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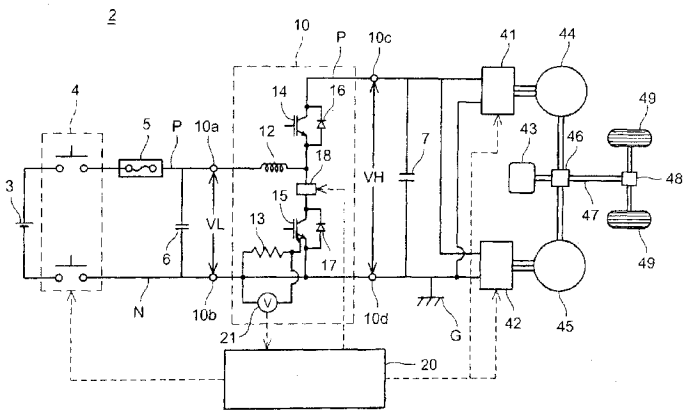
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(54) **Title**: ELECTRIC VEHICLE

FIG. 1



(57) **Abstract**: A step-up voltage converter of an electric vehicle includes a reactor having one end connected to a low voltage-side positive electrode terminal of the voltage converter and the other end connected to a high voltage-side positive electrode terminal, and a step-up switching element connected between a high voltage side of the reactor and a common negative electrode line connecting low-voltage side and high voltage-side negative electrode terminals of the voltage converter. The electric vehicle includes an interrupter isolating the step-up switching element from a circuit of the voltage converter when the step-up switching element has a short-circuit fault. Once the interrupter is activated, a short circuit between the positive and negative electrode terminals of the voltage converter is cancelled, and the voltage converter serves as a mere conducting path that directly couples the low voltage-side terminals to the high voltage-side terminals, so the vehicle is able to continue travelling.

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ELECTRIC VEHICLE

BACKGROUND OF THE INVENTION

1. Field of the Invention

[0001] The invention relates to an electric vehicle. The "electric vehicle" in the specification includes a hybrid vehicle, which includes both a motor and an engine, and a fuel cell vehicle.

2. Description of Related Art

[0002] An electric vehicle includes a high capacity and high power battery for driving a drive motor. Various techniques for protecting the battery when there occurs inconvenience in an electrical system have been suggested. In the following description, the battery that stores electric power to be supplied to the drive motor is referred to as "battery".

[0003] An electric vehicle described in Japanese Patent Application Publication No. 2007-068336 (JP 2007-068336 A) includes a fuse for interrupting a battery. The fuse can be welded at the time when the fuse should be disconnected. With a technique described in Japanese Patent Application Publication No. 2007-068336 (JP 2007-068336 A), in such a case, one of switching elements of a voltage converter connected to the battery is short-circuited to place the battery in a short-circuit state, and the fuse is forcibly interrupted by intentionally supplying excessive current to the fuse.

[0004] Japanese Patent Application Publication No. 2010-226869 (JP 2010-226869 A) describes a technique relating to an electric vehicle that includes two sets of battery, voltage converter, inverter and motor. The voltage converters are provided in order to step up the output voltage of the battery to a motor driving voltage. The two voltage converters are connected in parallel with each other at a high voltage side. Therefore, if one of switching elements of one of the voltage converters has a short-circuit

fault, short-circuit current may flow from one of the batteries to the other one of the batteries. With the technique described in JP 2010-226869, in preparation for such a case, if a short-circuit fault of one of the voltage converters has been detected, the batteries are isolated from the faulty voltage converter.

[0005] Japanese Patent Application Publication No. 07-59202 (JP 07-59202 A) describes an electric vehicle that includes an interrupter that interrupts a battery from an electrical circuit in the event of a collision. An interrupter described in JP 07-59202 A physically breaks an electrically conducting path with the use of an explosive.

[0006] In the case of an electric vehicle, if a battery is isolated from an electrical circuit, the electric vehicle is not able to travel. Therefore, even when there occurs some inconvenience in an electrical system, but when it is allowed not to isolate the battery, it is desirable to cope with the inconvenience without isolating the battery. The electric vehicle described in JP 2010-226869 A includes the two sets of battery, voltage converter, inverter and motor, so, even when one of the sets malfunctions and becomes unusable, the electric vehicle is able to continue travelling using the other one of the sets.

[0007] In addition, Japanese Patent Application Publication No. 2009-100507 (JP 2009-100507 A) describes an electric vehicle that, when an abnormality of a voltage converter that steps up the output voltage of a battery has been detected, stops the voltage converter, and that continues travelling by driving a motor using a non-stepped-up battery output. However, when a regenerative current that exceeds an allowable value flows to the battery, the battery is isolated from a circuit.

[0008] As described in JP 2010-226869 A and JP 2009-100507 A, there is an electric vehicle on which a voltage converter that steps up the output voltage of a battery is mounted and that drives a motor at a voltage higher than the battery output voltage. Most of step-up voltage converters include a switching element between a positive electrode line and a negative electrode line that are respectively connected to low voltage-side (battery-side) positive electrode terminal and negative electrode terminal. If the switching element has a short-circuit fault, the battery enters a short-circuit state and overcurrent may flow through the battery. The short-circuit state is not cancelled only by

stopping the voltage converter, so the technique described in JP 2009-100507 A cannot be used. In addition, in an electric vehicle that includes only one set of battery and voltage converter, the technique described in JP 2010-226869 A also cannot be used.

SUMMARY OF THE INVENTION

[0009] The invention provides an electric vehicle that is able to protect a battery and continue travelling when a switching element of a step-up converter has a short-circuit fault.

[0010] An electric vehicle that drives a motor at a voltage higher than an output voltage of a battery includes a voltage converter configured to step up the voltage of the battery and supply the stepped-up voltage to an inverter. A general step-up voltage converter includes, as main components, a reactor of which one end is connected to a low voltage-side positive electrode terminal of the voltage converter and the other end is connected to a high voltage-side positive electrode terminal of the voltage converter, and a step-up switching element connected between a high voltage side of the reactor and a common negative electrode line that connects a low voltage-side negative electrode terminal of the voltage converter to a high voltage-side negative electrode terminal of the voltage converter. Thus, if the step-up switching element has a short-circuit fault, the positive electrode terminal and negative electrode terminal of the voltage converter are short-circuited, and, as a result, the battery is short-circuited. An electric vehicle according to a first aspect of the invention includes an interrupter configured to isolate the step-up switching element from a circuit of the voltage converter when the step-up switching element has a short-circuit fault. A controller detects a short-circuit fault, and the controller activates the interrupter. Once the interrupter is activated, a short circuit between the positive electrode terminal and negative electrode terminal of the voltage converter is cancelled, and the voltage converter serves as a mere conducting path that directly couples the low voltage-side terminals to the high voltage-side terminals. Therefore, it is possible to supply electric power to the inverter without causing short-circuit current to flow through the battery.

[0011] A voltage stepped up from the output voltage of the battery is normally supplied to the inverter, and the vehicle is able to travel if the output of the motor is limited even at a non-stepped-up voltage. Therefore, the controller of the electric vehicle is configured to, when the controller drives the motor in a state where the step-up switching element is isolated by the interrupter, limit an output upper limit of the motor to a value smaller than that before the step-up switching element is isolated. Here, the output upper limit before the step-up switching element is isolated means an output upper limit at the time when there is no inconvenience.

[0012] Incidentally, as described above, most of electric vehicles include a fuse for isolating the battery from the circuit (that is, the voltage converter). In such a case, it is better for the interrupter to isolate the step-up switching element prior to a break of the fuse. For this purpose, a high-response interrupter is desirable. The high-response interrupter that is able to reliably isolate the step-up switching element is desirably of a type that isolates the step-up switching element with the use of an explosive.

[0013] The voltage converter of the above-described electric vehicle is a device that steps up the voltage of the battery and then supplies the stepped-up voltage to the inverter. In most of electric vehicles, the motor is rotated by deceleration energy of the vehicle, and the battery is charged with electric power generated by the motor. In such case, direct-current power that is output from the inverter needs to be stepped down to a voltage suitable for charging the battery. Thus, the above-described voltage converter may have the function of stepping up direct-current power of the battery and then supplying the stepped-up direct-current power to the inverter and the function of stepping down direct-current power, converted by the inverter from alternating-current power, and then supplying the direct-current power to the battery.

[0014] The details of the technique described in the specification and further improvements will be described in the following "DETAILED DESCRIPTION OF EMBODIMENTS".

BRIEF DESCRIPTION OF THE DRAWINGS

[0015] Features, advantages, and technical and industrial significance of exemplary embodiments of the invention will be described below with reference to the accompanying drawings, in which like numerals denote like elements, and wherein:

FIG. 1 is a block diagram of an electrical system and drive system of an electric vehicle according to an embodiment.

DETAILED DESCRIPTION OF EMBODIMENTS

[0016] An electric vehicle according to an embodiment will be described with reference to the accompanying drawing. The electric vehicle according to the embodiment is a hybrid vehicle that includes a single engine and two motors for travelling. FIG. 1 shows a block diagram of an electrical system and drive system of the hybrid vehicle 2.

[0017] First, the drive system will be described. The output shafts of the two motors 44, 45 and the output shaft of the engine 43 are coupled to a power distribution mechanism 46. The power distribution mechanism 46 is a planetary gear unit in which the output shaft of the first motor 44 is coupled to a sun gear, the output shaft of the engine 43 is coupled to a planetary carrier and the second motor 45 is coupled to a ring gear. In addition, the ring gear is also coupled to an axle 47. The axle 47 operates in synchronization with wheels 49 via a differential gear 48. By appropriately adjusting the output of the engine 43 and the outputs of the two motors 44, 45, the power distribution mechanism 46 combines the outputs of the engine 43 and two motors 44, 45 and then outputs the resultant output to the axle 47 or distributes the output of the engine 43 to the first motor 44 and the axle 47. In the latter case, the first motor 44 generates electric power using the driving force of the engine 43. In addition, the hybrid vehicle 2 generates electric power by rotating the two motors 44, 45 using deceleration energy of the vehicle. Generation of electric power using deceleration energy of the vehicle is generally called "regeneration". The hybrid vehicle 2 charges a battery 3 with electric power obtained through regeneration.

[0018] Next, the electrical system will be described. The battery 3 is connected

to a voltage converter 10 via a system main relay 4 and a fuse 5. The voltage converter 10 has a step-up function of stepping up a voltage VL of the battery 3 and then supplying the stepped-up voltage to two inverters 41, 42 and a step-down function of stepping down the voltage of direct-current power, converted by the inverter 41 (42) from alternating-current power obtained through regeneration, to a voltage suitable for charging the battery 3. Battery-side terminals 10a, 10b of the voltage converter 10 function as low voltage-side terminals, and terminals 10c, 10d connected to the inverters 41, 42 function as high voltage-side terminals. The terminals 10a, 10c are positive electrodes, and the terminals 10b, 10d are negative electrodes. A conducting path at the side of the positive electrode terminals 10a, 10c is referred to as positive electrode line P, and a conducting path at the side of the negative electrode terminals 10b, 10d is referred to as common negative electrode line N. The common negative electrode line N is connected to a ground G of the system.

[0019] The two inverters 41, 42 are connected in parallel with the high voltage-side terminals 10c, 10d. The two inverters 41, 42 each convert stepped-up direct-current power to alternating-current power having a frequency suitable for motor drive and then supply the alternating-current power to a corresponding one of the motors 44, 45. The amplitude and frequency of the alternating-current power depend on the rotation speed of the corresponding motor and the operation amount of an accelerator pedal (not shown). The accelerator operation amount corresponds to the magnitude of output that is required for the motor (that is, the amplitude of alternating-current power that should be output from the inverter), and the rotation speed of the motor corresponds to the frequency of alternating-current power that should be output from the inverter.

[0020] A capacitor 6 and a capacitor 7 are respectively connected to the low voltage side and high voltage side of the voltage converter 10. The capacitors 6, 7 are provided for the purpose of smoothing flowing current.

[0021] The system main relay 4 and the fuse 5 are inserted between the battery 3 and the voltage converter 10. The system main relay 4 turns on or off in synchronization with a main switch (so-called ignition switch) of the hybrid vehicle 2. The fuse 5 is

inserted in order to protect the battery 3 from overcurrent. The fuse 5 breaks (melts) if a predetermined overcurrent flows through the positive electrode line P.

[0022] The circuit configuration of the voltage converter 10 will be described. The voltage converter 10 is formed of two switching elements 14, 15, diodes 16, 17 and a reactor 12. The switching elements 14, 15 are connected in series with each other. The diodes 16, 17 are respectively connected in antiparallel with the switching elements. The switching elements 14, 15 are transistors, and typically IGBTs. The above-described components implement the step-up function and the step-down function. The voltage converter 10 further includes an interrupter 18, a resistor 13 (shunt resistor) and a voltage sensor 21.

[0023] Among the components of the voltage converter 10, the reactor 12, the step-up switching element (step-up switching element 15) and the diode 16 implement the step-up function. One end of the reactor 12 is connected to the low voltage-side positive electrode terminal 10a of the voltage converter 10, and the other end of the reactor 12 is connected to the high voltage-side positive electrode terminal 10c (via the diode 16 (described later)). In the case of step-up operation, current flows from the low voltage side to the high voltage side. Therefore, during step-up operation, the high voltage side of the reactor 12 and the positive electrode terminal 10c are substantially directly coupled to each other.

[0024] The step-up switching element 15 is connected between the high voltage side of the reactor 12 and the common negative electrode line N that connects the low voltage-side negative electrode terminal 10b and high voltage-side negative electrode terminal 10d of the voltage converter 10. The diode 16 is connected between the high voltage side of the reactor 12 and the high voltage-side positive electrode terminal 10c of the voltage converter 10, and prevents backflow of current. During step-up operation, the step-down switching element 14 is constantly in an off state.

[0025] Among the components of the voltage converter 10, the reactor 12, the step-down switching element (step-down switching element 14) and the diode 17 implement the step-down function. One end of the reactor 12 is connected to the low

voltage-side positive electrode terminal 10a of the voltage converter 10, and the other end of the reactor 12 is connected to the high voltage-side positive electrode terminal 10c via the step-down switching element 14. The diode 17 is connected between the high voltage side of the reactor 12 and the common negative electrode line N that connects the low voltage-side negative electrode terminal 10b and high voltage-side negative electrode terminal 10d of the voltage converter 10. The diode 17 is provided in order to prevent backflow of current. During step-down operation, the step-up switching element 15 is constantly in an off state. The step-up operation and step-down operation of the circuit shown in FIG. 1 are well known, so the description thereof is omitted.

[0026] The step-up switching element 15 includes a sensing emitter. The sensing emitter is connected to the common negative electrode line (that is, ground G) via the shunt resistor 13. The voltage sensor 21 is connected to both sides of the shunt resistor 13. The voltage sensor 21, the shunt resistor 13 and the sensing emitter constitute a current sensor, and measures a current flowing between the collector and emitter of the step-up switching element 15. A measured value of the voltage sensor 21 is transmitted to a controller 20.

[0027] The interrupter 18 is a device that physically breaks the high voltage-side conducting path of the step-up switching element 15 with the use of an explosive. The interrupter 18 is controlled by a signal from the controller 20. In the block diagram of FIG. 1, the controller 20 controls the inverters 41, 42, the switching elements of the voltage converter 10 and the system main relay 4. The hybrid vehicle 2 normally implements various processes by cooperation of a large number of controllers; however, in the present embodiment, for the sake of convenience, it is assumed that the single controller 20 implements all the processes.

[0028] The operation of the electrical system will be described. During normal travelling, the voltage converter 10 steps up the output voltage of the battery 3, and then supplies the stepped-up voltage to the inverters 41, 42. The inverters 41, 42 each generate alternating-current power based on a vehicle speed and an accelerator operation amount and supply the alternating-current power to a corresponding one of the motors 44, 45. In

the voltage converter 10, during step-up operation, the step-up switching element 15 repeatedly turns on and off in response to an appropriate PWM signal. If the step-up switching element 15 has a short-circuit fault from any cause, the positive electrode and negative electrode of the battery 3 are short-circuited as is apparent from FIG. 1.

[0029] The controller 20 constantly monitors the current sensor (which is formed of the sensing emitter, the shunt resistor 13 and the voltage sensor 21), and determines that the step-up switching element 15 has a short-circuit fault when a current larger than or equal to a predetermined value is flowing through the sensing emitter even at the timing when the step-up switching element 15 turns off. When the controller 20 determines that the step-up switching element 15 has a short-circuit fault, the controller 20 activates the interrupter 18. That is, the step-up switching element 15 is isolated from the circuit of the voltage converter 10. As a result, the voltage converter 10 serves as a conducting path that merely connects the battery 3 to the inverters 41, 42. The inverters 41, 42 are normally driven on electric power of a stepped-up voltage VH. However, after the step-up switching element 15 has been isolated, only electric power of the battery voltage VL is supplied to the inverters 41, 42. For example, the battery voltage VL is 300 volts, and the stepped-up voltage VH is 600 volts.

[0030] The controller 20 normally determines target outputs of the motors 44, 45 (and engine 43) on the basis of a vehicle speed and an accelerator operation amount, and generates PWM signals such that the target outputs are obtained. The PWM signals are command values to the voltage converter 10 and the inverters 41, 42. After the interrupter 18 has been activated and the step-up switching element 15 has been isolated, the controller 20 limits the maximum target outputs of the motors 44, 45. In other words, after the step-up switching element 15 has been isolated, the controller 20 limits the upper limit values of the outputs of the motors 44, 45 to values lower than those before the switching element is isolated. Specifically, the speed or acceleration of the vehicle is limited. By limiting the upper limit values of the target outputs of the motors 44, 45, the vehicle is able to continue travelling without stepping up the battery voltage VL.

[0031] The hybrid vehicle 2 includes the fuse 5 that protects the battery 3 from

overcurrent. Therefore, if the step-up switching element 15 has a short-circuit fault and the battery 3 enters a short-circuit state, overcurrent flows, and the fuse 5 eventually melts. However, if a short circuit of the step-up switching element 15 has been detected, the controller 20 immediately activates the interrupter 18. Therefore, it is possible to isolate the step-up switching element 15 having a short-circuit fault before the fuse 5 melts, so it is possible to cancel the short-circuit state of the battery 3.

[0032] The advantages of the hybrid vehicle 2 described in the embodiment will be described again. The hybrid vehicle 2 according to the embodiment includes the voltage converter 10 that steps up the voltage of the battery 3 and then supplies the stepped-up voltage to the inverters 41, 42. If a short-circuit fault of the step-up switching element 15 arranged between the positive electrode line P and the negative electrode line N has been detected in the voltage converter 10, the step-up switching element 15 is immediately isolated from the circuit of the voltage converter 10. With such configurations and processes, it is possible to cancel the short-circuit state of the battery 3 and to continue travelling. After the step-up switching element 15 has been isolated from the circuit, the hybrid vehicle 2 limits the upper limit values of the target outputs of the motors 44, 45. Thus, the vehicle is able to continue travelling on the non-stepped-up output voltage of the battery.

[0033] The hybrid vehicle 2 includes the fuse 5 that protects the battery 3 from a short circuit. If the short-circuit fault of the step-up switching element 15 continues for a while, the fuse 5 melts. However, the hybrid vehicle 2 includes the high-response explosive interrupter 18 in order to isolate the step-up switching element 15. The controller 20 constantly monitors the step-up switching element 15, and immediately activates the interrupter 18 if a short-circuit fault has been detected. Therefore, it is possible to isolate the step-up switching element 15 before the fuse 5 melts.

[0034] Points to be noted regarding the technique described in the embodiment will be described. The interrupter 18 is desirably a device that physically breaks the conducting path; however, the interrupter 18 is not limited to a device that interrupts the conducting path with the use of an explosive. For example, a mechanical relay or a

solenoid may be employed as the interrupter. The interrupter 18 is desirably a device that physically breaks the conducting path; however, a semiconductor switch is also able to implement the technical idea described in the specification.

[0035] In the embodiment, a sensor that detects a short-circuit fault of the step-up switching element 15 is formed of the sensing emitter of the step-up switching element, the shunt resistor 13 and the voltage sensor 21. The sensor that detects a short-circuit fault may be a simple current sensor. The current sensor may be, for example, configured to measure a current flowing through the reactor 12. The controller 20 determines that the step-up switching element 15 has a short-circuit fault when a current larger than or equal to a predetermined value flows through the reactor 12 while the step-up switching element 15 is in an off state.

[0036] The electric vehicle according to the embodiment is the hybrid vehicle 2 that includes the engine 43 and the two motors 44, 45 for travelling. The technique described in the specification may be suitably applied to a so-called pure EV that includes no engine or may be applied to a fuel cell vehicle.

[0037] The voltage converter 10 according to the embodiment has both the step-up function and the step-down function. The technique described in the specification may also be applied to a step-up only voltage converter that has no step-down function. The configuration of the voltage converter having both the step-up and step-down functions may be described as follows. The voltage converter includes two switching elements, two diodes, a reactor and an interrupter. The two switching elements are connected in series with each other between a high voltage-side positive electrode of the voltage converter and a negative electrode of the voltage converter. The low voltage-side switching element functions as a step-up switching element, and the high voltage-side switching element functions as a step-down switching element. The two diodes are respectively connected in antiparallel with the switching elements. One end of the reactor is connected to a low voltage-side positive electrode of the voltage converter, and the other end of the reactor is connected to a midpoint of the switching elements connected in series with each other. If the interrupter has detected a short-circuit fault of the step-up

switching element, the interrupter isolates the step-up switching element from the circuit of the voltage converter.

[0038] The example embodiment of the invention is described in detail above. However, these are only illustrative and do not limit the appended claims. The technique described in the appended claims includes various modifications and replacements of the embodiment illustrated above. Technical elements described in the specification or the drawing exhibit the technical utility solely or in various combinations, and a combination of the technical elements is not limited to combinations described in the claims at the time of filing. In addition, the technique illustrated in the specification or the drawing can achieve multiple purposes at the same time, and provides technical utility only by achieving one of the purposes.

CLAIMS:

1. An electric vehicle including a battery, a drive motor, a voltage converter configured to step up an output voltage of the battery and an inverter configured to convert an output of the voltage converter to alternating-current power, the inverter being configured to supply the alternating-current power to the motor, characterized in that:

the voltage converter includes:

a reactor of which one end is connected to a low voltage-side positive electrode terminal and the other end is connected to a high voltage-side positive electrode terminal;

a step-up switching element connected between a high voltage side of the reactor and a common negative electrode line that connects a low voltage-side negative electrode terminal to a high voltage-side negative electrode terminal; and

an interrupter configured to isolate the step-up switching element from the voltage converter when the step-up switching element has a short-circuit fault.

2. The electric vehicle according to claim 1, wherein

the motor is driven in a state where the step-up switching element is isolated by the interrupter.

3. The electric vehicle according to claim 2, wherein

when the motor is driven in a state where the step-up switching element is isolated by the interrupter, an upper limit of an output of the motor is limited to a value smaller than that before the step-up switching element is isolated.

4. The electric vehicle according to any one of claims 1 to 3, further comprising:

a fuse configured to interrupt the battery from the voltage converter, wherein

the interrupter is configured to isolate the step-up switching element with the use of an explosive.

5. An electric vehicle comprising:

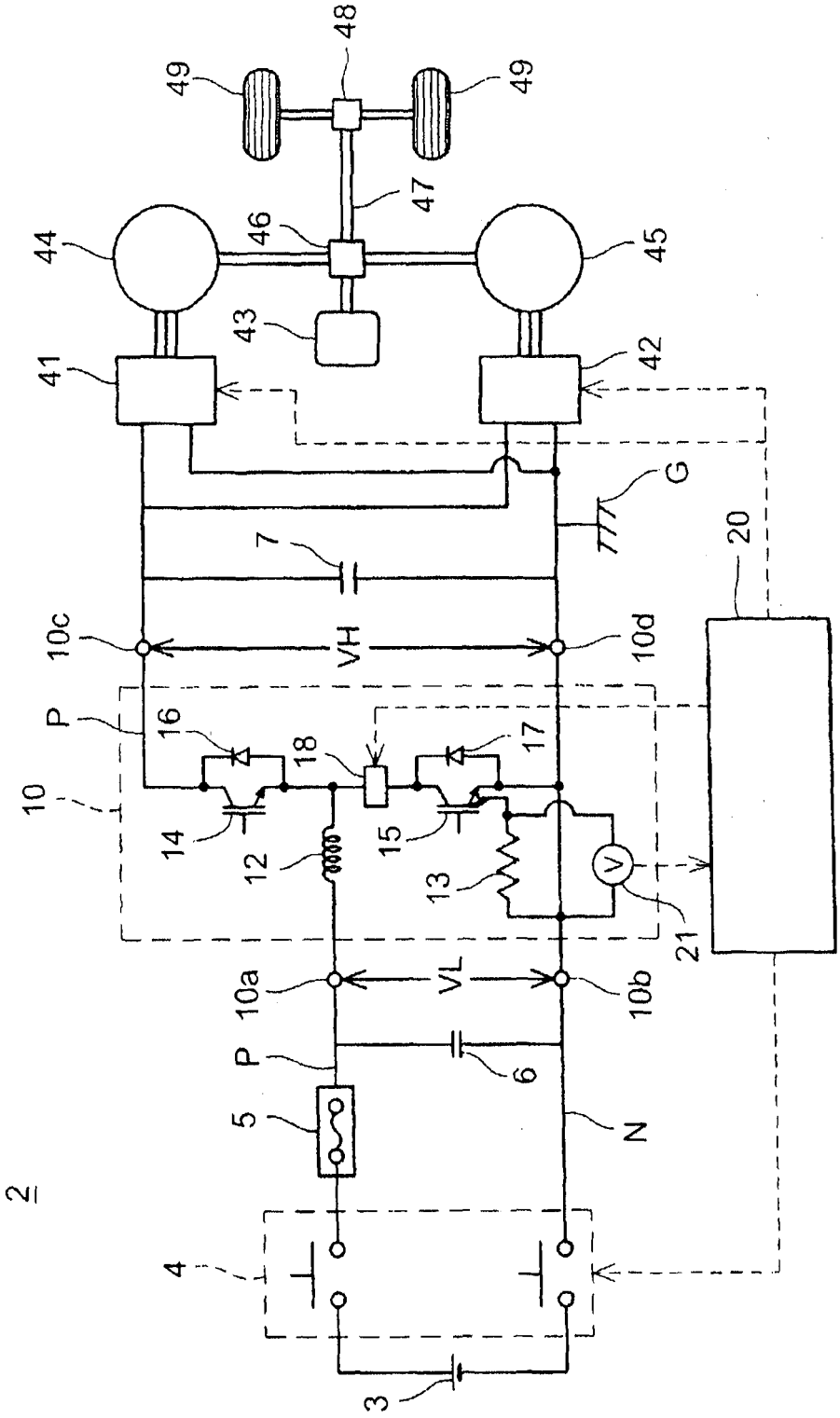
a battery;

a drive motor;

a voltage converter including: a reactor of which one end is connected to a low voltage-side positive electrode terminal and the other end is connected to a high voltage-side positive electrode terminal; a step-up switching element connected between a high voltage side of the reactor and a common negative electrode line that connects a low voltage-side negative electrode terminal to a high voltage-side negative electrode terminal; and an interrupter configured to isolate the step-up switching element from a circuit of the voltage converter when the step-up switching element has a short-circuit fault, the voltage converter being configured to step up an output voltage of the battery; and

an inverter configured to convert an output of the voltage converter to alternating-current power and supply the alternating-current power to the motor.

FIG. 1


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G
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10c
VH
10d
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14
12
15
13
V
21
10a
VL
10b
P
6
5
N
2
4
3