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Power supply control apparatus and power supply control method

Abstract

A power supply control apparatus includes: a first connection device provided in an inter-system line that connects a first system as defined herein and a second system as defined herein; a second connection device as defined herein; and a controller that brings the first connection device and the second connection device into a disconnected state and performs a first fail-safe control using the electric power of the first power supply when a ground fault of the second system is detected, and that brings the first connection device into a conductive state while keeping the second connection device in a disconnected state and performs a second fail-safe control using the electric power of the second power supply when a failure of the first power supply is detected during the first fail-safe control.

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Background/Summary

CROSS-REFERENCE TO RELATED APPLICATION

(1) This application is based on and claims priority under 35 USC 119 from Japanese Patent Application No. 2022-071687 filed on Apr. 25, 2022, and Japanese Patent Application No. 2022-208464 filed on Dec. 26, 2022.

TECHNICAL FIELD

(2) The disclosed embodiment relates to a power supply control apparatus and a power supply control method.

BACKGROUND ART

(3) There is a power supply control apparatus including a first system that supplies electric power

of a first power supply to a first load, a second system that supplies electric power of a second power supply to a second load, and an inter-system separator capable of connecting and disconnecting the first system and the second system (for example, see JP2019-62727A).

(4) When a ground fault of the first system or the second system is detected, the power supply control apparatus separates the first system and the second system by the inter-system separator, determines a ground fault system, and uses a system without the ground fault to perform a fail-safe control.

SUMMARY OF INVENTION

(5) However, for example, during a fail-safe control using the first system due to a ground fault of the second system, the power supply control apparatus cannot continue the fail-safe control when an abnormality occurs in the first power supply.

(6) An aspect of the embodiment has been made in view of the above circumstance, and an object thereof is to provide a power supply control apparatus and a power supply control method capable of continuing, during a fail-safe control using a first system due to a ground fault of a second system, the fail-safe control even when an abnormality occurs in a first power supply.

(7) A power supply control apparatus according to an aspect of an embodiment includes a first connection device, a second connection device, and a controller. The first connection device is provided in an inter-system line that connects a first system configured to supply electric power of a first power supply to a first system load and a second system configured to supply electric power of a second power supply to a second system load. The second connection device is provided between the second system load and a connection point between the second system and the inter-system line. The controller brings the first connection device and the second connection device into a disconnected state and performs a first fail-safe control using the electric power of the first power supply when a ground fault of the second system is detected, and brings the first connection device into a conductive state while keeping the second connection device in a disconnected state and performs a second fail-safe control using the electric power of the second power supply when a failure of the first power supply is detected during the first fail-safe control.

(8) The power supply control apparatus and a power supply control method according to the aspect of the embodiment have an effect capable of continuing, during a fail-safe control using the first system due to the ground fault of the second system, the fail-safe control even when an abnormality occurs in the first power supply.

Description

BRIEF DESCRIPTION OF DRAWINGS

(1) FIG. 1 is an explanatory diagram showing a configuration example of a power supply control apparatus according to a first embodiment;

(2) FIG. 2 is an explanatory diagram showing an operation example of the power supply control apparatus according to the first embodiment;

(3) FIG. 3 is an explanatory diagram showing an operation example of the power supply control apparatus according to the first embodiment;

(4) FIG. 4 is an explanatory diagram showing an operation example of the power supply control apparatus according to the first embodiment;

(5) FIG. 5 is an explanatory diagram showing an operation example of the power supply control apparatus according to the first embodiment;

(6) FIG. 6 is an explanatory diagram showing an operation example of the power supply control apparatus according to the first embodiment;

(7) FIG. 7 is an explanatory diagram showing an operation example of the power supply control apparatus according to the first embodiment;

- (8) FIG. 8 is an explanatory diagram showing an operation example of the power supply control apparatus according to the first embodiment;
- (9) FIG. 9 is a flowchart showing an example of processing executed by a controller of the power supply control apparatus according to the first embodiment;
- (10) FIG. 10 is a flowchart showing a modification of the processing executed by the controller of the power supply control apparatus according to the first embodiment;
- (11) FIG. 11 is a flowchart showing the modification of the processing executed by the controller of the power supply control apparatus according to the first embodiment;
- (12) FIG. 12 is a flowchart showing the modification of the processing executed by the controller of the power supply control apparatus according to the first embodiment;
- (13) FIG. 13 is an explanatory diagram showing a configuration example of a power supply control apparatus according to a second embodiment;
- (14) FIG. 14 is a flowchart showing an example of processing executed by a controller of the power supply control apparatus according to the second embodiment;
- (15) FIG. 15 is a flowchart showing the example of the processing executed by the controller of the power supply control apparatus according to the second embodiment;
- (16) FIG. 16 is a flowchart showing an example of processing executed by the controller of the power supply control apparatus according to the second embodiment;
- (17) FIG. 17 is a flowchart showing an example of processing executed by the controller of the power supply control apparatus according to the second embodiment; and
- (18) FIG. 18 is a flowchart showing a modification of the processing executed by the controller of the power supply control apparatus according to the second embodiment.

DETAILED DESCRIPTION OF THE INVENTION

- (19) Hereinafter, embodiments of a power supply control apparatus and a power supply control method will be described in detail with reference to the accompanying drawings. The present invention is not limited to the following embodiments. Hereinafter, a power supply control apparatus mounted on a vehicle that has an automatic driving function and supplying electric power to a load will be described as an example, but the power supply control apparatus according to the embodiment may be mounted on a vehicle that does not have the automatic driving function.
- (20) Further, a case where the vehicle on which the power supply control apparatus is mounted is an electric vehicle or a hybrid vehicle will be described, but the vehicle on which the power supply control apparatus is mounted may be an engine vehicle traveling by an internal combustion engine.
- (21) The power supply control apparatus according to the embodiment includes a first power supply and a second power supply. When a power supply failure occurs in a power supply system of either the first power supply or the second power supply, the power supply control apparatus may be mounted on any apparatus that backs up the first power supply by the other power supply system.

1. Configuration of Power Supply Control Apparatus According to First Embodiment

- (22) FIG. 1 is an explanatory diagram showing a configuration example of a power supply control apparatus according to a first embodiment. As shown in FIG. 1, a power supply control apparatus 1 according to the first embodiment is connected to a first power supply 10, a first load 101, a second load 102, an external device 100, and a notification device 111.
- (23) The notification device 111 is, for example, a DIAG lamp that notifies a driver of an abnormality of a vehicle or the like. The notification device 111 may be a warning device that outputs a display or a sound to notify the driver of the abnormality of the vehicle or the like.
- (24) The power supply control apparatus 1 includes a first system 110 that supplies electric power of the first power supply 10 to the first load 101 and the second load 102 which are first system loads, and a second system 120 that supplies electric power of a second power supply 20 to be described later to the second load 102 which is a second system load.
- (25) The first load 101 includes, for example, a display, an air conditioner, an audio, a video, and

various lights. The second load **102** includes a load for automatic driving. For example, the second load **102** includes a steering motor, an electric brake device, various sensors, and an in-vehicle camera that operate during the automatic driving. The first load **101** and the second load **102** are operated by electric power supplied from the power supply control apparatus **1**.

(26) The second load **102** is supplied with electric power from both the first system **110** and the second system **120**, but the second load **102** may be different loads with the same function. For example, the second load **102** is an in-vehicle camera and a radar for recognition. In this case, one load is supplied with electric power from the first system, and the other load is supplied with electric power from the second system.

(27) The external device **100** is, for example, an automatic driving control device. The external device **100** may be an electronic control unit (ECU) that controls the entire vehicle. The external device **100** causes the vehicle to travel by automatic driving by operating the second load **102**.

(28) The first power supply **10** includes a lead battery (hereinafter, referred to as a “PbB **11**”) and an electrical power generator **12**. A battery of the first power supply **10** may be any secondary battery other than the PbB **11**. The external device **100** monitors a state of the generator **12** and transmits a notification indicating the state of the generator **12** to the power supply control apparatus **1**.

(29) The generator **12** includes a DC/DC converter that is connected to a high-voltage battery having a voltage higher than that of the PbB **11**, steps down the voltage of the high-voltage battery, and outputs the stepped-down voltage to the first system **110**. Further, the generator **12** includes, for example, an alternator that converts kinetic energy of a traveling vehicle into electricity to generate electricity.

(30) The high-voltage battery is, for example, a battery for driving a vehicle mounted on an electric vehicle or a hybrid vehicle. The generator **12** charges the PbB **11**, supplies electric power to the first load **101** and the second load **102**, and charges the second power supply **20** to be described later.

(31) The power supply control apparatus **1** includes the second power supply **20**, a first connection device **41**, a second connection device **42**, a third connection device **43**, a controller **3**, a first voltage sensor **51**, and a second voltage sensor **52**. Hereinafter, bringing the first connection device **41**, the second connection device **42**, and the third connection device **43** into a conductive state may be referred to as turning on, and bringing these connection devices into a disconnected state may be referred to as turning off.

(32) The second power supply **20** is a backup power supply for a case where the electric power cannot be supplied by the first power supply **10**. The second power supply **20** includes a lithium ion battery (hereinafter, referred to as a “LiB **21**”). A battery of the second power supply **20** may be any secondary battery other than the LiB **21**.

(33) The first connection device **41** is a switch provided in an inter-system line **130** that connects the first system **110** and the second system **120**, and capable of connecting and disconnecting the first system **110** and the second system **120**. The first connection device **41** may be a DC/DC converter that establishes conduction between the first system **110** and the second system **120** by being activated, and disconnects the first system **110** and the second system **120** by stopping an operation.

(34) The second connection device **42** is a switch provided between the second load **102** and a connection point P between the second system **120** and the inter-system line **130**. The third connection device **43** is a switch that connects the second power supply **20** to the second system **120**.

(35) The first voltage sensor **51** is provided in the first system **110**, detects a voltage of the first system **110**, and outputs a detection result to the controller **3**. The second voltage sensor **52** is provided in the second system **120**, detects a voltage of the second system **120**, and outputs a detection result to the controller **3**.

(36) The controller **3** includes various circuits and a microcomputer including a central processing unit (CPU), a read only memory (ROM), a random access memory (RAM), and the like. The controller **3** may be implemented by hardware such as an application specific integrated circuit (ASIC) or a field programmable gate array (FPGA).

(37) The controller **3** controls an operation of the power supply control apparatus **1** by the CPU executing a program stored in the ROM using the RAM as a work area. The controller **3** turns on the first connection device **41** and the second connection device **42** and turns off the third connection device **43** when being activated.

(38) The controller **3** detects a ground fault of the first system **110** or the second system **120** based on the detection results input from the first voltage sensor **51** and the second voltage sensor **52**. The controller **3** turns on the first connection device **41** in normal operations during automatic driving and during non-automatic driving, and turns off the first connection device **41** when the ground fault of the first system **110** or the second system **120** is detected. A specific example of a method for detecting the ground fault by the controller **3** will be described later.

(39) When the ground fault of the first system **110** or the second system **120** is detected, the controller **3** notifies the external device **100** of the fact. When the ground fault of the first system **110** or the second system **120** is detected, the controller **3** outputs, to the external device **100**, an automatic driving prohibition signal indicating that automatic driving is impossible. When the ground fault of the first system **110** or the second system **120** is not detected, the controller **3** outputs, to the external device **100**, an automatic driving permission signal indicating that the automatic driving is possible.

(40) When a voltage of the second power supply **20** becomes equal to or lower than a predetermined voltage, the controller **3** outputs, to the external device **100**, the automatic driving prohibition signal indicating that the automatic driving is impossible. The predetermined voltage here is a minimum voltage of the second power supply **20** required for backing up the first power supply **10**. The voltage of the second power supply **20** and the predetermined voltage here include a concept of state of charge (SOC). For example, the predetermined voltage is a voltage corresponding to SOC of 80%. The predetermined voltage is greater than a threshold for ground fault determination to be described later.

(41) The second power supply **20** includes a measurement device (not shown) that detects a voltage of the LiB **21** and outputs a detection result to the controller **3**. If the third connection device **43** is turned off at the time of measuring the voltage of the second power supply **20**, the controller **3** cannot measure the voltage of the second power supply **20** because no current flows through the LiB **21**. Therefore, at least the third connection device **43** is turned on so that the voltage of the LiB **21** can be detected.

(42) Thereafter, the controller **3** instructs, via a communication line **22**, the measurement device of the second power supply **20** to measure the voltage of the LiB **21**, acquires voltage information of the LiB **21** from the measurement device via the communication line **22**, and detects SOC of the LiB **21**.

(43) When a power supply failure such as a ground fault occurs in the first system **110**, the controller **3** turns off the first connection device **41** and turns on the third connection device **43** to supply electric power from the second power supply **20** to the second load **102**. When the power supply failure such as a ground fault occurs in the second system **120**, the controller **3** supplies electric power from the first power supply **10** to the first load **101** and the second load **102** in a state where the first connection device **41** is turned off and the second connection device **42** is turned off.

(44) Accordingly, even if one of the systems has a ground fault during the automatic driving, the power supply control apparatus **1** can use the other system, perform a fail-safe control (hereinafter, referred to as a fail operation (FOP)) for causing the vehicle to perform retreat traveling to a safe place by using the external device **100**, and stop the vehicle. Next, operations of the power supply

control apparatus **1** will be described with reference to FIGS. **2** to **8**.

2. Normal Operation of Power Supply Control Apparatus

(45) First, a normal operation of the power supply control apparatus **1** will be described with reference to FIG. **2**. In a normal operation in which no ground fault occurs in the first system **110** and the second system **120**, as shown in FIG. **2**, the controller **3** turns off the third connection device **43** and turns on the first connection device **41** and the second connection device **42** to supply electric power from the first power supply **10** to the first load **101** and the second load **102**. The controller **3** outputs the automatic driving permission signal to the external device **100** when the voltage of the second power supply **20** is higher than the predetermined voltage in the normal operation in which no ground fault occurs as described above. In this case, the driver of the vehicle can select either automatic driving by using the external device **100** or non-automatic driving by a manual operation.

3. Operations of Power Supply Control Apparatus When Ground Fault Occurs

(46) Next, operations of the power supply control apparatus **1** when a ground fault occurs will be described with reference to FIGS. **3** to **8**. As shown in FIG. **3**, in the power supply control apparatus **1**, when a ground fault **200** occurs in the first system **110** or the second system **120**, an overcurrent flows toward a ground fault point, and thus the voltages detected by the first voltage sensor **51** and the second voltage sensor **52** become equal to or less than a ground fault threshold.

(47) Therefore, when the voltages detected by the first voltage sensor **51** and the second voltage sensor **52** become equal to or less than the ground fault threshold, the controller **3** temporarily determines that the ground fault **200** occurs in the first system **110** or the second system **120**, and outputs the automatic driving prohibition signal to the external device **100**.

(48) When it is temporarily determined that the ground fault **200** occurs, the controller **3** turns off the first connection device **41** and turns on the third connection device **43** as shown in FIG. **3**. Accordingly, the first system **110** and the second system **120** are disconnected, electric power is supplied from the first power supply **10** to the first system **110**, and electric power is supplied from the second power supply **20** to the second system **120**.

(49) When the voltage detected by at least one of the first voltage sensor **51** and the second voltage sensor **52** becomes equal to or less than the ground fault threshold, the controller **3** can also temporarily determine that the ground fault **200** occurs in the first system **110** or the second system **120**.

(50) The temporary determination may be performed by a hardware circuit including a comparator. In this case, the comparator compares the detection voltages obtained by the first voltage sensor **51** and the second voltage sensor **52** with the ground fault threshold. When the detection voltages become equal to or less than the ground fault threshold, the comparator outputs a ground fault detection signal indicating the temporary determination, turns off the first connection device **41**, and turns on the third connection device **43**.

(51) Thereafter, when the voltage detected by the first voltage sensor **51** is equal to or less than the ground fault threshold for a predetermined time or more and the voltage detected by the second voltage sensor **52** returns to a value exceeding the ground fault threshold within the predetermined time, the controller **3** finally determines that the ground fault **200** occurs in the first system **110**.

(52) In this case, as shown in FIG. **4**, the controller **3** continues the turning off of the first connection device **41** and the turning on of the second connection device **42** and the third connection device **43** to supply electric power from the second power supply **20** to the second load **102**, and notifies the external device **100** of the fact.

(53) Accordingly, the external device **100** can operate the second load **102** with the electric power supplied from the second power supply **20** to cause the vehicle to perform the retreat traveling to a safe place and stop the vehicle. The external device **100** may be configured to start the retreat traveling at a time point when the automatic driving prohibition signal is input from the power supply control apparatus **1**.

(54) Further, after temporarily determining that the ground fault **200** occurs in the first system **110** or the second system **120**, when the voltage detected by the second voltage sensor **52** is equal to or less than the ground fault threshold even after the predetermined time elapses, and the voltage detected by the first voltage sensor **51** returns to a value exceeding the ground fault threshold within the predetermined time, the controller **3** finally determines that the ground fault **200** occurs in the second system **120**.

(55) In this case, as shown in FIG. 5, when the ground fault **200** of the second system **120** is detected, the controller **3** turns off the second connection device **42** while continuing the turning off of the first connection device **41**, supplies electric power from the first power supply **10** to the first load **101** and the second load **102**, notifies the external device **100** of the fact, and performs a first FOP.

(56) Accordingly, the external device **100** can operate the second load **102** with the electric power supplied from the first power supply **10** to cause the vehicle to perform the retreat traveling to a safe place and stop the vehicle. The external device **100** may be configured to start the retreat traveling at a time point when the automatic driving prohibition signal is input from the power supply control apparatus **1**.

(57) Further, in the power supply control apparatus **1**, when the first load **101** or the second load **102** temporarily becomes an overload state instead of the ground fault **200**, the voltage detected by the first voltage sensor **51** may temporarily become equal to or less than the ground fault threshold. In the power supply control apparatus **1**, when the second load **102** temporarily becomes the overload state, the voltage detected by the second voltage sensor **52** may temporarily become equal to or less than the ground fault threshold.

(58) In this case, in the power supply control apparatus **1**, electric power is continuously supplied from the first power supply **10** to the first load **101** and the second load **102**, and electric power is supplied from the second power supply **20** to the second load **102**. Therefore, after temporarily determining that the ground fault **200** occurs in the first system **110** or the second system **120**, if the voltages detected by the first voltage sensor **51** and the second voltage sensor **52** both return to the values exceeding the ground fault threshold before the predetermined time elapses, the controller **3** finally determines that a transient voltage drop occurs and that there is no abnormality in the power supplies. Thereafter, in order to return to the normal operation shown in FIG. 2, the controller **3** turns off the third connection device **43** and turns on the first connection device **41** again.

(59) When the temporary determination is performed by the hardware circuit, the controller **3** includes the hardware circuit and a CPU. The CPU receives a ground fault detection signal output from the hardware circuit, and the CPU takes over the turning off of the first connection device **41** and the turning on of the third connection device **43**. Thereafter, the CPU performs the final determination described above.

4. First Operation Example in First FOP

(60) Next, a first operation example in the first FOP of the power supply control apparatus **1** will be described with reference to FIGS. 6 to 8. In the vehicle, a failure may occur in the first power supply **10** during the first FOP performed when the ground fault **200** occurs in the second system **120**.

(61) The controller **3** detects that the first power supply **10** is failed when receiving a notification indicating an abnormality of the generator **12** from the external device **100**. Accordingly, the controller **3** can reliably detect the failure of the first power supply **10**. When the failure occurs in the first power supply **10**, the external device **100** cannot continue the first FOP because electric power is no longer supplied from the first power supply **10** to the second load **102**.

(62) As shown in FIG. 6, when a failure **201** of the first power supply **10** is detected during the first FOP, the controller **3** turns on the first connection device **41** while keeping the second connection device **42** off, and performs a second FOP with the electric power of the second power supply **20**.

(63) Accordingly, the power supply control apparatus **1** can supply electric power from the second

power supply **20** to the second load **102** via the third connection device **43** and the first connection device **41**, and thus even when the failure occurs in the first power supply **10**, the power supply control apparatus **1** can cause the external device **100** to continue the second FOP and cause the vehicle to perform the retreat traveling.

(64) Thereafter, the controller **3** monitors the detection result of the first voltage sensor **51**, and keeps the first connection device **41** on if the voltage of the first system **110** returns to an operable voltage of the second load **102** as a result of performing the second FOP.

(65) This means that the ground fault **200** of the second system **120** occurs between the second connection device **42** and the second load **102** as shown in FIG. **6**. Therefore, if the second connection device **42** is turned off, a ground fault point of the second system **120** can be disconnected from the second power supply **20**, and the electric power of the second power supply **20** can be supplied to the first system **110**. Accordingly, even when the failure occurs in the first power supply **10** during the first FOP, the power supply control apparatus **1** can safely continue the second FOP.

(66) In the vehicle, during the second FOP, a disconnection or the ground fault **200** may occur in the first system **110**. As shown in FIG. **7**, when a disconnection **202** occurs in the first system **110**, no voltage is applied to the first voltage sensor **51**. The same applies to a case where the ground fault **200** occurs in the first system **110**.

(67) As shown in FIG. **8**, if the voltage of the first system **110** does not return to the operable voltage of the second load **102** as a result of performing the second FOP, the controller **3** determines that the disconnection **202** or the ground fault occurs in the first system **110**, and turns off the first connection device **41**. Accordingly, when the disconnection **202** or the ground fault occurs in the first system **110**, the power supply control apparatus **1** can stop the second FOP and stop the vehicle.

(68) If the voltage of the first system **110** does not return to the operable voltage of the second load **102** as a result of performing the second FOP, the controller **3** causes the notification device **111** to notify that both the first system **110** and the second system **120** are failed. Accordingly, the power supply control apparatus **1** can make the driver of the vehicle recognize that the vehicle is stopped due to the power supply failure.

5. Processing Executed by Controller

(69) Next, an example of processing executed by the controller of the power supply control apparatus according to the first embodiment will be described with reference to FIG. **9**. FIG. **9** is a flowchart showing the example of the processing executed by the controller of the power supply control apparatus according to the first embodiment.

(70) The controller **3** repeatedly executes the processing shown in FIG. **9** during the normal operation. As described above, in the power supply control apparatus **1**, during the normal operation, the first connection device **41** and the second connection device **42** are in a conductive state, and the third connection device **43** is in a disconnected state.

(71) As shown in FIG. **9**, first, the controller **3** temporarily determines whether the ground fault **200** of the first system **110** or the second system **120** is detected, based on the detection voltage of the first voltage sensor **51** or the second voltage sensor **52** (step **S101**). When it is determined that the ground fault **200** is not detected (step **S101**, No), the controller **3** ends the processing, and starts the processing from step **S101** again. In a case of detecting a ground fault using the hardware circuit, the controller **3** temporarily determines that the ground fault **200** is detected when the hardware circuit detects that the ground fault detection signal is output.

(72) When it is temporarily determined that the ground fault **200** is detected (step **S101**, Yes), the controller **3** brings the first connection device **41** into the disconnected state (step **S102**), and brings the third connection device **43** into the conductive state (step **S103**).

(73) Then, the controller **3** finally determines whether the ground fault **200** is in the first system **110** based on the detection voltages of the first voltage sensor **51** and the second voltage sensor **52** (step

S104). When it is finally determined that the ground fault **200** is in the first system **110** (step **S104**, Yes), the controller **3** ends the processing. Accordingly, electric power is supplied to the second load **102** by the second power supply **20**, and the FOP is performed.

(74) When it is finally determined that the ground fault is not in the first system **110** (step **S104**, No), the controller **3** finally determines whether the ground fault **200** is in the second system **120** (step **S105**). When it is finally determined that the ground fault **200** is not in the second system **120** (step **S105**, No), the controller **3** brings the first connection device **41** into the conductive state (step **S106**), brings the third connection device **43** into the disconnected state (step **S107**), and ends the processing. In this way, when it is finally determined that neither the first system **110** nor the second system **120** has the ground fault **200**, the controller **3** determines that the ground fault detected in step **S101** is a transient voltage drop, returns to a state during the normal operation shown in FIG. 2, and ends the processing.

(75) When it is finally determined that the ground fault **200** is in the second system **120** (step **S105**, Yes), the controller **3** brings the second connection device **42** into the disconnected state (step **S108**). At this time, the first connection device **41** and the second connection device **42** are in the disconnected state, and the third connection device **43** is in the conductive state. Accordingly, the controller **3** can perform the first FOP by supplying electric power from the first power supply **10** to the second load **102** while preventing discharge of the second power supply **20**.

(76) Thereafter, the controller **3** determines whether the failure **201** occurs in the first power supply **10** (step **S109**). When it is determined that the failure **201** does not occur in the first power supply **10** (step **S109**, No), the controller **3** ends the processing. Accordingly, the controller **3** can continue the first FOP.

(77) When it is determined that the failure **201** occurs in the first power supply **10** (step **S109**, Yes), the controller **3** brings the first connection device **41** into the conductive state (step **S110**). Accordingly, the controller **3** can perform the second FOP by supplying electric power from the second power supply **20** to the second load **102** via the first connection device **41**.

(78) Thereafter, the controller **3** determines whether the voltage of the first system **110** returns (step **S111**). When it is determined that the voltage of the first system **110** returns (step **S111**, Yes), the controller **3** ends the processing. Accordingly, the controller **3** can continue the second FOP.

(79) When it is determined that the voltage of the first system **110** does not return (step **S111**, No), the controller **3** brings the first connection device **41** into the disconnected state (step **S112**). Thereafter, the controller **3** notifies of the failures of the first system **110** and the second system **120** (step **S113**), and ends the processing. Accordingly, the controller **3** can stop the second FOP, and make the driver of the vehicle recognize that the failures occur in the first system **110** and the second system **120**.

6. Modification of Processing Executed by Controller

(80) Next, a modification of the processing executed by the controller of the power supply control apparatus according to the first embodiment will be described with reference to FIGS. 10 to 12. FIGS. 10 to 12 illustrate a flowchart showing the modification of the processing executed by the controller **3** of the power supply control apparatus according to the first embodiment.

(81) The controller **3** repeatedly executes processing shown in FIGS. 10 to 12 during the normal operation. As described above, in the power supply control apparatus **1**, during the normal operation, the first connection device **41** and the second connection device **42** are in a conductive state, and the third connection device **43** is in a disconnected state.

(82) As shown in FIG. 10, first, the controller **3** temporarily determines whether the ground fault **200** of the first system **110** or the second system **120** is detected, based on the detection voltage of the first voltage sensor **51** or the second voltage sensor **52** (step **S201**). When it is determined that the ground fault **200** is not detected (step **S201**, No), the controller **3** ends the processing.

Thereafter, the controller **3** starts the processing from step **S201** again. In a case of detecting a ground fault using the hardware circuit, the controller **3** temporarily determines that the ground

fault **200** is detected when the hardware circuit detects that the ground fault detection signal is output.

(83) When it is temporarily determined that the ground fault **200** is detected (step **S201**, Yes), the controller **3** brings the first connection device **41** into the disconnected state (step **S202**). Then, the controller **3** brings the third connection device **43** into the conductive state (step **S203**).

(84) Subsequently, the controller **3** finally determines whether the ground fault **200** is in the first system **110** based on the detection voltages of the first voltage sensor **51** and the second voltage sensor **52** (step **S204**). When it is finally determined that the ground fault **200** is in the first system **110** (step **S204**, Yes), the controller **3** ends the processing. Accordingly, the FOP is performed by using the second power supply **20**.

(85) When it is finally determined that the ground fault is not in the first system **110** (step **S204**, No), the controller **3** advances the processing to step **S205** shown in FIG. **11**. In step **S205**, the controller **3** finally determines whether the ground fault **200** is in the second system **120**.

(86) When it is finally determined that the ground fault **200** is not in the second system **120** (step **S205**, No), the controller **3** brings the first connection device **41** into the conductive state (step **S206**). Then, the controller **3** brings the third connection device **43** into the disconnected state (step **S207**). Thereafter, the controller **3** ends the processing. In this way, when it is finally determined that neither the first system **110** nor the second system **120** has the ground fault **200**, the controller **3** returns to a state during the normal operation shown in FIG. **2**, and ends the processing.

(87) When it is finally determined that the ground fault **200** is in the second system **120** (step **S205**, Yes), the controller **3** brings the second connection device **42** into the disconnected state (step **S208**). Then, the controller **3** determines whether the voltage of the second system **120** returns to a value exceeding the ground fault threshold (step **S209**).

(88) Here, the controller **3** has a second fail-safe control permission flag. A state in which the second fail-safe control permission flag is set to "1" is a state in which the second FOP is permitted to be performed. A state in which the second fail-safe control permission flag is set to "0" is a state in which the second FOP is not permitted to be performed.

(89) When it is determined that the voltage of the second system **120** returns to the value exceeding the ground fault threshold (step **S209**, Yes), the controller **3** determines that a side at the second system load of the second connection device **42** has the ground fault **200**. That is, it is determined that the ground fault **200** occurs between the second connection device **42** and the second system load in the second system **120**. Then, the controller **3** sets the second fail-safe control permission flag to "1" (step **S210**). That is, the controller **3** permits the second FOP. Thereafter, the controller **3** advances the processing to step **S213** shown in FIG. **12**.

(90) When it is determined that the voltage of the second system **120** does not return to the value exceeding the ground fault threshold (step **S209**, No), the controller **3** determines that a side at the second power supply **20** of the second connection device **42** has the ground fault **200**. That is, it is determined that the ground fault **200** occurs between the second connection device **42** and the second power supply **20** in the second system **120**. Then, the controller **3** brings the third connection device **43** into the disconnected state (step **S211**). Thereafter, the controller **3** sets the second fail-safe control permission flag to "0" (step **S212**). That is, the controller **3** prohibits the second FOP.

(91) In this way, when the ground fault **200** of the second system **120** is detected, the controller **3** determines that a side at the second system load of the second connection device **42** has the ground fault **200** if the voltage of the second system **120** returns by bringing the second connection device **42** into the disconnected state, and determines that a side at the second power supply **20** of the second connection device **42** has the ground fault **200** if the voltage of the second system **120** does not return. Accordingly, the controller **3** can accurately identify an occurrence location of the ground fault **200** in the second system **120**.

(92) When the ground fault **200** of the second system **120** is detected, the controller **3** brings the

first connection device **41** and the third connection device **43** into the disconnected state to prohibit the second FOP in a case where the ground fault occurs between the second connection device **42** and the second power supply **20**. Accordingly, the controller **3** can prevent discharge of the second power supply **20**. Therefore, the controller **3** can secure the electric power of the second power supply **20** when the ground fault **200** of the second system **120** is resolved later. Thereafter, the controller **3** advances the processing to step **S213** shown in FIG. **12**.

(93) In step **S213**, the controller **3** determines whether the failure **201** occurs in the first power supply **10**. When it is determined that the failure **201** does not occur in the first power supply **10** (step **S213**, No), the controller **3** ends the processing. Accordingly, the controller **3** can continue the first FOP.

(94) When it is determined that the failure **201** occurs in the first power supply **10** (step **S213**, Yes), the controller **3** determines whether the second fail-safe control permission flag is set to "1" (step **S214**). When it is determined that the fail-safe control permission flag is not set to "1" (step **S214**, No), the controller **3** advances the processing to step **S218**.

(95) When it is determined that the fail-safe control permission flag is set to "1" (step **S214**, Yes), the controller **3** brings the first connection device **41** into the conductive state (step **S215**).

Accordingly, the controller **3** can perform the second FOP by supplying electric power from the second power supply **20** to the second load **102** via the first connection device **41**.

(96) In this way, when the ground fault **200** of the second system **120** is detected, the controller **3** performs the second FOP in a case where the ground fault **200** occurs between the second connection device **42** and the second system load. Accordingly, the controller **3** can reliably perform the second FOP.

(97) Thereafter, the controller **3** determines whether the voltage of the first system **110** returns to a value exceeding the ground fault threshold (step **S216**). When it is determined that the voltage of the first system **110** returns to the value exceeding the ground fault threshold (step **S216**, Yes), the controller **3** ends the processing. Accordingly, the controller **3** can continue the second FOP.

(98) When it is determined that the voltage of the first system **110** does not return to the value exceeding the ground fault threshold (step **S216**, No), the controller **3** brings the first connection device **41** into the disconnected state (step **S217**). Thereafter, since the ground fault **200** occurs in the second power supply **20** of the second connection device **42** and the failure **201** occurs in the first power supply **10**, the controller **3** notifies of the failures of the first system **110** and the second system **120** (step **S218**). Then, the controller **3** ends the processing. Accordingly, the controller **3** can stop the second FOP, and make the driver of the vehicle recognize that the failures occur in the first system **110** and the second system **120**.

7. Configuration of Power Supply Control Apparatus According to Second Embodiment

(99) Next, a configuration of a power supply control apparatus **1A** according to a second embodiment will be described with reference to FIG. **13**. FIG. **13** is an explanatory diagram showing a configuration example of the power supply control apparatus **1A** according to the second embodiment.

(100) The power supply control apparatus **1A** is connected to a plurality of second system loads. In the example shown in FIG. **13**, the second load **102**, a third load **103**, and a fourth load **104** are examples of the second system loads to which electric power is supplied from the second power supply **20** via the second system **120**.

(101) A second connection device is provided between each of the plurality of second system loads and the connection point P between the second system **120** and the inter-system line **130**. In the example shown in FIG. **13**, a first load switch SW1 which is the second connection device is provided between the connection point P and the second load **102**. A second load switch SW2 which is the second connection device is provided between the connection point P and the third load **103**. A third load switch SW3 which is the second connection device is provided between the connection point P and the fourth load **104**.

(102) The first to third load switches SW1 to SW3 are switched between a conductive state and a disconnected state by a controller 3A. The first load switch SW1 electrically connects the connection point P and the second load 102 when brought into the conductive state. The first load switch SW1 disconnects the electrical connection between the connection point P and the second load 102 when brought into the disconnected state.

(103) The second load switch SW2 electrically connects the connection point P and the third load 103 when brought into the conductive state. The second load switch SW2 disconnects the electrical connection between the connection point P and the third load 103 when brought into the disconnected state. The third load switch SW3 electrically connects the connection point P and the fourth load 104 when brought into the conductive state. The third load switch SW3 disconnects the electrical connection between the connection point P and the fourth load 104 when brought into the disconnected state.

(104) In addition, the power supply control apparatus 1A is connected to a plurality of first system loads. In the example shown in FIG. 13, the first load 101, the second load 102, and the third load 103 are examples of the first system loads to which electric power is supplied from the first power supply 10 via the first system 110.

(105) Fourth connection devices are provided between the first system 110 and the plurality of first system loads. In the example shown in FIG. 13, a fourth load switch SW4 which is the fourth connection device is provided between the first system 110 and the second load 102. A fifth load switch SW5 which is the fourth connection device is provided between the first system 110 and the third load 103.

(106) The fourth load switch SW4 and the fifth load switch SW5 are switched between a conductive state and a disconnected state by the controller 3A. The fourth load switch SW4 electrically connects the first system 110 and the second load 102 when brought into the conductive state. The fourth load switch SW4 disconnects the electrical connection between the first system 110 and the second load 102 when brought into the disconnected state.

(107) The fifth load switch SW5 electrically connects the first system 110 and the third load 103 when brought into the conductive state. The fifth load switch SW5 disconnects the electrical connection between the first system 110 and the third load 103 when brought into the disconnected state.

(108) As shown in FIG. 13, the controller 3A brings the first connection device 41 and the first to fifth load switches SW1 to SW5 into the conductive state during a normal operation. The controller 3A brings the third connection device 43 into the disconnected state during the normal operation. In this way, the power supply control apparatus 1A supplies electric power of the first power supply 10 to the first to fourth loads 101 to 104 via the first system 110 and the second system 120.

8. Processing Executed by Controller

(109) Next, an example of processing executed by the controller 3A of the power supply control apparatus 1A according to the second embodiment will be described with reference to FIGS. 10 and 14 to 18. FIGS. 14 to 17 are flowcharts showing examples of the processing executed by the controller 3A of the power supply control apparatus 1A according to the second embodiment. FIG. 18 is a flowchart showing a modification of the processing executed by the controller 3A of the power supply control apparatus 1A according to the second embodiment.

(110) During the normal operation, the controller 3A of the power supply control apparatus 1A according to the second embodiment executes the processing of steps S201 to S204 shown in FIG. 10, and then executes processing of steps S305 to S321 shown in FIGS. 14 and 15. In the power supply control apparatus 1A, during the normal operation, the first connection device 41 and the first to fifth load switches SW1 to SW5 are in the conductive state, and the third connection device 43 is in the disconnected state.

(111) As shown in FIG. 10, first, the controller 3A temporarily determines whether the ground fault 200 of the first system 110 or the second system 120 is detected, based on a detection voltage of the

first voltage sensor **51** or the second voltage sensor **52** (step **S201**). When it is determined that the ground fault **200** is not detected (step **S201**, No), the controller **3A** ends the processing. Thereafter, the controller **3A** starts the processing from step **S201** again. In a case of detecting a ground fault using a hardware circuit, the controller **3A** temporarily determines that the ground fault **200** is detected when the hardware circuit detects that a ground fault detection signal is output.

(112) When it is temporarily determined that the ground fault **200** is detected (step **S201**, Yes), the controller **3A** brings the first connection device **41** into the disconnected state (step **S202**). Then, the controller **3A** brings the third connection device **43** into the conductive state (step **S203**).

(113) Subsequently, the controller **3A** finally determines whether the ground fault **200** is in the first system **110** based on detection voltages of the first voltage sensor **51** and the second voltage sensor **52** (step **S204**). When it is finally determined that the ground fault **200** is in the first system **110** (step **S204**, Yes), the controller **3A** ends the processing. Accordingly, an FOP is performed by using the second power supply **20**.

(114) When it is finally determined that the ground fault is not in the first system **110** (step **S204**, No), the controller **3A** advances the processing to step **S305** shown in FIG. **14**. In step **S305**, the controller **3A** finally determines whether the ground fault **200** is in the second system **120**.

(115) When it is finally determined that the ground fault **200** is not in the second system **120** (step **S305**, No), the controller **3A** brings the first connection device **41** into the conductive state (step **S306**). Then, the controller **3A** brings the third connection device **43** into the disconnected state (step **S307**). Thereafter, the controller **3A** ends the processing. In this way, when it is finally determined that neither the first system **110** nor the second system **120** has the ground fault **200**, the controller **3A** returns to a state during the normal operation shown in FIG. **13**, and ends the processing.

(116) When it is finally determined that the ground fault **200** is in the second system **120** (step **S305**, Yes), the controller **3A** brings the first to third load switches **SW1** to **SW3** which are the second connection devices into the disconnected state (step **S308**). Then, the controller **3A** determines whether a voltage of the second system **120** returns to a value exceeding a ground fault threshold (step **S309**).

(117) When it is determined that the voltage of the second system **120** returns to the value exceeding the ground fault threshold (step **S309**, Yes), the controller **3A** determines that a side at the second system load of any one of the first to third load switches **SW1** to **SW3** which are the second connection devices has the ground fault **200**.

(118) Then, the controller **3A** sets a second fail-safe control permission flag to “1” (step **S310**). That is, the controller **3A** permits a second FOP. Subsequently, the controller **3A** brings the first connection device **41** into the conductive state (step **S311**). Then, the controller **3A** executes ground fault location identification processing (step **S312**). A specific example of the ground fault location identification processing will be described later with reference to FIG. **16**. Thereafter, the controller **3A** advances the processing to step **S315** shown in FIG. **15**.

(119) When it is determined that the voltage of the second system **120** does not return to the value exceeding the ground fault threshold (step **S309**, No), the controller **3A** determines that a side at the second power supply **20** of the first to third load switches **SW1** to **SW3** which are the second connection devices has the ground fault **200**.

(120) Then, the controller **3A** brings the third connection device **43** into the disconnected state (step **S313**). Thereafter, the controller **3A** sets the second fail-safe control permission flag to “0” (step **S314**). That is, the controller **3A** prohibits the second FOP. Thereafter, the controller **3A** advances the processing to step **S315** shown in FIG. **15**.

(121) In step **S315**, the controller **3A** determines whether the failure **201** occurs in the first power supply **10**. When it is determined that the failure **201** does not occur in the first power supply **10** (step **S315**, No), the controller **3A** ends the processing. Accordingly, the controller **3A** can continue a first FOP.

(122) When it is determined that the failure **201** occurs in the first power supply **10** (step **S315**, Yes), the controller **3A** determines whether the second fail-safe control permission flag is set to “1” (step **S316**). When it is determined that the fail-safe control permission flag is not set to “1” (step **S316**, No), the controller **3A** advances the processing to step **S320**.

(123) When it is determined that the fail-safe control permission flag is set to “1” (step **S316**, Yes), the controller **3A** brings the first connection device **41** into the conductive state (step **S317**). Accordingly, the controller **3A** can perform the second FOP by supplying electric power from the second power supply **20** to the second load **102** and the third load **103** via the first connection device **41**.

(124) In this way, when the ground fault **200** of the second system **120** is detected, the controller **3A** performs the second FOP in a case where the ground fault **200** occurs between the second system load and any one of the first to third load switches **SW1** to **SW3** which are the second connection devices. Accordingly, the controller **3A** can reliably perform the second FOP.

(125) Thereafter, the controller **3A** determines whether a voltage of the first system **110** returns to a value exceeding the ground fault threshold (step **S318**). When it is determined that the voltage of the first system **110** returns to the value exceeding the ground fault threshold (step **S318**, Yes), the controller **3A** executes disconnection control processing for the second connection devices (step **S321**).

(126) The second connection devices here are the first to third load switches **SW1** to **SW3**. Specific examples of the disconnection control processing for the second connection devices will be described later with reference to FIGS. **17** and **18**. Thereafter, the controller **3A** ends the processing.

(127) When it is determined that the voltage of the first system **110** does not return to the value exceeding the ground fault threshold (step **S318**, No), the controller **3A** brings the first connection device **41** into the disconnected state (step **S319**).

(128) The fact that the controller **3A** executes the processing of step **S319** means that the first power supply **10** is failed (step **S315**, Yes) and a ground fault occurs in the first system **110** (step **S318**, No), and thus the first power supply **10** and the second power supply **20** can not be used for the FOP. The fact that the controller **3A** determines No in step **S316** means that the first power supply **10** is failed (step **S315**, Yes) and a ground fault occurs between the second connection devices and the second power supply **20** in the second system **120** (step **S316**, No), and thus the first power supply **10** and the second power supply **20** can not be used for the FOP in this case either.

(129) Therefore, the controller **3A** notifies of the failures of the first system **110** and the second system **120** (step **S320**). Then, the controller **3A** ends the processing. Accordingly, the controller **3A** can stop the second FOP, and make a driver of a vehicle recognize that the failures occur in the first system **110** and the second system **120**.

9. Ground Fault Location Identification Processing

(130) Next, an example of the ground fault location identification processing (step **S312**) executed by the controller **3A** of the power supply control apparatus **1A** according to the second embodiment will be described with reference to FIG. **16**.

(131) As shown in FIG. **16**, when the controller **3A** starts the ground fault location identification processing, first, the controller **3A** brings the first load switch **SW1** which is the second connection device into the conductive state (step **S401**). Subsequently, the controller **3A** determines whether the voltage of the second system **120** drops to a value equal to or less than the ground fault threshold (step **S402**). When it is determined that the voltage of the second system **120** does not drop to the value equal to or less than the ground fault threshold (step **S402**, No), the controller **3A** advances the processing to step **S405**.

(132) When it is determined that the voltage of the second system **120** drops to the value equal to or less than the ground fault threshold (step **S402**, Yes), the controller **3A** brings the first load

switch SW1 into the disconnected state (step S403). Then, the controller 3A identifies that a side at the second system load of the first load switch SW1, that is, a side at the second load 102 has the ground fault 200 (step S404).

(133) Thereafter, the controller 3A brings the second load switch SW2 which is the second connection device into the conductive state (step S405). Subsequently, the controller 3A determines whether the voltage of the second system 120 drops to the value equal to or less than the ground fault threshold (step S406). When it is determined that the voltage of the second system 120 does not drop to the value equal to or less than the ground fault threshold (step S406, No), the controller 3A advances the processing to step S409.

(134) When it is determined that the voltage of the second system 120 drops to the value equal to or less than the ground fault threshold (step S406, Yes), the controller 3A brings the second load switch SW2 into the disconnected state (step S407). Then, the controller 3A identifies that a side at the second system load of the second load switch SW2, that is, a side at the third load 103 has the ground fault 200 (step S408).

(135) Thereafter, the controller 3A brings the third load switch SW3 which is the second connection device into the conductive state (step S409). Subsequently, the controller 3A determines whether the voltage of the second system 120 drops to the value equal to or less than the ground fault threshold (step S410). When it is determined that the voltage of the second system 120 does not drop to the value equal to or less than the ground fault threshold (step S410, No), the controller 3A ends the processing.

(136) When it is determined that the voltage of the second system 120 drops to the value equal to or less than the ground fault threshold (step S410, Yes), the controller 3A brings the third load switch SW3 into the disconnected state (step S411). Then, the controller 3A identifies that a side at the second system load of the third load switch SW3, that is, a side at the fourth load 104 has the ground fault 200 (step S412). Thereafter, the controller 3A ends the ground fault location identification processing.

(137) In this way, when the first FOP is performed, in a case where the ground fault 200 of the second system 120 occurs between one of the second connection devices and one of the second system loads, the controller 3A brings the one second connection device into the disconnected state, and brings the first connection device 41 and the other second connection devices into the conductive state.

(138) For example, if the ground fault 200 occurs between the first load switch SW1 and the second load 102, the controller 3A brings the first load switch SW1 into the disconnected state. Then, the controller 3A brings the first connection device 41, the second load switch SW2, and the third load switch SW3 into the conductive state.

(139) In this case, the controller 3A can improve a control of the first FOP by using the third load 103 and the fourth load 104 which are available second system loads, without using the unavailable second load 102.

(140) When it is determined that the second system 120 has the ground fault 200, the controller 3A repeats, for each of the second connection devices, processing of bringing one of the second connection devices into the conductive state and bringing the other second connection devices into the disconnected state. Then, if the voltage of the second system 120 drops when one of the second connection devices is brought into the conductive state, the controller 3A determines that a load side of the second connection device brought into the conductive state has the ground fault 200.

(141) In addition, if the voltage of the second system 120 does not return even if all the second connection devices are brought into the disconnected state, the controller 3A determines that a power supply side of the second connection devices has the ground fault 200. Accordingly, the controller 3A can accurately identify an occurrence location of the ground fault 200 in the second system 120.

10. Disconnection Control Processing for Second Connection Devices

(142) Next, an example of the disconnection control processing for the second connection devices (step S321) executed by the controller 3A of the power supply control apparatus 1A according to the second embodiment will be described with reference to FIG. 17.

(143) As shown in FIG. 17, when the controller 3A starts the disconnection control processing for the second connection devices, the controller 3A brings a second connection device in the conductive state into the disconnected state (step S501). Specifically, the controller 3A brings a second connection device that is not brought into the disconnected state, among the first to third load switches SW1 to SW3 which are the second connection devices, to the disconnected state after being brought into the conductive state in the ground fault location identification processing shown in FIG. 16. Thereafter, the controller 3A ends the processing.

(144) In this way, when the second FOP is performed, the controller 3A brings a second connection device in which the ground fault 200 does not occur on a load side thereof into the disconnected state. Accordingly, the controller 3A can prevent electric power consumption of the second power supply 20 and can increase an operable time of the second FOP as compared to a case where the second connection device is not brought into the disconnected state.

11. Modification of Disconnection Control Processing for Second Connection Devices

(145) Next, a modification of the disconnection control processing for the second connection devices (step S321) executed by the controller 3A of the power supply control apparatus 1A according to the second embodiment will be described with reference to FIG. 18.

(146) As shown in FIG. 18, when the controller 3A starts disconnection control processing according to the modification for the second connection devices, the controller 3A determines whether SOC of the second power supply 20 is 60% or more (step S601). For example, the controller 3A instructs a measurement device of the second power supply 20 to measure a voltage of the LiB 21.

(147) The controller 3A acquires voltage information of the LiB 21 from the measurement device. The controller 3A detects SOC of the LiB 21 based on the acquired voltage information. Then, with the detected SOC of the LiB 21 as the SOC of the second power supply 20, the controller 3A determines whether the SOC of the second power supply 20 is 60% or more.

(148) When it is determined that the SOC of the second power supply 20 is 60% or more (step S601, Yes), the controller 3A ends the processing. That is, a second connection device in which no ground fault occurs in the ground fault location identification processing of step S312 is conducted, and thus the controller 3A continues the second FOP in this state. When it is determined that the SOC of the second power supply 20 is not 60% or more (step S610, No), that is, the SOC of the second power supply 20 is less than 60%, the controller 3A brings a second connection device having a low priority into the disconnected state (step S602).

(149) The second connection device having a low priority is a second connection device connected to a second system load having a low priority. The second system load having a low priority is a second system load that does not affect automatic driving or traveling of the vehicle itself. The second system load that does not affect the automatic driving or the traveling of the vehicle itself includes, for example, a display, an air conditioner, an audio, a video, and various lights.

(150) A second connection device having a high priority is a second connection device connected to a second system load having a high priority. The second system load having a high priority is a second system load that affects the automatic driving or the traveling of the vehicle itself. The second system load that affects the automatic driving or the traveling of the vehicle itself includes, for example, a steering motor, an electric brake device, various sensors, and an in-vehicle camera.

(151) When the second FOP is performed, the controller 3A can also bring a second connection device in the conductive state corresponding to the second system load having a lower priority into the disconnected state as a charge amount of the second power supply 20 is lower. Accordingly, the controller 3A can increase the operable time of the second FOP while increasing an accuracy of the second FOP.

(152) Thereafter, the controller 3A brings the fourth connection device having a lower priority among the fourth load switch SW4 and the fifth load switch SW5 which are the fourth connection devices into the disconnected state (step S603).

(153) The fourth connection device having a low priority is a fourth connection device connected to a first system load having a low priority. The first system load having a low priority is a first system load that does not affect the automatic driving or the traveling of the vehicle itself. The first system load that does not affect the automatic driving or the traveling of the vehicle itself includes, for example, a display, an air conditioner, an audio, a video, and various lights.

(154) A fourth connection device having a high priority is a fourth connection device connected to a first system load having a high priority. The first system load having a high priority is a first system load that affects the automatic driving or the traveling of the vehicle itself. The first system load that affects the automatic driving or the traveling of the vehicle itself includes, for example, a steering motor, an electric brake device, various sensors, and an in-vehicle camera.

(155) When the second FOP is performed, the controller 3A can also bring a fourth connection device corresponding to the first system load having a lower priority into the disconnected state as the charge amount of the second power supply 20 is lower. Accordingly, the controller 3A can increase the operable time of the second FOP while increasing the accuracy of the second FOP.

(156) In this way, when the second FOP is performed, the controller 3A brings a connection device corresponding to a load having a lower priority into a disconnected state as the charge amount of the second power supply 20 is lower. Accordingly, the controller 3A can increase the operable time of the second FOP while increasing the accuracy of the second FOP.

12. Appendixes

(157) As appendixes, the features of the present invention are shown as follows.

(158) (1) A power supply control apparatus including: a first connection device provided in an inter-system line that connects a first system configured to supply electric power of a first power supply to a first system load and a second system configured to supply electric power of a second power supply to a second system load; a second connection device provided between the second system load and a connection point between the second system and the inter-system line and; and a controller that brings the first connection device and the second connection device into a disconnected state and performs a first fail-safe control using the electric power of the first power supply when a ground fault of the second system is detected, and that brings the first connection device into a conductive state while keeping the second connection device in a disconnected state and performs a second fail-safe control using the electric power of the second power supply when a failure of the first power supply is detected during the first fail-safe control.

(159) (2) The power supply control apparatus according to (1), in which if a voltage of the first system returns as a result of performing the second fail-safe control, the controller keeps a conductive state of the first connection device.

(160) (3) The power supply control apparatus according to (1) or (2), in which if a voltage of the first system does not return as a result of performing the second fail-safe control, the controller brings the first connection device into a disconnected state.

(161) (4) The power supply control apparatus according to (3), in which if the voltage of the first system does not return as a result of performing the second fail-safe control, the controller notifies that both the first system and the second system are failed.

(162) (5) The power supply control apparatus according to any one of (1) to (4), in which the first power supply includes an electrical power generator, and the controller detects that the first power supply is failed when receiving a notification indicating an abnormality of the electrical power generator from an external device configured to monitor a state of the electrical power generator.

(163) (6) The power supply control apparatus according to any one of (1) to (5), in which when the ground fault of the second system is detected, the controller performs the second fail-safe control in a case where the ground fault occurs between the second connection device and the second system

load.

(164) (7) The power supply control apparatus according to (6), in which when the ground fault of the second system is detected, the controller determines that a side at the second system load of the second connection device has a ground fault if a voltage of the second system returns by bringing the second connection device into a disconnected state, and determines that a side at the second power supply of the second connection device has a ground fault if the voltage of the second system does not return.

(165) (8) The power supply control apparatus according to any one of (1) to (7), further including: a third connection device configured to connect the second power supply to the second system, in which when the ground fault of the second system is detected, the controller brings the first connection device and the third connection device into a disconnected state to prohibit the second fail-safe control in a case where the ground fault occurs between the second connection device and the second power supply.

(166) (9) The power supply control apparatus according to any one of (1) to (8), in which the second system load includes a plurality of second system loads, the second connection device is provided between the connection point and each of the plurality of second system loads, and when the first fail-safe control is performed, in a case where the ground fault of the second system occurs between one of the second connection devices and one of the second system loads, the controller brings the one second connection device into a disconnected state and brings the first connection device and the other second connection devices into a conductive state.

(167) (10) The power supply control apparatus according to (9), in which when it is determined that the second system has a ground fault, the controller repeats, for each of the second connection devices, processing of bringing one of the second connection devices into a conductive state and bringing the other second connection devices into a disconnected state, determines that a side at the second system load of one of the second connection devices has a ground fault if a voltage of the second system drops when the one second connection device is brought into a conductive state, and determines that a side at the second power supply of the second connection devices has a ground fault if the voltage of the second system does not return even if all the second connection devices are in a disconnected state.

(168) (11) The power supply control apparatus according to (9) or (10), in which when the second fail-safe control is performed, the controller brings the other second connection devices into a disconnected state.

(169) (12) The power supply control apparatus according to any one of (9) to (11), in which when the second fail-safe control is performed, the controller brings the other second connection device corresponding to the second system load having a lower priority into a disconnected state as a charge amount of the second power supply is lower.

(170) (13) The power supply control apparatus according to any one of (9) to (12), in which the first system load includes a plurality of first system loads, a fourth connection device is provided between the first system and each of the plurality of first system loads, and when the second fail-safe control is performed, the controller brings the fourth connection device corresponding to the first system load having a lower priority into a disconnected state as a charge amount of the second power supply is lower.

(171) (14) The power supply control apparatus according to any one of (9) to (13), in which when the second fail-safe control is performed, the controller brings a connection device corresponding to a load having a lower priority into a disconnected state as a charge amount of the second power supply is lower.

(172) (15) A power supply control method performed by a controller of a power supply control apparatus, the power supply control apparatus including a first connection device provided in an inter-system line that connects a first system configured to supply electric power of a first power supply to a first system load and a second system configured to supply electric power of a second

power supply to a second system load, and a second connection device provided between the second system load and a connection point between the second system and the inter-system line, wherein the method includes: bringing the first connection device and the second connection device into a disconnected state and performing a first fail-safe control using the electric power of the first power supply when a ground fault of the second system is detected; and bringing the first connection device into a conductive state while keeping the second connection device in a disconnected state and performing a second fail-safe control using the electric power of the second power supply when a failure of the first power supply is detected during the first fail-safe control. (173) Additional effects and modifications can be easily derived by those skilled in the art.

Therefore, broader aspects of the present invention are not limited to the specific details and the representative embodiments shown and described above. Therefore, various modifications can be made without departing from the spirit or scope of the general inventive concept as defined by the appended claims and equivalents of the claims.

REFERENCE SIGNS LIST

(174) **1**: power supply control apparatus **10**: first power supply **11**: PbB **12**: generator **20**: second power supply **21**: LiB **3**: controller **41**: first connection device **42**: second connection device **43**: third connection device **51**: first voltage sensor **52**: second voltage sensor **100**: external device **101**: first load **102**: second load **103**: third load **104**: fourth load **110**: first system **111**: notification device **120**: second system **130**: inter-system line **P**: connection point **SW1**: first load switch **SW2**: second load switch **SW3**: third load switch **SW4**: fourth load switch **SW5**: fifth load switch

Claims

1. A power supply control apparatus comprising: a first connection device provided in an inter-system line that connects (i) a first system configured to supply electric power of a first power supply to a first system load and a second system load and (ii) a second system configured to supply electric power of a second power supply to the second system load; a second connection device provided between the second system load and a connection point between the second system and the inter-system line; a first voltage sensor provided in the first system and configured to detect a voltage of the first system; a second voltage sensor provided in the second system and configured to detect a voltage of the second system; and a controller that performs a first fail-safe control by bringing the first connection device and the second connection device into a disconnected state so that the electric power of the first power supply is supplied to the first system load and the second system load when a ground fault of the second system is detected by comparing the voltage detected by the first voltage sensor and the voltage detected by the second voltage sensor to a ground fault threshold and determining that the voltage detected by the second voltage sensor is equal to or less than the ground fault threshold, and that performs a second fail-safe control by bringing the first connection device into a conductive state while keeping the second connection device in a disconnected state so that the electric power of the second power supply is supplied to the second system load through the first connection device and the first system when a failure of the first power supply is detected during the first fail-safe control.
2. The power supply control apparatus according to claim 1, wherein in a case where a voltage of the first system detected by the first voltage sensor returns as a result of performing the second fail-safe control, the controller keeps a conductive state of the first connection device.
3. The power supply control apparatus according to claim 1, wherein in a case where a voltage of the first system detected by the first voltage sensor does not return as a result of performing the second fail-safe control, the controller brings the first connection device into a disconnected state.
4. The power supply control apparatus according to claim 3, wherein in a case where the voltage of the first system detected by the first voltage sensor does not return as a result of performing the second fail-safe control, the controller notifies that both of the first system and the second system

are failed.

5. The power supply control apparatus according to claim 1, wherein the first power supply comprises an electrical power generator, and the controller detects that the first power supply is failed when receiving a notification indicating an abnormality of the electrical power generator from an external device configured to monitor a state of the electrical power generator.

6. The power supply control apparatus according to claim 1, wherein when the ground fault of the second system is detected, the controller performs the second fail-safe control in a case where the ground fault occurs between the second connection device and the second system load.

7. The power supply control apparatus according to claim 6, wherein when the ground fault of the second system is detected, the controller determines that a side at the second system load of the second connection device has a ground fault in a case where a voltage of the second system detected by the second voltage sensor returns by bringing the second connection device into a disconnected state, and determines that a side at the second power supply of the second connection device has a ground fault in a case where the voltage of the second system detected by the second voltage sensor does not return.

8. The power supply control apparatus according to claim 1, further comprising: a third connection device configured to connect the second power supply to the second system, wherein when the ground fault of the second system is detected, the controller brings the first connection device and the third connection device into a disconnected state to prohibit the second fail-safe control in a case where the ground fault occurs between the second connection device and the second power supply.

9. The power supply control apparatus according to claim 1, wherein the second system load comprises a plurality of second system loads, the second connection device is provided between the connection point and each of the plurality of second system loads, and when the first fail-safe control is performed, in a case where the ground fault of the second system occurs between one of the second connection devices and one of the second system loads, the controller brings the one of the second connection devices into a disconnected state and brings the first connection device and other of the second connection devices into a conductive state.

10. The power supply control apparatus according to claim 9, wherein when the second system is determined to have a ground fault, the controller repeats, for each of the second connection devices, processing of bringing one of the second connection devices into a conductive state and bringing other of the second connection devices into a disconnected state, determines that a side at the second system load of one of the second connection devices has a ground fault in a case where a voltage of the second system detected by the second voltage sensor drops when the one of the second connection devices is brought into a conductive state, and determines that a side at the second power supply of the second connection devices has a ground fault in a case where the voltage of the second system detected by the second voltage sensor does not return even in a case where all the second connection devices are in a disconnected state.

11. The power supply control apparatus according to claim 9, wherein when the second fail-safe control is performed, the controller brings the other of the second connection devices into a disconnected state.

12. The power supply control apparatus according to claim 9, wherein when the second fail-safe control is performed, the controller brings the other of the second connection devices corresponding to the second system load having a lower priority into a disconnected state as a charge amount of the second power supply is lower.

13. The power supply control apparatus according to claim 9, wherein the first system load comprises a plurality of first system loads, a fourth connection device is provided between the first system and each of the plurality of first system loads, and when the second fail-safe control is performed, the controller brings the fourth connection device corresponding to the first system load having a lower priority into a disconnected state as a charge amount of the second power supply is

lower.

14. The power supply control apparatus according to claim 9, wherein when the second fail-safe control is performed, the controller brings a connection device corresponding to a load having a lower priority into a disconnected state as a charge amount of the second power supply is lower.

15. A power supply control method performed by a controller of a power supply control apparatus, the power supply control apparatus including (1) a first connection device provided in an inter-system line that connects (i) a first system configured to supply electric power of a first power supply to a first system load and a second system load and (ii) a second system configured to supply electric power of a second power supply to the second system load, (2) a second connection device provided between the second system load and a connection point between the second system and the inter-system line, (3) a first voltage sensor provided in the first system and configured to detect a voltage of the first system, and (4) a second voltage sensor provided in the second system and configured to detect a voltage of the second system, wherein the method comprises:

performing a first fail-safe control by bringing the first connection device and the second connection device into a disconnected state so that the electric power of the first power supply is supplied to the first system load and the second system load when a ground fault of the second system is detected by comparing the voltage detected by the first voltage sensor and the voltage detected by the second voltage sensor to a ground fault threshold and determining that the voltage detected by the second voltage sensor is equal to or less than the ground fault threshold; and performing a second fail-safe control by bringing the first connection device into a conductive state while keeping the second connection device in a disconnected state so that the electric power of the second power supply is supplied to the second system load through the first connection device and the first system when a failure of the first power supply is detected during the first fail-safe control.

16. A power supply control apparatus comprising: a first connection device provided in an inter-system line that connects a first power supply line to a second power supply line, the first power supply line extending from a first power supply to a first system load and a second system load and being configured to supply electric power of the first power supply to the first system load and to the second system load, the second power supply line extending from a second power supply to the second system load and being configured to supply electric power of the second power supply to the second system load; a second connection device provided between the second system load and a connection point between the second power supply line and the inter-system line; a first voltage sensor provided in the first power supply line and configured to detect a voltage of the first power supply line; a second voltage sensor provided in the second power supply line and configured to detect a voltage of the second power supply line; and a controller that performs (i) a first fail-safe control by bringing the first connection device and the second connection device into a disconnected state so that the electric power of the first power supply is supplied by the first power supply line to the first system load and to the second system load when a ground fault of the second power supply line is detected by comparing the voltage detected by the first voltage sensor and the voltage detected by the second voltage sensor to a ground fault threshold and determining that the voltage detected by the second voltage sensor is equal to or less than the ground fault threshold, and that performs (ii) a second fail-safe control by bringing the first connection device into a conductive state while keeping the second connection device in a disconnected state so that the electric power of the second power supply is supplied by the inter-system line and the first power supply line to the second system load when a failure of the first power supply is detected during the first fail-safe control.
