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VEHICLE

Abstract

ECU performs a process including the steps of acquiring a resistance value of an insulation resistance, determining that a resistance value is equal to or less than a threshold value, determining that an electric leakage occurs on the vehicle body side, turning on a SMR when the resistance value is greater than the threshold value, acquiring a resistance value of the insulation resistance, determining that an electric leakage occurs on the battery pack side when the resistance value is equal to or less than the threshold value, and determining that there is no electric leakage when the resistance value is greater than the threshold value.

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Background/Summary

CROSS-REFERENCE TO RELATED APPLICATION

[0001] This application claims priority to Japanese Patent Application No. 2024-020157 filed on Feb. 14, 2024, incorporated herein by reference in its entirety.

BACKGROUND

1. Technical Field

[0002] The present disclosure relates to a vehicle including a detachable battery.

2. Description of Related Art

[0003] Japanese Unexamined Patent Application Publication No. 2021-189122 (JP 2021-189122 A) discloses an electric leakage detection device that calculates an insulation resistance for each path of an electric circuit provided in an electrified vehicle and identifies a path having an electric leakage based on the calculated value.

SUMMARY

[0004] In the above electric leakage detection device, however, a vehicle including a detachable battery is not assumed. Therefore, electric leakage detection according to the attached or detached state of the battery is not assumed. There is a possibility that appropriate electric leakage detection cannot be performed.

[0005] The present disclosure has been made to solve the above problem, and an object thereof is to provide a vehicle that includes a detachable battery and performs appropriate electric leakage detection.

[0006] A vehicle according to an aspect of the present disclosure includes: [0007] a vehicle body; [0008] a battery detachable from the vehicle body; and [0009] a detection device provided to an electric circuit on the vehicle body side and configured to detect whether an electric leakage has occurred. The detection device is configured to detect whether the electric leakage has occurred in at least one of a conductive state in which the battery and the electric circuit are connected and a disconnected state in which the battery and the electric circuit are disconnected.

[0010] In this way, whether the electric leakage has occurred is detected when the battery and the electric circuit on the vehicle body side are in the conductive state or the disconnected state. Accordingly, it is possible to accurately determine whether the electric leakage is caused by the electric circuit on the vehicle body side or by the battery.

[0011] In one embodiment, the detection device may be configured to detect whether the electric leakage of the electric circuit has occurred in the disconnected state and, when the electric leakage is not detected, detect whether the electric leakage has occurred in the conductive state.

[0012] In this way, whether the electric leakage of the electric circuit on the vehicle body side has occurred can be detected in the disconnected state. When the electric leakage of the electric circuit on the vehicle body side is not detected, whether the electric leakage of the battery has occurred can be detected in the conductive state.

[0013] In a further embodiment, the vehicle body may be configured such that a plurality of the batteries is mountable. Each of the batteries may include a relay configured to connect or disconnect the electric circuit.

[0014] The detection device may be configured to change a combination of an ON state and an OFF state of the relays of the batteries and detect whether the electric leakage has occurred in each of the batteries.

[0015] In this way, in the vehicle including the plurality of batteries, the combination of the ON state and the OFF state of the relays is changed and whether the electric leakage has occurred in each of the batteries is detected. Thus, it is possible to determine which battery has the electric leakage.

[0016] In a further embodiment,
[0017] the vehicle may further include a notification device. The notification device may be configured to give a notification about occurrence of the electric leakage in the vehicle body when the detection device has detected the electric leakage of the electric circuit in the disconnected state.
[0018] In this way, the user can recognize that the electric leakage is caused by the electric circuit on the vehicle body side.
[0019] In a further embodiment, the vehicle may further include a notification device. The notification device may be configured to give a notification about occurrence of the electric leakage in the battery when the detection device has not detected the electric leakage of the electric circuit in the disconnected state and has detected the electric leakage of the electric circuit in the conductive state.
[0020] In this way, the user can recognize that the electric leakage is caused by the battery.
[0021] According to the present disclosure, it is possible to provide the vehicle that includes the detachable battery and performs appropriate electric leakage detection.

Description

BRIEF DESCRIPTION OF THE DRAWINGS
[0022] Features, advantages, and technical and industrial significance of exemplary embodiments of the disclosure will be described below with reference to the accompanying drawings, in which like signs denote like elements, and wherein:
[0023] FIG. **1** is a diagram illustrating an example of a configuration of a vehicle according to the present embodiment;
[0024] FIG. **2** is a diagram illustrating an example of a configuration of a battery replacement system for replacing a battery pack;
[0025] FIG. **3** is a flowchart illustrating an example of a method of replacing a battery pack;
[0026] FIG. **4** is a flowchart illustrating an example of the electric leakage determination process of FIG. **3**;
[0027] FIG. **5** is a diagram illustrating an example of a configuration of vehicles according to a modification; and
[0028] FIG. **6** is a flowchart illustrating an example of the electric leakage determination process according to the modification.
DETAILED DESCRIPTION OF EMBODIMENTS
[0029] Hereinafter, an embodiment of the present disclosure will be described in detail with reference to the drawings. It should be noted that the same or corresponding parts in the drawings are designated by the same reference characters and repetitive description will be omitted.
[0030] FIG. **1** is a diagram illustrating an example of a configuration of a vehicle according to the present embodiment. Referring to FIG. **1**, a vehicle **100** includes a vehicle body **10** and a battery pack **20**. The vehicle body **10** is a portion of the vehicle **100** other than the battery pack **20**. The vehicle body **10** includes a vehicle driving device serving as a driving source. Vehicle-driven devices include MG (Motor Generator) **11***a* and inverters **11***b*.
[0031] The vehicle driving device is configured to drive the vehicle **100** using the electric power output from the battery pack **20**. The battery-pack **20** is configured to be connectable to an inverter **11***b*. The vehicles **100** are, for example, battery electric vehicle that do not include an internal combustion engine. However, the present disclosure is not limited thereto, and the vehicles **100** may be plug-in hybrid electric vehicle including an internal combustion engine or other electrified vehicle.
[0032] The vehicle body **10** includes a circuit CR**11** and a CR**12**. The battery-pack **20** includes a

circuit CR**21** and a CR**22**. The circuit CR**12** includes an auxiliary battery **17**. The circuit CR**21** includes a battery **21**. The battery **21** is, for example, a secondary battery such as a lithium ion battery, a nickel metal hydride battery, or a sodium ion battery. The type of the secondary battery may be a liquid secondary battery or an all-solid secondary battery. A plurality of secondary batteries may form a battery pack. The auxiliary battery **17** corresponds to a low-voltage power supply that outputs power at a voltage lower than the voltage of the battery **21**. A DC/DC converter **16** is provided between the circuit CR**11** and the circuit CR**12**.

[0033] The circuit CR**11** in the vehicle body **10** includes a MG **11***a*, an inverter **11***b*, a DC charge relay **14***a*, a DC inlet **14***b*, a AC charger **15***a*, and a AC inlet **15***b*. Further, the circuit CR**11** is provided with a leakage detector **12**. A BMS (Battery Management System) **22***a* is provided in a circuit CR**21** in the battery pack **20**.

[0034] The vehicle body **10** further includes a terminal T**11** to which the battery pack **20** can be attached and a SMR (System Main Relay) **13** disposed between the terminal T**11** and the vehicle driving device (inverter **11***b*). The circuit CR**11** (high-voltage power supply line) is connected to the terminal T**11** via a SMR **13**. The battery-pack **20** includes a terminal T**21** to which the vehicle body **10** is attachable and detachable, and a SMR **23** disposed between the terminal T**21** and the circuit CR**21**. The circuit CR**21** (high-voltage power supply line) is connected to the terminal T**21** via a SMR **23**.

[0035] The terminal T**21** of the battery pack **20** is connected to the terminal T**11** of the vehicle body **10**. SMR **23** of the battery pack **20** is disposed between the terminal T**21** of the battery pack **20** and the battery **21**. SMR **23** enables the connection/disconnection between the target device (inverter **11***b*) and the battery **21** to be easily and appropriately switched.

[0036] The vehicle body **10** further includes a terminal T**12** to which the battery

[0037] **10** pack **20** can be attached and detached. Circuit CR**12** (low-voltage power supply line) in the vehicle body **10** is connected to the terminal T**12**. A communication line CL**1** (a broken line in FIG. **1**) in the vehicle body **10** is also connected to the terminal T**12**. The battery-pack **20** further includes a terminal T**22**. In the battery-pack **20**, the circuit CR**22** (low-voltage power supply line) and the communication line CL**2** (broken line in FIG. **1**) are connected to the terminal T**22**. **15**

[0038] The auxiliary battery **17** supplies electric power for driving auxiliary machines mounted on the vehicle **100**. The auxiliary battery **17** outputs DC power to the circuit CR**12** (low-voltage power supply line). The circuit CR**12** further includes an ECU **18***a*, **18***b*, **18***c*, **18***d* in addition to the auxiliary battery **17**. The circuit CR**22** further includes an ECU **28***a*. The auxiliary battery **17** supplies power to each of **18***d*, **28***a* from, for example, an ECU **18***a* connected to the low-voltage power supply line. “ECU” means an electronic control unit (Electronic Control Unit).

[0039] ECU **18***a* corresponds to a control device (EV-ECU) that controls various types of control related to the vehicles **100**. ECU **18***b* corresponds to a control device (Plg-ECU) that detects the status of each of DC inlet **14***b* and AC inlet **15***b*. ECU **18***c* corresponds to a control device (Bat-C-ECU) that controls DC charge-relay **14***a* and AC charger **15***a*. ECU **18***d* corresponds to a control device (earth leakage ECU) that monitors the earth leakage status of the circuit CR**11**. For example, ECU **18***d* detects a current between the electric circuit including the circuit CR**11** and the grounding, calculates a resistance value of the insulation resistance using the detected current, and calculates the calculated resistance value as a leakage condition. ECU **28***a* corresponds to a control device (Bat-ECU) that monitors the status of the batteries **21** and controls SMR **23**.

[0040] ECU includes a processor and a storage device. The storage device is configured to be able to save the stored information. In addition to the program, the storage device stores various kinds of information used in the program. In this embodiment, various kinds of control are executed by the processor executing a program stored in the storage device. However, these processes may be executed only by hardware (electronic circuit) without using software.

[0041] In the vehicle **100**, ECU are communicably connected to each other via an in-vehicle network (e.g., a CAN (Controller Area Network)). ECU **18***a* obtains information from other ECU, controls the inverter **11***b*, DC/DC converters **16** and SMR **13**, **23**, and sends control commands to ECU **18***c* and ECU **28***a*.

[0042] The leakage detector **12** detects a leakage condition of the circuit CR**11** (for example, a resistance of an insulating resistor), and outputs the detection result to ECU **18***d*. BMS **22***a* detects the condition (current, voltage, temperature, etc.) of the battery **21**, and outputs the detected condition to ECU **28***a*. ECU **18***a* acquires information indicating the leakage state and the battery state from ECU **18***d*, **28***a*.

[0043] DC/DC converters **16** transform DC power between the circuit CR**11** and the circuit CR**12**. Specifically, DC/DC converters **16** step down the DC power from the batteries **21**, and provide the DC power to the auxiliary battery **17** and other auxiliary devices connected to the circuit CR**12**. The capacity of the battery **21** is larger than the capacity of the auxiliary battery **17**.

[0044] When the terminal T**21**, T**22** of the battery pack **20** is connected to the terminal T**11**, T**12**, the battery pack **20** is attached to the vehicle body **10**, thereby forming the vehicle **100**. In the vehicle **100**, the communication line CL**1** of the vehicle body **10** and the communication line CL**2** of the battery pack **20** are connected. These communication lines constitute an in-vehicle network (e.g., a CAN) of the vehicle **100**.

[0045] MG **11***a* functions as a driving motor. The inverter **11***b* functions as a PCU (Power Control Unit for MG **11***a*). The inverter **11***b* drives MG **11***a* using the electric power supplied from the battery **21** of the battery pack **20**. MG **11***a* converts power to torques and rotates the drive wheels of the vehicles **100**. In addition, MG **11***a* performs regenerative power generation at the time of deceleration of the vehicles **100**, for example, and charges the batteries **21**.

[0046] Each of DC inlet **14***b* and AC inlet **15***b* has a terminal for detecting connection/disconnection of the charging cable (plug), and outputs a signal indicating whether or not the charging cable is connected to ECU **18***b*. ECU **18***a* acquires information indicating the inlet state from ECU **18***b*, and transmits a control command to ECU **18***c*. AC charger **15***a* performs AC/DC transformation. The plug-in charge of the batteries **21** is executed by cooperation of ECU **18***a* and **18***c*.

[0047] The vehicle body **10** further includes a HMI (Human Machine Interface) **19***a* and a communication device **19***b*. HMI **19***a* and the communication device **19***b* are also supplied with electric power from the auxiliary battery **17**. HMI **19***a* includes a notification device such as an inputting device and a displaying device provided in the vehicle cabin. HMI **19***a* may include a touch panel display. The input device outputs a signal corresponding to an input from the user to ECU **18***a*. The communication device **19***b* is configured to be capable of wirelessly communicating with the server **380** (FIG. **2**) described later. In addition, various sensors (typically referred to as in-vehicle sensor **19***c*) that are not illustrated are also mounted on the vehicle body **10**. ECU **18***a* is configured to acquire the detections of these sensors, either directly or via other ECU.

[0048] In this embodiment, HMI **19***a* includes an activation switch. The user of the vehicle **100** can activate or deactivate the control system (including ECU) of the vehicle **100** or turn the vehicle **100** Ready-ON or Ready-OFF by operating the activation switch.

[0049] Ready-ON state is a state in which the voltage of the battery **21** of the battery pack **20** connected to the vehicle body **10** is applied to the circuit CR**11** of the vehicle body **10**. In Ready-ON state, SMR **13** is in the closed state, SMR **23** of the battery pack **20** is also in the closed state, and electric power is supplied from the battery **21** corresponding to the closed state SMR **23** to the vehicle driving device (MG **11***a* and inverter **11***b*). Ready-OFF state is a state in which the voltage of the battery **21** is not applied to the circuit CR**11**. In Ready-OFF state, SMR **13** is in the open state, and no electric power is supplied to the vehicle-driven device from the battery **21** of the battery pack **20**.

[0050] The battery pack **20** mounted on the vehicle **100** can be replaced with another battery pack. FIG. **2** is a diagram illustrating an example of a configuration of a battery replacement system for replacing a battery pack. The battery replacement system **300** illustrated in FIG. **2** is mounted in, for example, a battery replacement station.

[0051] Referring to FIG. **2**, the battery replacement system **300** is configured to remove a battery pack mounted on the vehicle **100** from the vehicle body **10** and attach another battery pack to the vehicle body **10**.

[0052] Hereinafter, the battery pack collected from the vehicle **100** is referred to as a "battery pack B**1**", and the battery pack attached to the vehicle **100** instead of the battery pack B**1** is referred to as a "battery pack B**2**". Each of the battery pack B**1**, B**2** has the configuration of the battery pack shown in FIG. **1**. The battery pack B**2** after being attached to the vehicle body **10** functions as the battery pack **20** (FIG. **1**) in the vehicle **100**.

[0053] Specifically, the battery replacement system **300** includes a first storage device **310**, a second storage device **320**, a recovery device **330**, a filling device **340**, an replacement device **350**, a server **380**, and a display device **390**. The first storage device **310** stores a plurality of battery packs to be supplied to the vehicle. The first storage device **310** includes a charger and a supply device in addition to a pack storage unit (for example, a storage). The second storage device **320** stores a plurality of battery packs collected from a plurality of vehicles. The second storage device **320** includes an inspection device and a sorting device in addition to a pack storage unit (for example, a storage box). The server **380** includes a processor, a storage device, and a communication device, and functions as a control device. The storage device stores information (e.g., specification information) related to the respective battery packs present in the battery replacement system **300** separately by the identification information (pack ID) of the battery packs. The display device **390** displays information in accordance with an instruction from the server **380**.

[0054] Hereinafter, a battery replacement method will be described with reference to FIGS. **1** to **4**. FIG. **3** is a flowchart illustrating an example of a method of replacing a battery pack. FIG. **4** is a flowchart illustrating an example of the electric leakage determination process illustrated in FIG. **3**. For example, after the vehicles **100** are parked in a predetermined area in the battery-replacing station, ECU **18***a* starts S**14** process from S**10** shown in FIG. **3**. ECU **18***a* may initiate the process flow in response to a request from a terminal (user terminal) of the user of the vehicle **100** or a request from an inputting device in the vehicle **100**. ECU **18***a* and the server **380** are configured to be wirelessly communicable.

[0055] In step (hereinafter, step is referred to as "S") **11**, ECU **18***a* transmits a signal requesting replacement of the battery pack (hereinafter, referred to as "replacement request signal") to the server **380**. The replacement request signal includes identification information (vehicle ID) of the vehicle **100** and specification information of the battery pack **20** (battery pack B**1**) mounted on the vehicle **100**. The replacement request signal may include the specification information of the vehicle body **10** in place of or in addition to the specification information of the battery-pack B**1**.

[0056] In S**12**, ECU **18***a* determines whether or not the battery pack **20** has been replaced. The determination of S**12** is repeated until the replacement of the battery-pack **20** is completed (NO in S**12**).

[0057] Upon receiving the exchange-request signal, the server **380** starts S**33** process from S**31** of FIG. **3**.

[0058] In S**31**, the server **380** selects a battery pack that matches the specification of the vehicle **100** (the battery pack B**1** or the specification of the vehicle body **10**) indicated by the replacement request signal from among the battery packs (stocks) held by the first storage device **310**. If it is determined that there is no battery pack in stock that matches the specifications of the vehicle **100**, the server **380** may cause the display device **390** to display a message for explanation of the situation, and stop the battery replacement process. If S**31** selects a battery pack, the process is transferred to S**32**.

[0059] In S**32**, the server **380** controls the replacement device **350** so that the battery-pack B**1** is removed from the vehicle body **10**. Accordingly, the vehicle body **10** and the battery-pack B**1** are separated from each other. The process is then transferred to a S**33**.

[0060] In S**33**, the server **380** controls the charger of the first storage device **310** so that the battery-pack B**2** selected by S**31** is charged. However, the charging timing can be changed as appropriate. The charged battery pack may be filled in the first storage device **310**. When the charging is completed, the server **380** controls the supply device of the first storage device **310** so that the battery-pack B**2** is conveyed (supplied) from the first storage device **310** to the replacement device **350**. Subsequently, the server **380** controls the replacement device **350** so that the battery-pack B**2** is attached to the vehicle body **10**. At this time, SMR **23** of the attached battery-pack B**2** is opened. Thereafter, the server **380** transmits a signal indicating completion of the installation of the battery pack (hereinafter, referred to as a "replacement completion signal") to ECU **18***a*.
[0061] FIG. **2** illustrates an example in which removal of the battery pack and attachment of the battery pack are performed at different positions. The vehicle position may be adjusted prior to removal of the battery pack, prior to installation of the battery pack, or both. A conveyance device (for example, a conveyance device of a conveyor type) or a conveyance robot (not shown) may move the vehicle. However, the removal of the battery pack and the attachment of the battery pack may be performed at the same position. The battery pack may be replaced (removed and attached) while the vehicle is stationary. The transport method of each of the recovery device **330**, the supply device, and the filling device **340** is also arbitrary. These conveyance methods may be a conveyor method or a method using a conveyance robot. Note that the battery pack (power storage device) may be manually replaced by the user without communication between the battery replacement system (station) and the vehicle.
[0062] For example, when the battery pack B**2** is attached to the vehicle body **10**, the terminal T**11**, T**12** of the battery pack B**2** is connected to the terminal T**21**, T**22** of the vehicle body **10**. As a result, the vehicle body **10** and the battery pack B**2** are connected to each other as shown in FIG. **1**. By attaching the battery pack B**2** to the vehicle body **10**, a low-voltage power supply line (circuit CR**12**, CR**22**) and a communication line (communication line CL**1**, CL**2**) are connected between the vehicle body **10** and the battery pack B**2**. Then, in the battery-pack B**2**, S**24** process is started from S**21** shown in FIG. **3**.
[0063] In S**21**, ECU **28***a* is activated by electric power supplied from a power source (auxiliary battery **17**) in the vehicle body **10**. The process is then transferred to a S**22**.
[0064] In S**22**, ECU **28***a* transmits information indicating the state of the battery pack (hereinafter, referred to as "state information") to ECU **18***a*. The status information includes, for example, information about the present-day voltage of the battery **21** detected by BMS **22***a*. The voltage of the battery **21** may vary depending on SOC (State Of Charge of the battery **21**). SOC represents, for example, a ratio of the present amount of stored electricity to the amount of stored electricity in a fully charged state, from 0 to 100%. The process is then transferred to a S**23**.
[0065] In S**23**, ECU **28***a* determines whether or not a SMR on-command has been received from the vehicle body **10**. ECU **28***a* waits for a SMR on-command from the vehicle body **10** in S**23** while keeping SMR **23** open. When ECU **28***a* receives SMR on-command (YES in S**23**), the process proceeds to S**24**.
[0066] In S**24**, ECU **28***a* switches SMR **23** from the open state (shut-off state) to the closed state (connected state).
[0067] On the other hand, when the battery-pack B**2** is attached to the vehicle body **10**, ECU **18***a* receives a replacement completion signal (S**33**) from the server **380**. Accordingly, when it is determined that S**12** is YES, the process proceeds to S**13**.
[0068] In S**13**, ECU **18***a* determines whether the status data is received from ECU **28***a* of the battery-pack B**2**. When ECU **18***a* receives the status information from the battery pack (YES in S**13**), the process is transferred to S**14**.
[0069] In S**14**, ECU **18***a* executes the electric leakage determination process. Hereinafter, the leakage determination process will be described with reference to the flowchart of FIG. **4**.
[0070] In S**100**, ECU **18***a* acquires the resistance of the insulating resistance. For example, ECU

18*a* acquires the resistance of the insulating resistance from ECU **18***d*. The process is then transferred to a S**102**.

[0071] In S**102**, ECU **18***a* determines whether or not the resistance value of the insulating resistance obtained by S**100** is larger than the threshold value α. The threshold value α is a predetermined value for determining the presence or absence of an electric leakage, and is adapted by an experiment or the like. When it is determined that the resistance value of the insulation resistance is larger than the threshold value α (YES in S**102**), the process proceeds to S**104**.

[0072] At S**104**, ECU **18***a* turns on SMR **13**, **23**. Specifically, ECU **18***a* transmits a SMR on command to each of SMR **13** and ECU **28***a*. The process is then transferred to a S**106**.

[0073] In S**106**, ECU **18***a* acquires the resistance of the insulating resistance. For example, ECU **18***a* acquires the resistance of the insulating resistance from ECU **18***d*. The process is then transferred to a S**112**. If it is determined in S**102** that the resistance value of the insulating resistance is equal to or less than the threshold value α (NO in S**102**), the process proceeds to S**108**.

[0074] In S**108**, ECU **18***a* determines that there is an electric leakage in the vehicle body **10**. For example, ECU **18***a* sets a flag indicating that there is an electric leakage in the vehicle body **10** to an on-state. The process is then transferred to a S**110**.

[0075] In S**110**, ECU **18***a* performs a first fail-safe process. The first fail-safe process may include at least one of a process of controlling SMR **13** to be in the off state, a process of prohibiting SMR **13** from being switched to the on state, a process of controlling SMR **23** to be in the off state, and a process of prohibiting SMR **23** from being switched to the on state. For example, ECU **18***a* may execute the first fail-safe process on the condition that a flag indicating that there is an electric leakage is on the vehicle body **10**. The process is then terminated.

[0076] In S**112**, ECU **18***a* determines whether or not the resistance value of the insulating resistance obtained by S**106** is larger than the threshold value α. Since the threshold value α is as described above, the detailed description thereof will not be repeated. When it is determined that the resistance value of the insulation resistance is larger than the threshold value α (YES in S**112**), the process proceeds to S**114**.

[0077] In S**114**, ECU **18***a* determines that there is no electric leakage. The process is then terminated. For example, ECU **18***a* sets a flag indicating that there is no electric leakage on both the vehicle body side and the battery pack side to the ON-state. ECU **18***a* may allow the transition to Ready-On condition provided that the flag indicating no leakage is in the on-state. If it is determined in S**112** that the resistance value of the insulating resistance is equal to or less than the threshold value α (NO in S**112**), the process proceeds to S**116**.

[0078] In S**116**, ECU **18***a* determines that there is an electric leakage in the battery pack **20**. ECU **18***a* sets, for example, a flag indicating that the battery pack **20** is in an on-state. The process is then transferred to a S**118**.

[0079] In S**118**, ECU **18***a* performs a second fail-safe process. The second fail-safe process may include, for example, at least one of a process of controlling SMR **13** to an off state, a process of prohibiting the switching of SMR **13** to an on state, a process of controlling SMR **23** to an off state, and a process of prohibiting the switching of SMR **23** to an on state. The second fail-safe process may be the same process as the first fail-safe process or may be a different process. For example, ECU **18***a* may execute the second fail-safe process on the condition that a flag indicating that there is an electric leakage is turned on in the battery pack **20**. The process is then terminated.

[0080] As described above, according to the vehicle **100** of the present embodiment, it is possible to identify the cause of the electric leakage while detecting the presence or absence of the electric leakage by using the detection result of whether or not the resistance value of the insulation resistance in a state in which the battery pack **20** and the electric circuit on the vehicle body **10** side are connected is lower than the threshold value and the detection result of whether or not the resistance value of the insulation resistance in a state in which the battery pack **20** and the electric circuit on the vehicle body **10** side are disconnected is lower than the threshold value. Therefore, when an electric leakage is detected prior to turning on SMR **23** of the battery pack **20**, it can be determined that the electric leakage is caused by the electric circuit of the vehicle body **10**. Further, when it is determined that there is no electric leakage in the vehicle body **10** side and SMR **23** of the battery pack **20** is turned on and it is determined that there is an electric leakage, it is possible to specify that the cause of the electric leakage is caused by the battery pack **20** side. Therefore, it is possible to provide a vehicle that performs appropriate electric leakage detection in a vehicle equipped with a detachable battery.

[0081] Modification examples will be described below.

[0082] In the above-described embodiment, ECU **18***a* has been described as executing the first fail-safe process when it is determined that there is an electric leakage on the vehicle body **10** that the resistance value of the insulation resistance is equal to or less than the threshold value α when SMR **13**, **23** is in the off-state. However, ECU **18***a* may notify the user of the occurrence of an electric leakage in the vehicle body **10** using an HMI **19***a* including a notification device instead of or in addition to executing the first fail-safe process. The notification method may be, for example, a method of displaying the occurrence of an electric leakage in the vehicle body **10** using image information or character information, or a method of notifying the occurrence of an electric leakage in the vehicle body **10** using sound or the like. ECU **18***a* may cause the display device **390** to display information indicating that an electric leakage has occurred in the vehicle body **10** via the server **380**.

[0083] In this way, the user can recognize that the cause of the electric leakage is caused by the electric circuit on the vehicle body side.

[0084] Further, in the above-described embodiment, ECU **18***a* has been described as executing the second fail-safe process when SMR **13**, **23** is in the off state and when it is determined that there is an electric leakage in the battery pack **20** that the resistance value of the insulation resistance is equal to or less than the threshold value α when SMR **13**, **23** is in the on state. ECU **18***a* may notify the user of the occurrence of an electric leakage in the battery pack **20** using HMI **19***a* instead of or in addition to the execution of the second fail-safe process. HMI **19***a* includes a notification device. ECU **18***a* may cause the display device **390** to display information indicating that an electric leakage has occurred in the battery pack **20** via the server **380**.

[0085] In this way, it is possible to allow the user to recognize that the cause of the electric leakage is caused by the battery pack **20**.

[0086] Further, in the above-described embodiment, the case where one battery pack **20** is mounted on the vehicle **100** has been described as an example, but a plurality of battery packs **20** may be mounted on the vehicle **100**. In this case, a SMR **23** for connecting and disconnecting the electric circuitry of the vehicle body **10** is provided in each of the plurality of battery-packs **20**. ECU **18***a* changes the combination of the on-state and the off-state of SMR **23** in the plurality of battery packs **20** to detect the presence or absence of an electric leakage for each battery.

[0087] FIG. **5** is a diagram illustrating an example of a configuration of a vehicle **100** according to a modification. The vehicle **100** illustrated in FIG. **5** differs from the vehicle **100** illustrated in FIG. **1** in that the battery pack **20** includes a battery pack **20**A, **20**B and a parallel-circuit CR**13** that connects the battery pack **20**A, **20**B to SMR **13** in parallel. The battery pack **20**A, **20**B has the same configuration as that of the battery pack **20**. Therefore, the detailed description thereof will not be repeated.

[0088] An example of the electric leakage determination process executed in the vehicle **100** will be described below. FIG. **6** is a flowchart illustrating an example of the electric leakage determination process according to the modification. The process illustrated in the flowchart of FIG. **6** is executed, for example, as a S**14** leakage determination process in the flowchart of FIG. **3**.

[0089] In S**200**, ECU **18***a* acquires the resistance of the insulating resistance from ECU **18***d*. The process is then transferred to a S**202**.

[0090] In S**202**, ECU **18***a* determines whether or not the resistance value of the insulating resistance obtained by S**100** is larger than the threshold value α. When it is determined that the resistance value of the insulation resistance is larger than the threshold value α (YES in S**202**), the process proceeds to S**204**.

[0091] In S**204**, ECU **18***a* sets SMR **23** of the battery-pack **20**A to the on-state. The process is then transferred to a S**206**.

[0092] In S**206**, ECU **18***a* acquires the resistance of the insulating resistance from ECU **18***d*. The process is then transferred to a S**212**. If it is determined that the resistance value of the insulating resistance acquired by S**100** is equal to or less than the threshold value α (NO in S**202**), the process proceeds to S**208**.

[0093] In S**208**, ECU **18***a* determines that there is an electric leakage in the vehicle body **10**. The process is then transferred to a S**210**.

[0094] In S**210**, ECU **18***a* performs a first fail-safe process. Since the first fail-safe process is as described above, the detailed description thereof will not be repeated. The process is then terminated.

[0095] In S**212**, ECU **18***a* determines whether or not the resistance value of the insulating resistance obtained by S**206** is larger than the threshold value α. When it is determined that the resistance value of the insulation resistance is larger than the threshold value α (YES in S**212**), the process proceeds to S**214**.

[0096] In S**214**, ECU **18***a* sets SMR **23** of the battery-pack **20**B to the on-state. The process is then transferred to a S**216**.

[0097] In S**216**, ECU **18***a* acquires the resistance of the insulating resistance from ECU **18***d*. The process is then transferred to a S**222**. If it is determined that the resistance value of the insulating resistance acquired by S**212** is equal to or less than the threshold value α (NO in S**212**), the process proceeds to S**218**.

[0098] In S**218**, ECU **18***a* determines that there is an electric leakage in the battery-pack **20**A. The process is then transferred to a S**220**.

[0099] In S**220**, ECU **18***a* performs a second fail-safe process. The second fail-safe process may include, for example, at least one of a process of controlling SMR **13** to the off state, a process of prohibiting the switching of SMR **13** to the on state, a process of controlling SMR **23** of the battery pack **20**A to the off state, and a process of prohibiting the switching of SMR **23** of the battery pack **20**A to the on state. The process is then terminated.

[0100] In S**222**, ECU **18***a* determines whether or not the resistance value of the insulating resistance obtained by S**216** is larger than the threshold value α. When it is determined that the resistance value of the insulation resistance is larger than the threshold value α (YES in S**222**), the process proceeds to S**224**.

[0101] In S**224**, ECU **18***a* determines that there is no electric leakage. The process is then terminated. If it is determined that the resistance value of the insulating resistance acquired by S**216** is equal to or less than the threshold value α (NO in S**222**), the process proceeds to S**226**.

[0102] In S**226**, ECU **18***a* determines that there is an electric leakage in the battery-pack **20**B. The process is then transferred to a S**228**.

[0103] In S**228**, ECU **18***a* performs a third fail-safe process. The third fail-safe process may include, for example, at least one of a process of controlling SMR **13** to the off state, a process of prohibiting the switching of SMR **13** to the on state, a process of controlling SMR **23** of the battery pack **20**B to the off state, and a process of prohibiting the switching of SMR **23** of the battery pack **20**B to the on state. The process is then terminated.

[0104] In this way, in vehicles equipped with a plurality of battery packs (battery pack **20**A, **20**B), the presence or absence of an electric leakage is detected for each battery pack by changing the combination of the on-state and the off-state of SMR **13**, **23**. As a result, it is possible to accurately identify which battery pack is generating an electric leakage. The number of battery packs **20** mounted on the vehicle **100** is not limited to two, and three or more battery packs **20** may be

mounted.
[0105] Note that, in this modification, when the resistance of the insulating resistance is larger than the threshold value α, SMR **23** of the battery pack **20**B is set in the ON state while SMR **23** of the battery pack **20**A is kept in the ON state. However, for example, after SMR **23** of the battery pack **20**A is turned off, SMR **23** of the battery pack **20**B may be turned on. Alternatively, the resistance value of the insulation resistance may be obtained by first turning on SMR **23** of the battery pack **20**B to obtain the resistance value of the insulation resistance, and when the resistance value is larger than the threshold value α, SMR **23** of the battery pack **20**A may be turned on to obtain the resistance value of the insulation resistance to detect the presence or absence of an electric leakage.
[0106] Further in the above embodiment has been described as an example when the execution subject of the electric leakage determination process including the switching of SMR **13**, **23** is ECU **18***a*. However, the execution subject of the leakage determination process or the switching subject of SMR **13**, **23** is not limited to ECU **18***a*. The execution subject of the leakage determination process or the switching subject of SMR **13**, **23** may be, for example, an ECU **18***d* or another ECU mounted on the vehicle body **10**.
[0107] Further, the configuration of the vehicle body **10** illustrated in FIG. **1** or FIG. **5** can be changed as appropriate. For example, SMR **13** of the vehicle body **10** may be omitted, or SMR **23** of the battery-pack **20**, **20**A, **20**B may be omitted. In addition, at least one of DC inlet **14***b* and AC inlet **15***b* may be omitted, or may be changed to one inlet shared by AC/DC. These inlets may be configured to be capable of bidirectional power transfer. The vehicle body may perform an external power supply (V2X: Vehicle to Everything) using the electric power outputted from the attached battery pack.
[0108] All or some of the above-mentioned modified examples may be combined for implementation.
[0109] It should be considered that the embodiments disclosed above are for illustrative purposes only and are not limitative of the disclosure in any aspect. The scope of the disclosure is represented by the appended claims, not by the above description, and includes all modifications within the meanings and scope equivalent to the claims.

Claims

1. A vehicle comprising: a vehicle body; a battery detachable from the vehicle body; and a detection device provided to an electric circuit on the vehicle body side and configured to detect whether an electric leakage has occurred, wherein the detection device is configured to detect whether the electric leakage has occurred in at least one of a conductive state in which the battery and the electric circuit are connected and a disconnected state in which the battery and the electric circuit are disconnected.
2. The vehicle according to claim 1, wherein the detection device is configured to detect whether the electric leakage of the electric circuit has occurred in the disconnected state and, when the electric leakage is not detected, detect whether the electric leakage has occurred in the conductive state.
3. The vehicle according to claim 1, wherein: the vehicle body is configured such that a plurality of the batteries is mountable; each of the batteries includes a relay configured to connect or disconnect the electric circuit; and the detection device is configured to change a combination of an ON state and an OFF state of the relays of the batteries and detect whether the electric leakage has occurred in each of the batteries.
4. The vehicle according to claim 1, further comprising a notification device configured to give a notification about occurrence of the electric leakage in the vehicle body when the detection device has detected the electric leakage of the electric circuit in the disconnected state.
5. The vehicle according to claim 1, further comprising a notification device configured to give a

notification about occurrence of the electric leakage in the battery when the detection device has not detected the electric leakage of the electric circuit in the disconnected state and has detected the electric leakage of the electric circuit in the conductive state.