configured to selectably set, as the first switching mode, the connection mode of the power storages to one of (i) a first series-connection mode in which the power storages are connected in series to the high-side power supply line, and (ii) a first parallel-connection mode in which the power storages are connected in parallel to the high-side power supply line. The switch controller is configured to turn off or maintain in the off state each of the first-A switch, the third-A switch, the third-B switch, and the fourth switch and turn on or maintain in the on state each of the first-B switch, the second-A switch, and the second-B switch to set the connection mode of the power storages to the first series-connection mode. The switch controller is configured to turn off or maintain in the off state each of the second-B switch, the third-A switch, and the third-B switch and turn on or maintain in the on state **20**) each of the first-A switch, the first-B switch, the second-A switch, and the fourth switch to set the connection mode of the power storages to the first parallel-connection mode.

Feature 10

[0437] In the power supply system of the feature 10, which depends from the feature 3, the power storages include a first power storage (**31**), a second power storage (**32**) lower in voltage than the first power storage, and a third power storage (**33**) connected in series to the second power storage, each of the first, second, and third power storages having a positive terminal and a negative terminal. The switch unit includes a first-A switch (SW**1***a*) mounted on a first-A electrical path (**1**A) connecting between the positive terminal of the first power storage and the high-side power supply line, and a first-B switch (SW**1***b*) mounted on a first-B electrical path (**1**B) connecting between the negative terminal of the first power storage and the high-side ground line, the second power storage and the third power storage being connected in series to one another to constitute a first series-connection module (**40**) that has a positive terminal and a negative terminal. The switch unit includes a second-A switch (SW**2***a*, SW**5**) configured to switch between electrical connection and electrical cutoff of a second-A electrical path (**2**A), the second-A electrical path (**2**A) connecting between the positive terminal of the first series-connection module and the high-side power supply line, and a second-B switch (SW**2***b*) mounted on a second-B electrical path (**2**B) connecting between the negative terminal of the first series-connection module and the high-side ground line. The switch unit includes a third-A switch (SW**3***a*) mounted on a third-A electrical path (**3**A) connecting between the positive terminal of the second power storage and the low-side power supply line, and a third-B switch (SW**3***b*) mounted on a third-B electrical path (**3**B) connecting between the negative terminal of the second power storage and the low-side ground line. The switch controller is configured to turn off or maintain in an off state each of the third-A switch and the third-B switch and turn on or maintain in an on state each of the first-A switch, the first-B switch, the second-A switch, and the second-B switch to set the connection mode of the power storages to the first connection mode. The switch controller is configured to turn off or maintain in the off state each of the second-A switch and the second-B switch and turn on or maintain in the on state each of the first-A switch, the first-B switch, the third-A switch, and the third-B switch to set the connection mode of the power storages to the second connection mode.

Feature 11

[0438] In the power supply system of the feature 11, which depends from the feature 3, the high-side power supply line includes a first high-side power supply line (H**401**) and a second high-side power supply line (H**402**). The high-side ground line includes a first high-side ground line (L**401**) and a second low-side ground line (L**402**). The power storages include a first power storage (**31**), a second power storage (**32**) lower in voltage than the first power storage, and a third power storage (**33**) connected in series to the second power storage, each of the first, second, and third power storages having a positive terminal and a negative terminal. The power supply system is connected to a first inverter (**420***a*) through the first high-side power supply line, a motor (**10**) including one or more armature windings (**11**), each of which has a first end and a second end, the first inverter being connected to the first ends of the one or more armature windings of the motor, the power supply system being configured to transmit power between the first inverter and the first power storage. The power supply system is connected to a second inverter (**420***b*) through the second high-side power supply line, the second inverter being connected to the second ends of the one or more armature windings of the motor, the second power storage and the third power storage being connected in series to one another to constitute a first series-connection module (**40**) that has a positive terminal and a negative terminal, the power supply system being configured to transmit power between the second inverter and the first series-connection module. The switch unit includes a first-A switch (SW**1***a*) mounted on a first-A electrical path (**1**A) connecting between the positive terminal of the first power storage and the first high-side power supply line, and a first-B switch (SW**1***b*) mounted on a first-B electrical path (**1**B) connecting between the negative terminal of the first power storage and the first high-side ground line. The switch unit includes a second-A switch (SW**2***a*, SW**5**) configured to switch between electrical connection and electrical cutoff of a second-A electrical path (**2**A), the second-A electrical path (**2**A) connecting between the positive terminal of the first series-connection module and the second high-side power supply line, and a second-B switch (SW**2***b*) mounted on a second-B electrical path (**2**B) connecting between the negative terminal of the first series-connection module and the second high-side ground line. The switch unit includes a third-A switch (SW**3***a*) mounted on a third-A electrical path (**3**A) connecting between the positive terminal of the second power storage and the low-side power supply line, and a third-B switch (SW**3***b*) mounted on a third-B electrical path (**3**B) connecting between the negative terminal of the second power storage and the low-side ground line. The switch controller is configured to turn off or maintain in an off state each of the third-A switch and the third-B switch and turn on or maintain in an on state each of the first-A switch, the first-B switch, the second-A switch, and the second-B switch to set the connection mode of the power storages to the first connection mode. The switch controller is configured to turn off or maintain in the off state each of the second-A switch and the second-B switch and turn on or maintain in the on state each of the first-A switch, the first-B switch, the third-A switch, and the third-B switch to set the connection mode of the power storages to the second connection mode.

Feature 12

[0439] In the power supply system of the feature 12, which depends from the feature 3, the power storages include a first power storage (**31**) and a second power storage (**32**) lower in voltage than the first power storage, each of the first and second power storages having a positive terminal and a negative terminal. The switch unit includes a first-A switch (SW**1***a*) mounted on a first-A electrical path (**1**A) connecting between the positive terminal of the first power storage and the high-side power supply line, and a first-B switch (SW**1***b*) mounted on a first-B electrical path (**1**B) connecting between the negative terminal of the first power storage and the high-side ground line. The switch unit includes a second-A switch (SW**2***a*, SW**5**) configured to switch between electrical connection and electrical cutoff of a second-A electrical path (**2**A), the second-A electrical path (**2**A) connecting between the positive terminal of the second power storage and the negative terminal of the first power storage, and a second-B switch (SW**2***b*) mounted on a second-B electrical path (**2**B) connecting between the negative terminal of the second power storage and the high-side ground line. The switch unit includes a third-A switch (SW**3***a*) mounted on a third-A electrical path (**3**A) connecting between the positive terminal of the second power storage and the low-side power supply line, and a third-B switch (SW**3***b*) mounted on a third-B electrical path (**3**B) connecting between the negative terminal of the second power storage and the low-side ground line. The switch controller is configured to turn off or maintain in an off state each of the first-B switch, the third-A switch, and the third-B switch and turn on or maintain in an on state each of the first-A switch, the second-A switch, and the second-B switch to set the connection mode of the power storages to the first connection mode. The switch controller is configured to turn off or maintain in the off state each of the second-A switch and the second-B switch and turn on or maintain in the on state each of the first-A switch, the first-B switch, the third-A switch, and the third-B switch to set the connection mode of the power storages to the second connection mode.

Feature 13

[0440] The power supply system of the feature 13, which depends from the feature 12, is connected to an inverter (**20**) through the high-side power supply line and the high-side ground line, the inverter being connected to a motor (**10**) that includes one or more armature windings (**11**) that have a neutral point. The switch unit includes a fourth switch (SW**4**) mounted on a bypass path (**60**) connecting between the neutral point of the one or more armature windings of the motor and the positive terminal of the second power storage. The switch controller is configured to selectably set, as the first switching mode, the connection mode of the power storages to one of (i) a first series-connection mode in which the power storages are connected in series to the high-side power supply line, and (ii) a first parallel-connection mode in which the power storages are connected in parallel to the high-side power supply line. The switch controller is configured to turn off or maintain in the off state each of the first-B switch, the third-A switch, the third-B switch, and the fourth switch and turn on or maintain in the on state each of the first-A switch, the second-A switch, and the second-B switch to set the connection mode of the power storages to the first series-connection mode. The switch controller is configured to turn off or maintain in the off state each of the second-A switch, the third-A switch, and the third-B switch and turn on or maintain in the on state each of the first-A switch, the first-B switch, the second-B switch, and the fourth switch to set the connection mode of the power storages to the first parallel-connection mode.

Feature 14

[0441] In the power supply system of the feature 14, which depends from the feature 3, the power storages include a first power storage (**31**) and a second power storage (**32**) lower in voltage than the first power storage, each of the first and second power storages having a positive terminal and a negative terminal. The switch unit includes a first-A switch (SW**1***a*) mounted on a first-A electrical path (**1**A) connecting between the positive terminal of the first power storage and the high-side power supply line, and a first-B switch (SW**1***b*) mounted on a first-B electrical path (**1**B) connecting between the negative terminal of the first power storage and the high-side ground line. The switch unit includes a second-A switch (SW**2***a*) mounted on a second-A electrical path (**2**A) connecting between the positive terminal of the second power storage and the high-side power supply line, and a second-B switch (SW**2***b*) mounted on a second-B electrical path (**2**B) connecting between the negative terminal of the second power storage and the positive terminal of the first power storage. The switch unit includes a third-A switch (SW**3***a*) mounted on a third-A electrical path (**3**A) connecting between the positive terminal of the second power storage and the low-side power supply line, and a third-B switch (SW**3***b*) mounted on a third-B electrical path (**3**B) connecting between the negative terminal of the second power storage and the low-side ground line. The switch controller is configured to turn off or maintain in an off state each of the first-A switch, the third-A switch, and the third-B switch and turn on or maintain in an on state each of the first-B switch, the second-A switch, and the second-B switch to set the connection mode of the power storages to the first connection mode. The switch controller is configured to turn off or maintain in the off state each of the second-A switch and the second-B switch and turn on or maintain in the on state each of the first-A switch, the first-B switch, the third-A switch, and the third-B switch to set the connection mode of the power storages to the second connection mode.

Feature 15

[0442] The power supply system of the feature 15, which depends from the feature 14, is connected to an inverter (**20**) through the high-side power supply line and the high-side ground line, the inverter being connected to a motor (**10**) that includes one or more armature windings (**11**) that have a neutral point. The switch unit includes a fourth switch (SW**4**) mounted on a bypass path (**60**) connecting between the neutral point of the one or more armature windings of the motor and the negative terminal of the second power storage. The switch controller is configured to selectably set, as the first switching mode, the connection mode of the power storages to one of (i) a first series-connection mode in which the power storages are connected in series to the high-side power supply line, and (ii) a first parallel-connection mode in which the power storages are connected in parallel to the high-side power supply line. The switch controller is configured to turn off or maintain in the off state each of the first-A switch, the third-A switch, the third-B switch, and the fourth switch and turn on or maintain in the on state each of the first-B switch, the second-A switch, and the second-B switch to set the connection mode of the power storages to the first series-connection mode. The switch controller is configured to turn off or maintain in the off state each of the second-B switch, the third-A switch, and the third-B switch and turn on or maintain in the on state each of the first-A switch, the first-B switch, the second-A switch, and the fourth switch to set the connection mode of the power storages to the first parallel-connection mode.

Feature 16

[0443] The power supply system of the feature 16, which depends from any one of the feature 3 to the feature 15, further includes a low-voltage power supply unit (**80**) configured to supply power to the low-side power supply line, and an anomaly determiner configured to determine whether there is an anomaly in power supply from the low-voltage power supply unit to the low-side power supply line. The switch controller is configured to set the connection mode of the power storages from the first connection mode to the second connection mode when the anomaly determiner determines that there is an anomaly in the power supply from the low-voltage power supply unit to the low-side power supply line while the connection mode of the power storages is set to the first connection mode.

Feature 17

[0444] The power supply system of the feature 17, which depends from any one of the feature 3 to the feature 16, further includes a load controller configured to limit, during the first connection mode of the power storages, a voltage inputted to the high-voltage load to which power is supplied from the power supply system before the connection mode of the power storages is changed from the first connection mode to the second connection mode, wherein the switch controller is configured to set the connection mode of the power storages from the first connection mode to the second connection mode after the voltage to the high-voltage load is limited by the load controller.

Feature 18

[0445] In the power supply system of the feature 18, which depends from any one of the feature 3 to the feature 17, an inverter and a smoothing capacitor are connected to the high-side power supply line, the power supply system further comprising an inverter controller configured to control the inverter. The switch controller is configured to cut off power supply between the high-side power supply line and the power storages, and thereafter change the connection mode of the power storages from the first connection mode to the second connection mode. The inverter controller is configured to control the inverter during power-supply cutoff between the high-side power supply line and the power storages to discharge the smoothing capacitor, thus adjusting a voltage across the smoothing capacitor.

Feature 19

[0446] The power supply system of the feature 19, which depends from any one of the feature 3 to the feature 18, further includes an estimation unit configured to estimate a power storage state of each of the batteries, and a charge/discharge controller configured to perform one of charging and discharging of the at least one power storage connected to the low-side power supply line to approach the power storage states of the batteries in response to determination that (i) an absolute difference in power storage state between the at least one power storage connected to the low-side power supply line and the at least one remaining power storage is greater than or equal to a predetermined difference threshold during the second connection mode of the power storages or (ii) the power storage state of the least one power storage connected to the low-side power supply line is outside a predetermined range.

Feature 20

[0447] The power supply system of the feature 20, which depends from the feature 19, further includes a voltage converter having a voltage boosting function. The charge/discharge controller is configured to, when performing discharging of the at least one power storage connected to the low-side power supply line to approach the power storage states of the batteries to one another during the second connection mode of the power storages, instruct the voltage converter to boost output power of the at least one power storage connected to the low-side power supply line and supply power boosted by the voltage converter to the high-side power supply line.

Feature 21

[0448] The power supply system of the feature 21, which depends from the feature 19, further includes a voltage converter having a voltage stepdown function. The charge/discharge controller is configured to, when performing discharging of the at least one power storage connected to the low-side power supply line to approach the power storage states of the batteries to one another during the second connection mode of the power storages, instruct the voltage converter to step down power inputted thereto from the at least one remaining power storage connected to the high-side power supply line and charge the at least one power storage connected to the low-side power supply line based on power stepped down by the voltage converter.

Feature 22

[0449] The power supply system of the feature 22, which depends from any one of the features 3 to 19, further includes a voltage converter configured to (i) step down power inputted thereto from the at least one remaining power storage connected to the high-side power supply line during the first connection mode of the power storages to supply stepped-down power to the low-side power supply line, and (ii) stop supply of the stepped-down power to the low-side power supply line after the connection mode of the power storages has been changed from the first connection mode to the second connection mode.

Feature 23

[0450] The power supply system of the feature 23, which depends from any one of the features 3 to 19, further includes a voltage converter configured to (i) step down power inputted thereto from the at least one remaining power storage connected to the high-side power supply line during the first connection mode of the power storages to supply stepped-down power to the low-side power supply line, and (ii) start supply of the stepped-down power to the low-side power supply line after the connection mode of the power storages has been changed from the third connection mode to the second connection mode.

Feature 24

[0451] The power supply system of the feature 24, which depends from any one of the features 3 to 23, further includes a consumed power monitor configured to monitor consumed power of the low-voltage load. The switch controller is configured to set the connection mode of the power storages to the first connection mode or the second connection mode in response to determination that the consumed power monitored by the consumed power monitor has exceeded a predetermined power threshold during the third connection mode of the power storages.

Feature 25

[0452] The power supply system according to any one of the features 3 to 23 further includes a consumed power monitor configured to monitor consumed power of the low-voltage load. The switch controller is configured to set the connection mode of the power storages to the third connection mode in response to determination that the consumed power monitored by the consumed power monitor is lower than or equal to a predetermined power threshold during the first connection mode of the power storages.

Feature 26

[0453] A program product of the feature 26 is applicable to a power supply system connected to both (i) a high-side power supply line (H**1**) connected to a high-voltage load (**71**) and (ii) a low-side power supply line (H**2**) connected to a low-voltage load (**72**). The power supply system includes a control apparatus. The program product includes program instructions that cause the control apparatus to perform a switching routine that controls a switch unit for connection-mode switching of the power storages to accordingly set a connection mode of the power storages to one of (i) a first connection mode in which a part or all of the power storages is connected between the high-side power supply line and a low-side ground line (L**1**), and (ii) a third connection mode in which power supply between the high-side ground line and a low-side ground line (L**2**) is cut off and a part of the power storages is connected between the low-side power supply line and the low-side ground line.

Feature 27

[0454] In the program product of the feature 27, which depends from the feature 26, the switching routine selectably sets, as the first switching mode, the connection mode of the power storages to one of (i) a first series-connection mode in which the power storages are connected in series to the high-side power supply line, and (ii) a first parallel-connection mode in which the power storages are connected in parallel to the high-side power supply line.

Feature 28

[0455] In the program product of the feature 28, which depends from the feature 26 or 27, the power supply system includes a low-voltage power supply unit for supplying power to the low-side power supply line. The program instructions cause the control apparatus to perform an anomaly determination step of determining whether there is an anomaly in power supply from the low-voltage power supply unit to the low-side power supply line. The switching routine sets the connection mode of the power storages to the third connection mode when the anomaly determination step determines that there is an anomaly in the power supply from the low-voltage power supply unit to the low-side power supply line while the connection mode of the power storages is set to the first connection mode.

[0456] While illustrative embodiments of the present disclosure have been described herein, the present disclosure is not limited to the embodiments described herein or disclosed configurations, but includes various modifications and adaptations and/or alternations within the equivalent scope of the descriptions. Additionally, various combinations, embodiments, combinations to which only one element or plural elements have been added, or modified embodiments to which only one element or plural elements have been added are within the category or scope of the present disclosure.

Claims

1. A power supply system connected to both (i) a high-side power supply line connected to a high-voltage load and (ii) a low-side power supply line connected to a low-voltage load, the power supply system comprising: a plurality of power storages; a switch unit for connection-mode switching of the power storages; and a switch controller configured to control the switch unit to set a connection mode of the power storages to one of: a first connection mode in which a part or all of the power storages is connected between the high-side power supply line and a low-side ground line; and a third connection mode in which power supply between the high-side ground line and a low-side ground line is cut off and a part of the power storages is connected between the low-side power supply line and the low-side ground line.

2. The power supply system according to claim 1, wherein: the switch controller is configured to selectably set, as the first switching mode, the connection mode of the power storages to one of: a first series-connection mode in which the power storages are connected in series to the high-side power supply line; and a first parallel-connection mode in which the power storages are connected in parallel to the high-side power supply line.

3. The power supply system according to claim 1, wherein: the switch controller is configured to control the switch unit to set the connection mode of the power storages to a second connection mode in which at least one power storage of the power storages is connected between the low-side power supply line and the low-side ground line and at least one remaining power storage of the power storages is connected between the high-side power supply line and the high-side ground line, so that the high-side ground line and the low-side ground line are electrically isolated from one another.

4. The power supply system according to claim 3, wherein: the power storages include a first power storage, a second power storage lower in voltage than the first power storage, and a third power storage connected in series to the second power storage, each of the first, second, and third power storages having a positive terminal and a negative terminal; the switch unit includes: a first-A switch mounted on a first-A electrical path connecting between the positive terminal of the first power storage and the high-side power supply line; a first-B switch mounted on a first-B electrical path connecting between the negative terminal of the first power storage and the high-side ground line, the second power storage and the third power storage being connected in series to one another to constitute a first series-connection module that has a positive terminal and a negative terminal; a second-A switch configured to switch between electrical connection and electrical cutoff of a second-A electrical path, the second-A electrical path connecting between the positive terminal of the first series-connection module and the negative terminal of the first power storage; a second-B

switch mounted on a second-B electrical path connecting between the negative terminal of the first series-connection module and the high-side ground line; a third-A switch mounted on a third-A electrical path connecting between the positive terminal of the second power storage and the low-side power supply line; and a third-B switch mounted on a third-B electrical path connecting between the negative terminal of the second power storage and the low-side ground line; and the switch controller is configured to: turn off or maintain in an off state each of the first-B switch, the third-A switch, and the third-B switch and turn on or maintain in an on state each of the first-A switch, the second-A switch, and the second-B switch to set the connection mode of the power storages to the first connection mode; and turn off or maintain in the off state each of the second-A switch and the second-B switch and turn on or maintain in the on state each of the first-A switch, the first-B switch, the third-A switch, and the third-B switch to set the connection mode of the power storages to the second connection mode.
5. The power supply system according to claim 4, wherein: the power supply system is connected to an inverter through the high-side power supply line and the high-side ground line, the inverter being connected to a motor that includes one or more armature windings that have a neutral point; the switch unit includes a fourth switch mounted on a bypass path connecting between the neutral point of the one or more armature windings of the motor and the positive terminal of the first series-connection module; the switch controller is configured to selectably set, as the first switching mode, the connection mode of the power storages to one of: a first series-connection mode in which the power storages are connected in series to the high-side power supply line; and a first parallel-connection mode in which the power storages are connected in parallel to the high-side power supply line; and the switch controller is configured to: turn off or maintain in the off state each of the first-B switch, the third-A switch, the third-B switch, and the fourth switch and turn on or maintain in the on state each of the first-A switch, the second-A switch, and the second-B switch to set the connection mode of the power storages to the first series-connection mode; and turn off or maintain in the off state each of the second-A switch, the third-A switch, and the third-B switch and turn on or maintain in the on state each of the first-A switch, the first-B switch, the second-B switch, and the fourth switch to set the connection mode of the power storages to the first parallel-connection mode.
6. The power supply system according to claim 4, wherein: the switch unit includes a fourth switch mounted on a bypass path connecting between the positive terminal of the first series-connection module and the high-side power supply line; the switch controller is configured to selectably set, as the first switching mode, the connection mode of the power storages to one of: a first series-connection mode in which the power storages are connected in series to the high-side power supply line; and a first parallel-connection mode in which the power storages are connected in parallel to the high-side power supply line; and the switch controller is configured to: turn off or maintain in the off state each of the first-B switch, the third-A switch, the third-B switch, and the fourth switch and turn on or maintain in the on state each of the first-A switch, the second-A switch, and the second-B switch to set the connection mode of the power storages to the first series-connection mode; and turn off or maintain in the off state each of the second-A switch, the third-A switch, and the third-B switch and turn on or maintain in the on state each of the first-A switch, the first-B switch, the second-B switch, and the fourth switch to set the connection mode of the power storages to the first parallel-connection mode.
7. The power supply system according to claim 3, wherein: the power storages include a first power storage, a second power storage lower in voltage than the first power storage, and a third power storage connected in series to the second power storage, each of the first, second, and third power storages having a positive terminal and a negative terminal; the switch unit includes: a first-A switch mounted on a first-A electrical path connecting between the positive terminal of the first power storage and the high-side power supply line; a first-B switch mounted on a first-B electrical path connecting between the negative terminal of the first power storage and the high-side ground

line, the second power storage and the third power storage being connected in series to one another to constitute a first series-connection module that has a positive terminal and a negative terminal; a second-A switch configured to switch between electrical connection and electrical cutoff of a second-A electrical path, the second-A electrical path connecting between the positive terminal of the first series-connection module and the high-side power supply line; a second-B switch mounted on a second-B electrical path connecting between the negative terminal of the first series-connection module and the positive terminal of the first power storage; a third-A switch mounted on a third-A electrical path connecting between the positive terminal of the second power storage and the low-side power supply line; and a third-B switch mounted on a third-B electrical path connecting between the negative terminal of the second power storage and the low-side ground line; and the switch controller is configured to: turn off or maintain in an off state each of the first-A switch, the third-A switch, and the third-B switch and turn on or maintain in an on state each of the first-B switch, the second-A switch, and the second-B switch to set the connection mode of the power storages to the first connection mode; and turn off or maintain in the off state each of the second-A switch and the second-B switch and turn on or maintain in the on state each of the first-A switch, the first-B switch, the third-A switch, and the third-B switch to set the connection mode of the power storages to the second connection mode.
8. The power supply system according to claim 7, wherein: the power supply system is connected to an inverter through the high-side power supply line and the high-side ground line, the inverter being connected to a motor that includes one or more armature windings that have a neutral point; the switch unit includes a fourth switch mounted on a bypass path connecting between the neutral point of the one or more armature windings of the motor and the negative terminal of the first series-connection module; the switch controller is configured to selectably set, as the first switching mode, the connection mode of the power storages to one of: a first series-connection mode in which the power storages are connected in series to the high-side power supply line; and a first parallel-connection mode in which the power storages are connected in parallel to the high-side power supply line; and the switch controller is configured to: turn off or maintain in the off state each of the first-A switch, the third-A switch, the third-B switch, and the fourth switch and turn on or maintain in the on state each of the first-B switch, the second-A switch, and the second-B switch to set the connection mode of the power storages to the first series-connection mode; and turn off or maintain in the off state each of the second-B switch, the third-A switch, and the third-B switch and turn on or maintain in the on state each of the first-A switch, the first-B switch, the second-A switch, and the fourth switch to set the connection mode of the power storages to the first parallel-connection mode.
9. The power supply system according to claim 7, wherein: the switch unit includes a fourth switch mounted on a bypass path connecting between the negative terminal of the first series-connection module and the high-side ground line; the switch controller is configured to selectably set, as the first switching mode, the connection mode of the power storages to one of: a first series-connection mode in which the power storages are connected in series to the high-side power supply line; and a first parallel-connection mode in which the power storages are connected in parallel to the high-side power supply line; and the switch controller is configured to: turn off or maintain in the off state each of the first-A switch, the third-A switch, the third-B switch, and the fourth switch and turn on or maintain in the on state each of the first-B switch, the second-A switch, and the second-B switch to set the connection mode of the power storages to the first series-connection mode; and turn off or maintain in the off state each of the second-B switch, the third-A switch, and the third-B switch and turn on or maintain in the on state each of the first-A switch, the first-B switch, the second-A switch, and the fourth switch to set the connection mode of the power storages to the first parallel-connection mode.
10. The power supply system according to claim 3, wherein: the power storages include a first power storage, a second power storage lower in voltage than the first power storage, and a third

power storage connected in series to the second power storage, each of the first, second, and third power storages having a positive terminal and a negative terminal; the switch unit includes: a first-A switch mounted on a first-A electrical path connecting between the positive terminal of the first power storage and the high-side power supply line; a first-B switch mounted on a first-B electrical path connecting between the negative terminal of the first power storage and the high-side ground line, the second power storage and the third power storage being connected in series to one another to constitute a first series-connection module that has a positive terminal and a negative terminal; a second-A switch configured to switch between electrical connection and electrical cutoff of a second-A electrical path, the second-A electrical path connecting between the positive terminal of the first series-connection module and the high-side power supply line; a second-B switch mounted on a second-B electrical path connecting between the negative terminal of the first series-connection module and the high-side ground line; a third-A switch mounted on a third-A electrical path connecting between the positive terminal of the second power storage and the low-side power supply line; and a third-B switch mounted on a third-B electrical path connecting between the negative terminal of the second power storage and the low-side ground line; and the switch controller is configured to: turn off or maintain in an off state each of the third-A switch and the third-B switch and turn on or maintain in an on state each of the first-A switch, the first-B switch, the second-A switch, and the second-B switch to set the connection mode of the power storages to the first connection mode; and turn off or maintain in the off state each of the second-A switch and the second-B switch and turn on or maintain in the on state each of the first-A switch, the first-B switch, the third-A switch, and the third-B switch to set the connection mode of the power storages to the second connection mode.

11. The power supply system according to claim 3, wherein: the high-side power supply line includes a first high-side power supply line and a second high-side power supply line; the high-side ground line includes a first high-side ground line and a second low-side ground line; the power storages include a first power storage, a second power storage lower in voltage than the first power storage, and a third power storage connected in series to the second power storage, each of the first, second, and third power storages having a positive terminal and a negative terminal; the power supply system is connected to a first inverter through the first high-side power supply line, a motor including one or more armature windings, each of which has a first end and a second end, the first inverter being connected to the first ends of the one or more armature windings of the motor, the power supply system being configured to transmit power between the first inverter and the first power storage; the power supply system is connected to a second inverter through the second high-side power supply line, the second inverter being connected to the second ends of the one or more armature windings of the motor, the second power storage and the third power storage being connected in series to one another to constitute a first series-connection module that has a positive terminal and a negative terminal, the power supply system being configured to transmit power between the second inverter and the first series-connection module; the switch unit includes: a first-A switch mounted on a first-A electrical path connecting between the positive terminal of the first power storage and the first high-side power supply line; a first-B switch mounted on a first-B electrical path connecting between the negative terminal of the first power storage and the first high-side ground line; a second-A switch configured to switch between electrical connection and electrical cutoff of a second-A electrical path, the second-A electrical path connecting between the positive terminal of the first series-connection module and the second high-side power supply line; a second-B switch mounted on a second-B electrical path connecting between the negative terminal of the first series-connection module and the second high-side ground line; a third-A switch mounted on a third-A electrical path connecting between the positive terminal of the second power storage and the low-side power supply line; and a third-B switch mounted on a third-B electrical path connecting between the negative terminal of the second power storage and the low-side ground line; and the switch controller is configured to: turn off or maintain in an off state each of the third-A switch and the third-B switch and turn on or maintain in an on state each of the first-A switch, the first-B switch, the second-A switch, and the second-B switch to set the connection mode of the power storages to the first connection mode; and turn off or maintain in the off state each of the second-A switch and the second-B switch and turn on or maintain in the on state each of the first-A switch, the first-B switch, the third-A switch, and the third-B switch to set the connection mode of the power storages to the second connection mode.

12. The power supply system according to claim 3, wherein: the power storages include a first power storage and a second power storage lower in voltage than the first power storage, each of the first and second power storages having a positive terminal and a negative terminal; the switch unit includes: a first-A switch mounted on a first-A electrical path connecting between the positive terminal of the first power storage and the high-side power supply line; a first-B switch mounted on a first-B electrical path connecting between the negative terminal of the first power storage and the high-side ground line; a second-A switch configured to switch between electrical connection and electrical cutoff of a second-A electrical path, the second-A electrical path connecting between the positive terminal of the second power storage and the negative terminal of the first power storage; a second-B switch mounted on a second-B electrical path connecting between the negative terminal of the second power storage and the high-side ground line; a third-A switch mounted on a third-A electrical path connecting between the positive terminal of the second power storage and the low-side power supply line; and a third-B switch mounted on a third-B electrical path connecting between the negative terminal of the second power storage and the low-side ground line; and the switch controller is configured to: turn off or maintain in an off state each of the first-B switch, the third-A switch, and the third-B switch and turn on or maintain in an on state each of the first-A switch, the second-A switch, and the second-B switch to set the connection mode of the power storages to the first connection mode; and turn off or maintain in the off state each of the second-A switch and the second-B switch and turn on or maintain in the on state each of the first-A switch, the first-B switch, the third-A switch, and the third-B switch to set the connection mode of the power storages to the second connection mode.

13. The power supply system according to claim 12, wherein: the power supply system is connected to an inverter through the high-side power supply line and the high-side ground line, the inverter being connected to a motor that includes one or more armature windings that have a neutral point; the switch unit includes a fourth switch mounted on a bypass path connecting between the neutral point of the one or more armature windings of the motor and the positive terminal of the second power storage; the switch controller is configured to selectably set, as the first switching mode, the connection mode of the power storages to one of: a first series-connection mode in which the power storages are connected in series to the high-side power supply line; and a first parallel-connection mode in which the power storages are connected in parallel to the high-side power supply line; and the switch controller is configured to: turn off or maintain in the off state each of the first-B switch, the third-A switch, the third-B switch, and the fourth switch and turn on or maintain in the on state each of the first-A switch, the second-A switch, and the second-B switch to set the connection mode of the power storages to the first series-connection mode; and turn off or maintain in the off state each of the second-A switch, the third-A switch, and the third-B switch and turn on or maintain in the on state each of the first-A switch, the first-B switch, the second-B switch, and the fourth switch to set the connection mode of the power storages to the first parallel-connection mode.

14. The power supply system according to claim 3, wherein: the power storages include a first power storage and a second power storage lower in voltage than the first power storage, each of the first and second power storages having a positive terminal and a negative terminal; the switch unit includes: a first-A switch mounted on a first-A electrical path connecting between the positive terminal of the first power storage and the high-side power supply line; a first-B switch mounted on a first-B electrical path connecting between the negative terminal of the first power storage and the high-side ground line; a second-A switch mounted on a second-A electrical path connecting between the positive terminal of the second power storage and the high-side power supply line; a second-B switch mounted on a second-B electrical path connecting between the negative terminal of the second power storage and the positive terminal of the first power storage; a third-A switch mounted on a third-A electrical path connecting between the positive terminal of the second power storage and the low-side power supply line; and a third-B switch mounted on a third-B electrical path connecting between the negative terminal of the second power storage and the low-side ground line; and the switch controller is configured to: turn off or maintain in an off state each of the first-A switch, the third-A switch, and the third-B switch and turn on or maintain in an on state each of the first-B switch, the second-A switch, and the second-B switch to set the connection mode of the power storages to the first connection mode; and turn off or maintain in the off state each of the second-A switch and the second-B switch and turn on or maintain in the on state each of the first-A switch, the first-B switch, the third-A switch, and the third-B switch to set the connection mode of the power storages to the second connection mode.

15. The power supply system according to claim 14, wherein: the power supply system is connected to an inverter through the high-side power supply line and the high-side ground line, the inverter being connected to a motor that includes one or more armature windings that have a neutral point; the switch unit includes a fourth switch mounted on a bypass path connecting between the neutral point of the one or more armature windings of the motor and the negative terminal of the second power storage; the switch controller is configured to selectably set, as the first switching mode, the connection mode of the power storages to one of: a first series-connection mode in which the power storages are connected in series to the high-side power supply line; and a first parallel-connection mode in which the power storages are connected in parallel to the high-side power supply line; and the switch controller is configured to: turn off or maintain in the off state each of the first-A switch, the third-A switch, the third-B switch, and the fourth switch and turn on or maintain in the on state each of the first-B switch, the second-A switch, and the second-B switch to set the connection mode of the power storages to the first series-connection mode; and turn off or maintain in the off state each of the second-B switch, the third-A switch, and the third-B switch and turn on or maintain in the on state each of the first-A switch, the first-B switch, the second-A switch, and the fourth switch to set the connection mode of the power storages to the first parallel-connection mode.

16. The power supply system according to claim 3, further comprising: a low-voltage power supply unit configured to supply power to the low-side power supply line; and an anomaly determiner configured to determine whether there is an anomaly in power supply from the low-voltage power supply unit to the low-side power supply line, wherein: the switch controller is configured to set the connection mode of the power storages from the first connection mode to the second connection mode when the anomaly determiner determines that there is an anomaly in the power supply from the low-voltage power supply unit to the low-side power supply line while the connection mode of the power storages is set to the first connection mode.

17. The power supply system according to claim 3, further comprising: a load controller configured to limit, during the first connection mode of the power storages, a voltage inputted to the high-voltage load to which power is supplied from the power supply system before the connection mode of the power storages is changed from the first connection mode to the second connection mode, wherein: the switch controller is configured to set the connection mode of the power storages from the first connection mode to the second connection mode after the voltage to the high-voltage load is limited by the load controller.

18. The power supply system according to claim 3, wherein an inverter and a smoothing capacitor are connected to the high-side power supply line, the power supply system further comprising an inverter controller configured to control the inverter, the switch controller being configured to cut off power supply between the high-side power supply line and the power storages, and thereafter change the connection mode of the power storages from the first connection mode to the second connection mode, the inverter controller being configured to control the inverter during power-supply cutoff between the high-side power supply line and the power storages to discharge the smoothing capacitor, thus adjusting a voltage across the smoothing capacitor.

19. The power supply system according to claim 3, further comprising: an estimation unit configured to estimate a power storage state of each of the batteries; and a charge/discharge controller configured to perform one of charging and discharging of the at least one power storage connected to the low-side power supply line to approach the power storage states of the batteries in response to determination that: (i) an absolute difference in power storage state between the at least one power storage connected to the low-side power supply line and the at least one remaining power storage is greater than or equal to a predetermined difference threshold during the second connection mode of the power storages or (ii) the power storage state of the least one power storage connected to the low-side power supply line is outside a predetermined range.

20. The power supply system according to claim 19, further comprising: a voltage converter having a voltage boosting function, wherein: the charge/discharge controller is configured to, when performing discharging of the at least one power storage connected to the low-side power supply line to approach the power storage states of the batteries to one another during the second connection mode of the power storages, instruct the voltage converter to boost output power of the at least one power storage connected to the low-side power supply line and supply power boosted by the voltage converter to the high-side power supply line.

21. The power supply system according to claim 19, further comprising: a voltage converter having a voltage stepdown function, wherein: the charge/discharge controller is configured to, when performing discharging of the at least one power storage connected to the low-side power supply line to approach the power storage states of the batteries to one another during the second connection mode of the power storages, instruct the voltage converter to step down power inputted thereto from the at least one remaining power storage connected to the high-side power supply line and charge the at least one power storage connected to the low-side power supply line based on power stepped down by the voltage converter.

22. The power supply system according to claim 3, further comprising: a voltage converter configured to: step down power inputted thereto from the at least one remaining power storage connected to the high-side power supply line **25** during the first connection mode of the power storages to supply stepped-down power to the low-side power supply line; and stop supply of the stepped-down power to the low-side power supply line after the connection mode of the power storages has been changed from the first connection mode to the second connection mode.

23. The power supply system according to claim 3, further comprising: a voltage converter configured to: step down power inputted thereto from the at least one remaining power storage connected to the high-side power supply line during the first connection mode of the power storages to supply stepped-down power to the low-side power supply line; and start supply of the stepped-down power to the low-side power supply line after the connection mode of the power storages has been changed from the third connection mode to the second connection mode.

24. The power supply system according to claim 3, further comprising: a consumed power monitor configured to monitor consumed power of the low-voltage load, wherein: the switch controller is configured to set the connection mode of the power storages to the first connection mode or the second connection mode in response to determination that the consumed power monitored by the consumed power monitor has exceeded a predetermined power threshold during the third connection mode of the power storages.

25. The power supply system according to claim 3, further comprising: a consumed power monitor configured to monitor consumed power of the low-voltage load, wherein: the switch controller is configured to set the connection mode of the power storages to the third connection mode in response to determination that the consumed power monitored by the consumed power monitor is lower than or equal to a predetermined power threshold during the first connection mode of the power storages.

26. A program product applicable to a power supply system connected to both (i) a high-side power supply line (H**1**) connected to a high-voltage load (**71**) and (ii) a low-side power supply line (H**2**) connected to a low-voltage load (**72**), the power supply system comprising a control apparatus, the program product comprising: a non-transitory storage medium; and program instructions stored in the non-transitory storage medium, the program instructions causing the control apparatus to perform a switching routine that controls a switch unit for connection-mode switching of the power storages to accordingly set a connection mode of the power storages to one of: a first connection mode in which a part or all of the power storages is connected between the high-side power supply line and a low-side ground line; and a third connection mode in which power supply between the high-side ground line and a low-side ground line is cut off and a part of the power storages is connected between the low-side power supply line and the low-side ground line.

27. The program product according to claim 26, wherein: the switching routine selectably sets, as the first switching mode, the connection mode of the power storages to one of: a first series-connection mode in which the power storages are connected in series to the high-side power supply line; and a first parallel-connection mode in which the power storages are connected in parallel to the high-side power supply line.

28. The program product according to claim 26, wherein: the power supply system includes a low-voltage power supply unit for supplying power to the low-side power supply line; the program instructions cause the control apparatus to perform an anomaly determination step of determining whether there is an anomaly in power supply from the low-voltage power supply unit to the low-side power supply line; and the switching routine sets the connection mode of the power storages to the third connection mode when the anomaly determination step determines that there is an anomaly in the power supply from the low-voltage power supply unit to the low-side power supply line while the connection mode of the power storages is set to the first connection mode.