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(54) **VEHICLE**

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(57) **ABSTRACT**

ECU executes a process including a step of determining that there is an electric leakage in the battery pack when the resistance value of the insulation resistance of the battery pack of each battery pack is equal to or less than the threshold value (NO in S**102**), and a step of determining that there is an electric leakage in the vehicle body (S**106**) when the resistance value of the insulation resistance of any of the battery packs is greater than the threshold value (YES in S**102**) and the resistance value of the insulation resistance of the vehicle body is equal to or less than the threshold value (S**114**).

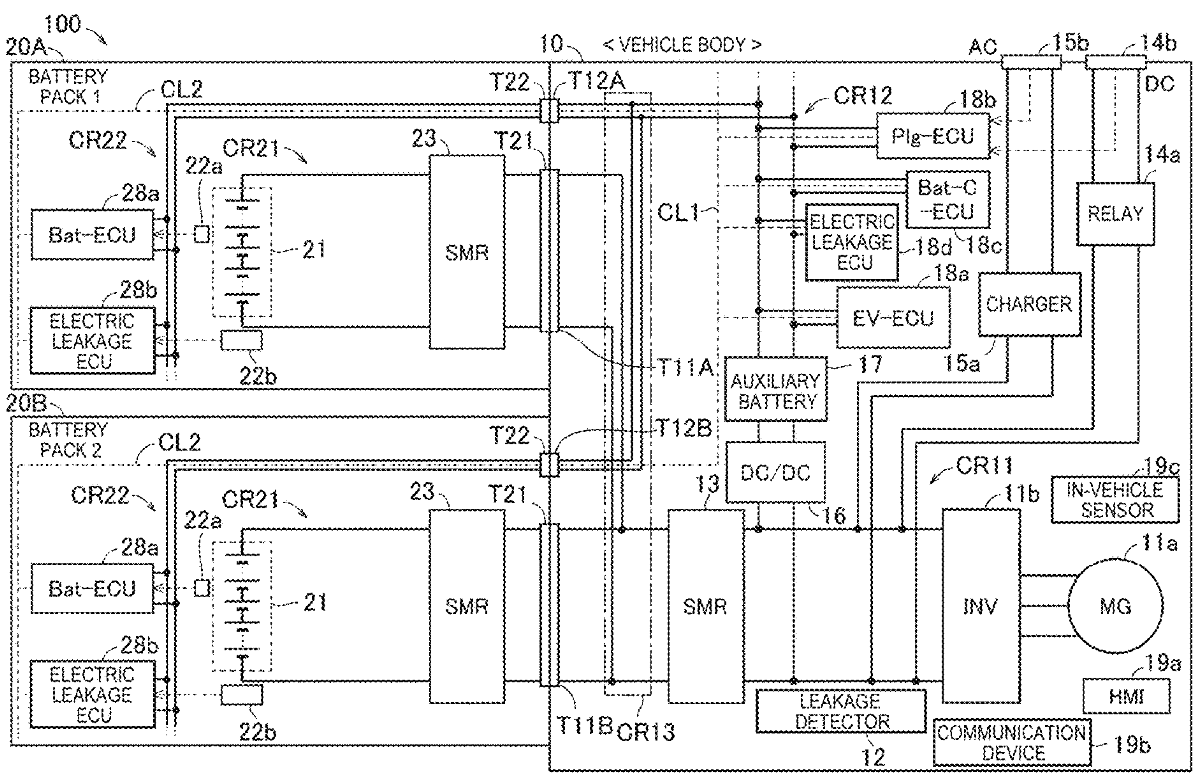


FIG. 1

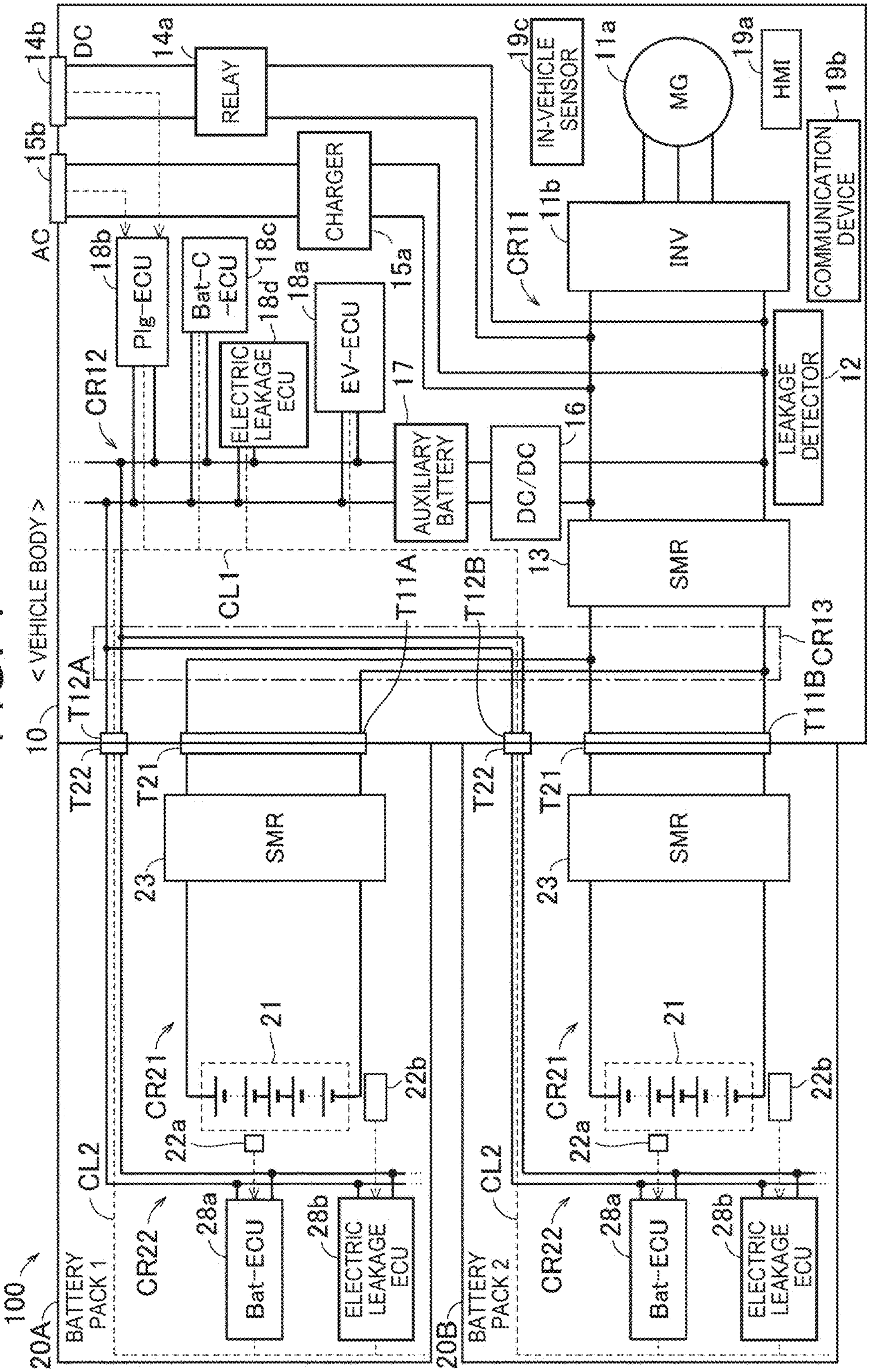

< VEHICLE BODY >
10
100
DC
AC
14b
15b
14a
RELAY
CHARGER
15a
Plg-ECU
18b
Bat-C -ECU
18c
18d
18a
ELECTRIC LEAKAGE ECU
EV-ECU
17
AUXILIARY BATTERY
DC/DC
16
SMR
13
CR11
CR12
CR13
CL1
T11A
T12B
T12A
T11B
19c
IN-VEHICLE SENSOR
11a
MG
19a
HMI
19b
COMMUNICATION DEVICE
11b
INV
LEAKAGE DETECTOR
12
20A
BATTERY PACK 1
20B
BATTERY PACK 2
T22
T21
SMR
23
21
CR21
CR22
22a
22b
CL2
28a
Bat-ECU
28b
ELECTRIC LEAKAGE ECU

FIG. 2

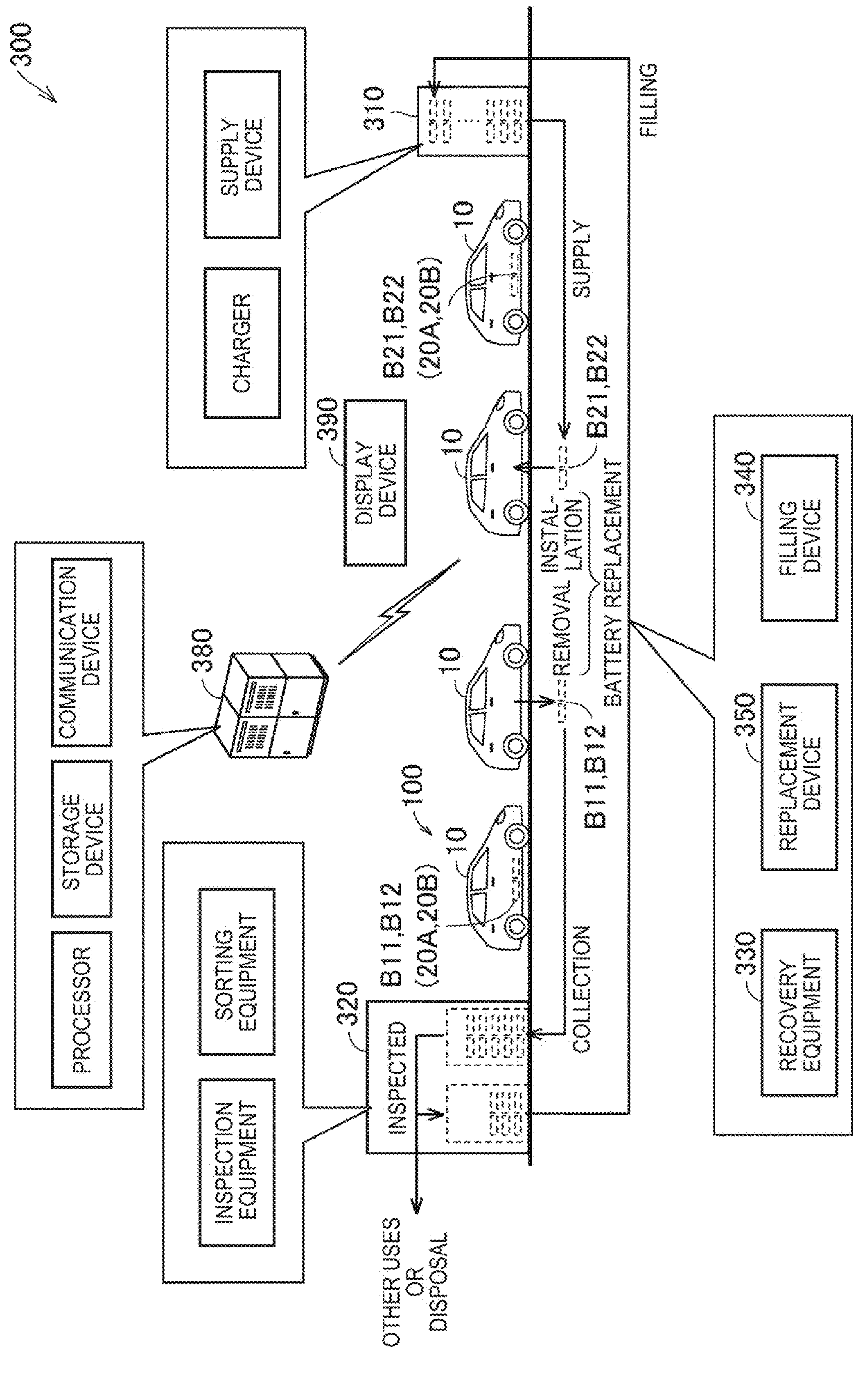

300
SUPPLY DEVICE
CHARGER
310
FILLING
SUPPLY
10
B21,B22
(20A,20B)
390
DISPLAY DEVICE
B21,B22
INSTAL-LATION
REMOVAL
BATTERY REPLACEMENT
340
FILLING DEVICE
350
REPLACEMENT DEVICE
330
RECOVERY EQUIPMENT
380
PROCESSOR
STORAGE DEVICE
COMMUNICATION DEVICE
100
B11,B12
B11,B12
(20A,20B)
320
INSPECTED
COLLECTION
INSPECTION EQUIPMENT
SORTING EQUIPMENT
OTHER USES OR DISPOSAL

FIG. 3

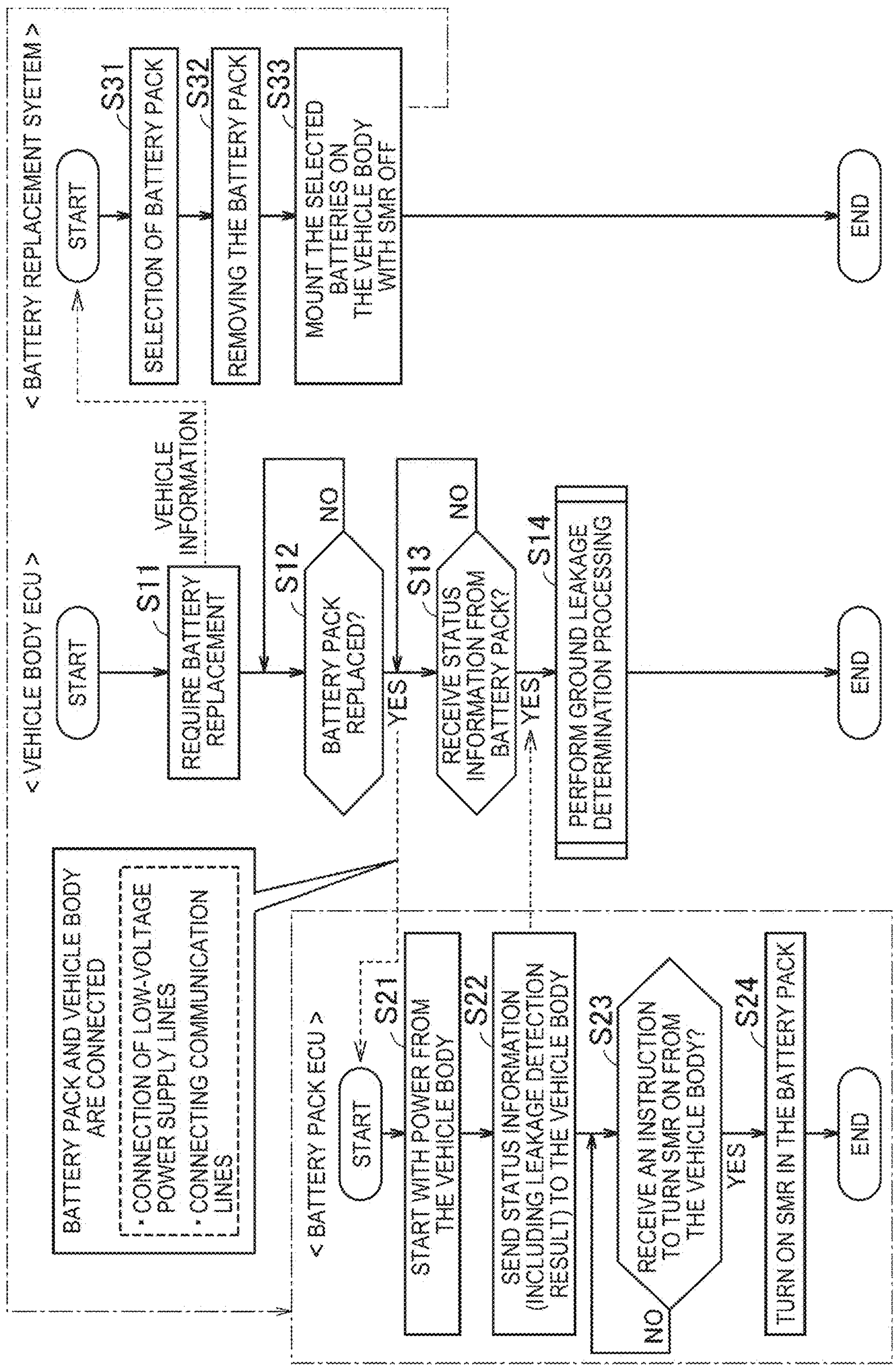

< VEHICLE BODY ECU >
START
S11
REQUIRE BATTERY REPLACEMENT
VEHICLE INFORMATION
S12
BATTERY PACK REPLACED?
NO
YES
S13
RECEIVE STATUS INFORMATION FROM BATTERY PACK?
NO
YES
S14
PERFORM GROUND LEAKAGE DETERMINATION PROCESSING
END
< BATTERY REPLACEMENT SYETEM >
START
S31
SELECTION OF BATTERY PACK
S32
REMOVING THE BATTERY PACK
S33
MOUNT THE SELECTED BATTERIES ON THE VEHICLE BODY WITH SMR OFF
END
BATTERY PACK AND VEHICLE BODY ARE CONNECTED
· CONNECTION OF LOW-VOLTAGE POWER SUPPLY LINES
· CONNECTING COMMUNICATION LINES
< BATTERY PACK ECU >
START
S21
START WITH POWER FROM THE VEHICLE BODY
S22
SEND STATUS INFORMATION (INCLUDING LEAKAGE DETECTION RESULT) TO THE VEHICLE BODY
S23
RECEIVE AN INSTRUCTION TO TURN SMR ON FROM THE VEHICLE BODY?
NO
YES
S24
TURN ON SMR IN THE BATTERY PACK
END

FIG. 4

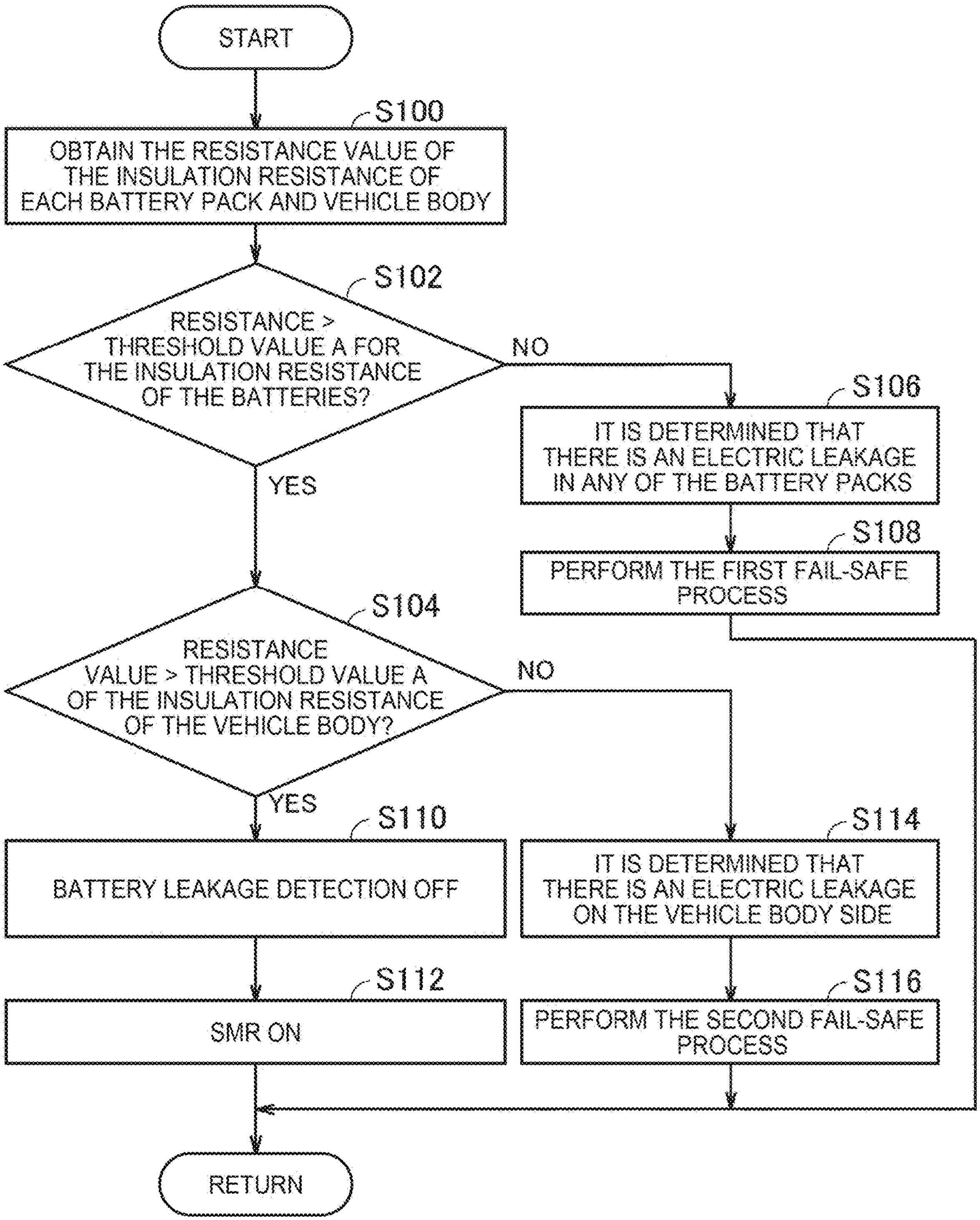

START
S100
OBTAIN THE RESISTANCE VALUE OF THE INSULATION RESISTANCE OF EACH BATTERY PACK AND VEHICLE BODY
S102
RESISTANCE > THRESHOLD VALUE A FOR THE INSULATION RESISTANCE OF THE BATTERIES?
NO
YES
S106
IT IS DETERMINED THAT THERE IS AN ELECTRIC LEAKAGE IN ANY OF THE BATTERY PACKS
S108
PERFORM THE FIRST FAIL-SAFE PROCESS
S104
RESISTANCE VALUE > THRESHOLD VALUE A OF THE INSULATION RESISTANCE OF THE VEHICLE BODY?
NO
YES
S110
BATTERY LEAKAGE DETECTION OFF
S114
IT IS DETERMINED THAT THERE IS AN ELECTRIC LEAKAGE ON THE VEHICLE BODY SIDE
S112
SMR ON
S116
PERFORM THE SECOND FAIL-SAFE PROCESS
RETURN

FIG. 5

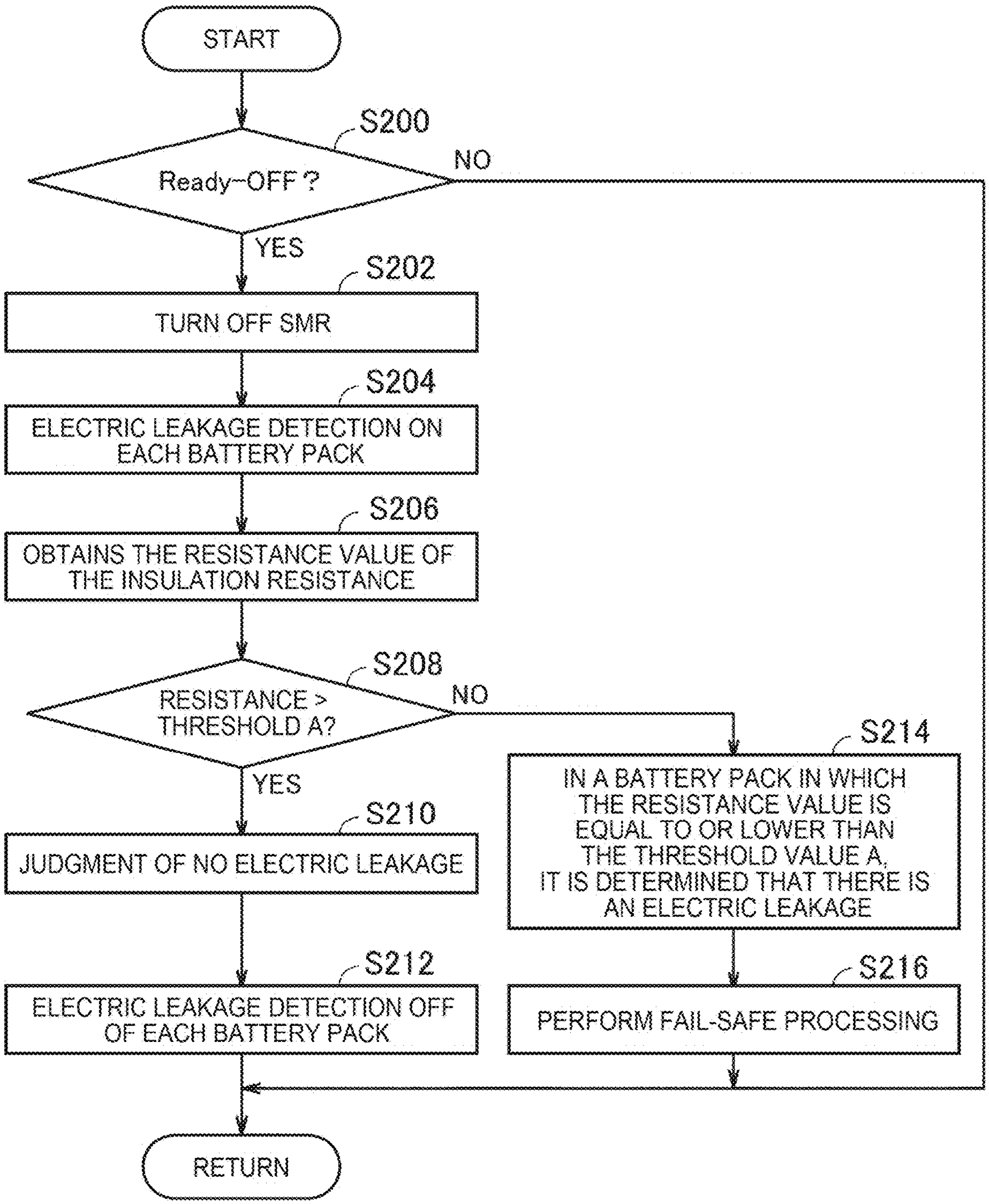
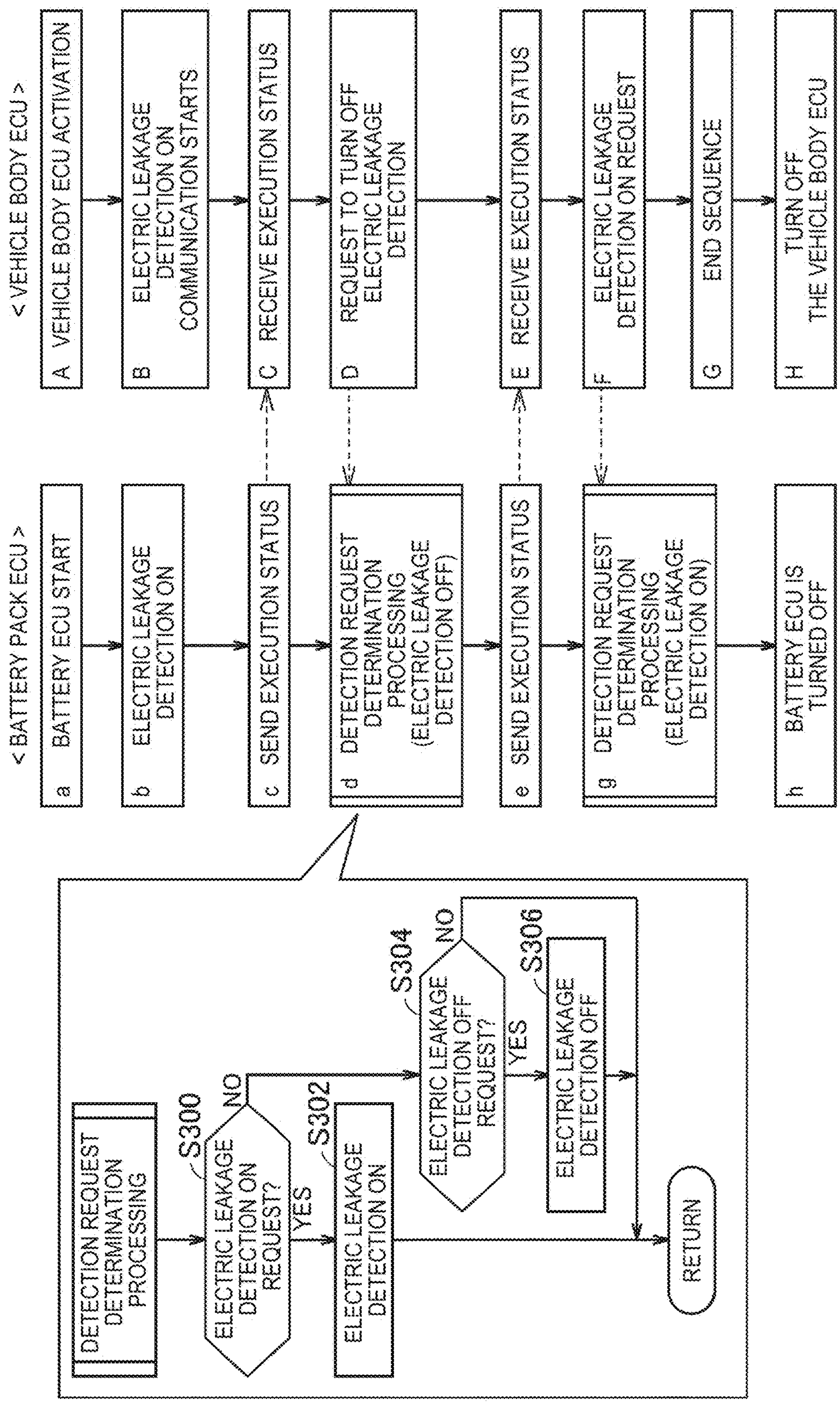

START
S200
Ready-OFF?
NO
YES
S202
TURN OFF SMR
S204
ELECTRIC LEAKAGE DETECTION ON EACH BATTERY PACK
S206
OBTAINS THE RESISTANCE VALUE OF THE INSULATION RESISTANCE
S208
RESISTANCE > THRESHOLD A?
NO
YES
S210
JUDGMENT OF NO ELECTRIC LEAKAGE
S212
ELECTRIC LEAKAGE DETECTION OFF OF EACH BATTERY PACK
S214
IN A BATTERY PACK IN WHICH THE RESISTANCE VALUE IS EQUAL TO OR LOWER THAN THE THRESHOLD VALUE A, IT IS DETERMINED THAT THERE IS AN ELECTRIC LEAKAGE
S216
PERFORM FAIL-SAFE PROCESSING
RETURN

FIG. 6


< BATTERY PACK ECU >
a BATTERY ECU START
b ELECTRIC LEAKAGE DETECTION ON
c SEND EXECUTION STATUS
d DETECTION REQUEST DETERMINATION PROCESSING (ELECTRIC LEAKAGE DETECTION OFF)
e SEND EXECUTION STATUS
g DETECTION REQUEST DETERMINATION PROCESSING (ELECTRIC LEAKAGE DETECTION ON)
h BATTERY ECU IS TURNED OFF
< VEHICLE BODY ECU >
A VEHICLE BODY ECU ACTIVATION
B ELECTRIC LEAKAGE DETECTION ON COMMUNICATION STARTS
C RECEIVE EXECUTION STATUS
D REQUEST TO TURN OFF ELECTRIC LEAKAGE DETECTION
E RECEIVE EXECUTION STATUS
F ELECTRIC LEAKAGE DETECTION ON REQUEST
G END SEQUENCE
H TURN OFF THE VEHICLE BODY ECU
DETECTION REQUEST DETERMINATION PROCESSING
S300
ELECTRIC LEAKAGE DETECTION ON REQUEST?
YES
NO
S302
ELECTRIC LEAKAGE DETECTION ON
S304
ELECTRIC LEAKAGE DETECTION OFF REQUEST?
YES
NO
S306
ELECTRIC LEAKAGE DETECTION OFF
RETURN

VEHICLE

CROSS-REFERENCE TO RELATED APPLICATION

[0001] This application claims priority to Japanese Patent Application No. 2024-020158 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 replaceable battery.

2. Description of Related Art

[0003] Japanese Unexamined Patent Application Publication No. 2015-082350 (JP 2015-082350 A), for example, discloses a configuration in which a battery management device provided in a battery pack is communicably connected to various electronic control devices on the vehicle side via a Controller Area Network (CAN) communication network and transmits information that indicates a result of detecting an electric leakage and the like.

SUMMARY

[0004] In a vehicle equipped with a replaceable battery, however, a plurality of electric leakage detection devices that detects an electric leakage may be mounted on the battery side and the vehicle side, for example. Therefore, when detection of an electric leakage is performed in parallel by the electric leakage detection devices, there is a case where an electric leakage cannot be appropriately detected due to interference with each other.

[0005] The present disclosure has been made to address the above issue, and an object thereof is to provide a vehicle that appropriately detects an electric leakage when a plurality of electric leakage detection devices is mounted.

[0006] A certain aspect of the present disclosure provides a vehicle including: a vehicle body; a battery detachable from the vehicle body; a first detection device provided in the battery to detect presence or absence of an electric leakage; and a second detection device provided on the vehicle body to detect presence or absence of an electric leakage. Each of the first detection device and the second detection device detects the presence or absence of the electric leakage when in a first state in which the battery and an electric device of the vehicle body are electrically disconnected from each other. The second detection device detects the presence or absence of the electric leakage when in a second state in which the battery and the electric device are electrically connected to each other.

[0007] In this way, the first detection device and the second detection device detect the presence or absence of an electric leakage in each of the battery and the electric device of the vehicle body in the first state, and the second detection device detects the presence or absence of an electric leakage in the battery and the electric device of the vehicle body in the second state. Therefore, detection of an electric leakage is executed according to the state of attachment and detachment of the battery, making it possible to specify the location where an electric leakage occurs while avoiding interference. Thus, it is possible to appropriately detect an electric leakage when a plurality of electric leakage detection devices is mounted.

[0008] In a certain embodiment, the second detection device may detect the presence or absence of the electric leakage when in the second state and while detection of the presence or absence of the electric leakage by the first detection device is stopped.

[0009] In this way, it is possible to detect an electric leakage using the second detection device by avoiding interference of other detection devices.

[0010] In another certain embodiment, the vehicle may further include a control device that acquires information about a detection result of the presence or absence of the electric leakage from the first detection device and the second detection device. When in the second state, the control device may acquire an execution status of detection of the electric leakage. The control device may either request detection of the electric leakage by the first detection device or request stop of detection of the electric leakage using the acquired execution status.

[0011] In this way, it is possible to detect an electric leakage with high accuracy by avoiding interference between the electric leakage detection by the first detection device and the electric leakage detection by the second detection device.

[0012] According to the present disclosure, it is possible to provide a vehicle that appropriately detects an electric leakage when a plurality of electric leakage detection devices is mounted.

BRIEF DESCRIPTION OF THE DRAWINGS

[0013] Features, advantages, and technical and industrial significance of exemplary embodiments of the disclosure will be described below with reference to the accompanying drawings, in which like signs denote like elements, and wherein:

[0014] FIG. **1** is a diagram illustrating an example of a configuration of a vehicle according to the present embodiment;

[0015] FIG. **2** is a diagram illustrating an example of a configuration of a battery replacement system for replacing a battery pack;

[0016] FIG. **3** is a flowchart illustrating an example of a method of replacing a battery pack;

[0017] FIG. **4** is a flowchart illustrating an example of the electric leakage determination process of FIG. **3**;

[0018] FIG. **5** is a flow chart illustrating an exemplary leakage determination process at the time of Ready-Off; and

[0019] FIG. **6** is a flowchart illustrating an example of a process of setting a state of electric leakage detection.

DETAILED DESCRIPTION OF EMBODIMENTS

[0020] 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.

[0021] FIG. **1** is a diagram illustrating an example of a configuration of a vehicle **100** according to the present embodiment. Referring to FIG. **1**, a vehicle **100** includes a vehicle body **10** and a battery-pack **20**A, **20**B. The vehicle body **10** is a part of the vehicle **100** other than the battery-pack **20**A, **20**B. The vehicle body **10** includes a vehicle driving device serving as a driving source. Vehicle-driven devices include Motor Generator (MG) **11***a* and inverters **11***b*. The vehicle driving device is configured to drive the vehicle **100** using the electric power outputted from each of the battery-pack **20**A, **20**B. The battery-pack **20**A and **20**B are configured to be connectable in parallel to the inverter **11***b*. Vehicle **100** is, for example, a battery electric vehicle that does 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. In this embodiment, since the battery pack **20**A and **20**B have the same configuration, they are referred to as "battery pack **20**" in the following cases where they are not distinguished from each other.

[0022] The vehicle body **10** includes a circuit CR**11** and a CR**12**. The battery-pack **20** includes a circuit CR**21** and a circuit 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**.

[0023] 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**. The circuit CR**21** in the battery pack **20** is provided with a Battery Management System (BMS) **22***a* and a leakage detector **22***b*.

[0024] The vehicle body **10** further includes a terminal T**11**A to which the battery pack **20**A is detachable, and a terminal T**11**B to which the battery pack **20**B is detachable. The vehicle body **10** further includes a parallel circuit CR **13** that connects the terminal T**11**A and the terminal T**11**B in parallel, and a System Main Relay (SMR) **13** disposed between the parallel circuit CR **13** and the vehicle driving device (inverter **11***b*). The circuit CR**11** is connected to each of the terminals T**11**A, T**11**B via SMR **13** and the parallel circuit CR**13**. Each of the battery-pack **20**A, **20**B includes a terminal T**21** to which the vehicle body **10** is detachable, and a SMR **23** disposed between the terminal T**21** and the circuit CR**21**. The circuit CR**21** is connected to the terminal T**21** via a SMR **23**.

[0025] The terminal T**21** of the battery-pack **20**A is connected to the terminal T**11**A of the vehicle body **10**. In the battery pack **20**A, SMR **23** of the battery pack **20**A is disposed between the terminal T**21** and the battery **21**. The terminal T**21** of the battery-pack **20**B is connected to the terminal T**11**B of the vehicle body **10**. In the battery pack **20**B, SMR **23** of the battery pack **20**B is disposed between the terminal T**21** and the battery **21**. The relays enable easy and appropriate switching of connection/disconnection between the inverter **11***b* and each of the battery-pack **20**A, **20**B.

[0026] The vehicle body **10** further includes a terminal T**12**A to which the battery pack **20**A is detachable, and a terminal T**12**B to which the battery pack **20**B is detachable. The circuit CR**12** in the vehicle body **10** is connected to each of the terminals T**12**A, T**12**B via a parallel circuit CR**13**. The parallel-circuit CR**13** connects the terminal T**12**A and the terminal T**12**B in parallel. A communication line CL**1** (a broken line in FIG. **1**) in the vehicle body **10** is also connected to each of the terminal T**12**A, T**12**B. Each of the battery-pack **20**A, **20**B further includes a terminal T**22**. In each of the battery-pack **20**A, **20**B, the circuit CR**22** and the communication line CL**2** (the broken line in FIG. **1**) are connected to the terminal T**22**.

[0027] 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**. The circuit CR**12** further includes ECUs **18***a*, **18***b*, **18***c*, **18***d* in addition to the auxiliary battery **17**. The circuit CR**22** further includes ECUs **28***a*, **28***b*. The auxiliary battery **17** supplies power to each of **18***d*, ECUs **28***a*, **28***b* from, for example, the ECU **18***a* connected to the low-voltage power supply line.

[0028] 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 (first leakage ECU) that monitors the electric leakage status of the circuit CR**11**. ECU **28***a* corresponds to a control device (Bat-ECU) that monitors the status of the battery **21** and controls SMR **23**. ECU **28***b* corresponds to a control device (second leakage ECU) that monitors the electric leakage status of the circuit CR**21**.

[0029] 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.

[0030] In the vehicle **100**, ECUs are communicatively connected to each other via an in-vehicle network (e.g., a CAN). ECU **18***a* obtains information from other ECUs, 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*.

[0031] The leakage detector **12** detects a leakage condition (e.g., an isolation resistor) of the circuit CR**11**, and outputs the detected condition 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*. The leakage detector **22***b* detects a leakage condition of the circuit CR**21**, and outputs the detected condition to ECU **28***b*. ECU **18***a* acquires information indicating a battery state and a leakage state from ECUs **18***d*, **28***a*, **28***b*.

[0032] 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 battery **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**.

[0033] The battery pack **20**A and/or the battery pack **20**B are/is attached to the vehicle body **10** by connecting the terminals T21, T22 of the battery pack 20A to the terminals T11A, T12A or connecting the terminals T21, T22 of the battery pack 20B to the terminals T11B, T12B, thereby configuring the vehicle 100. In the vehicle 100, a communication line CL1 of the vehicle body 10, a communication line CL2 of the battery pack 20A, and a communication line CL2 of the battery pack 20B are connected. These communication lines constitute an in-vehicle network of the vehicle 100.

[0034] 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 ECUs 18*a* and 18*c*.

[0035] The vehicle body 10 further includes a Human Machine Interface (HMI) 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 an input device and a display 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 servers 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 ECUs.

[0036] In this embodiment, HMI 19*a* includes an activation switch. In general, the activation switch is referred to as a "power switch" or an "ignition switch" or the like. 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.

[0037] Ready-ON state is a state in which the voltage of at least one battery 21 of the battery pack 20A, 20B connected to the vehicle body 10 is applied to the circuit CR11 of the vehicle body 10. In Ready-ON state, SMR 13 is in the closed state, and at least one SMR 23 of the battery-pack 20A, 20B is also in the closed state. Power is supplied from the batteries 21 corresponding to the closed SMR 23 to the vehicle-driven devices (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 CR11. In Ready-OFF state, SMR 13 is in the open state, and no electric power is supplied to the vehicle-driven device from any of the batteries 21 in the battery-pack 20A, 20B.

[0038] The battery pack 20A, 20B mounted on the vehicles 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 shown in FIG. 2 is implemented in, for example, a battery exchange station.

[0039] 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. Two battery packs (battery pack 20A and 20B) are simultaneously removed from the vehicle 100, and two alternative battery packs are simultaneously attached to the vehicle 100. However, the present disclosure is not limited thereto, and the battery-pack 20A, 20B may be replaced one by one in order. In addition, the replacement of the battery pack includes cases where only one battery pack is mounted at the mounting position of either the battery pack 20A or the battery pack 20B after the two battery packs are removed.

[0040] Hereinafter, the two battery packs collected from the vehicle 100 are referred to as "battery pack B11, B12", and the two battery packs attached to the vehicle 100 instead of the battery packs B11, B12 are referred to as "battery packs B21, B22". Each of the battery packs B11, B12, B21, B22 has a configuration of the battery pack shown in FIG. 1. The battery packs B21, B22 function as battery packs 20A, 20B (FIG. 1) in the vehicles 100.

[0041] 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, a 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 unit). 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 the pack accommodating portion. 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.

[0042] 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. After the vehicles 100 are parked in a predetermined area in the battery-replacing station, ECU 18*a* starts S14 process from S11 shown in FIG. 3. The processing flow may be started in response to a request from a terminal (user terminal) of the user of the vehicle 100 or an input device in the vehicle 100. ECU 18*a* and servers 380 are configured to be wirelessly communicable.

[0043] In step (hereinafter, step is referred to as "S") 10, ECU 18*a* transmits a signal requesting replacement of the battery pack (hereinafter, referred to as "replacement request signal") to the servers 380. The replacement request signal includes identification information (vehicle ID) of the vehicle 100 and specification information of battery packs (battery pack B11, B12) 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 B11, B12.

[0044] In S12, ECU 18*a* determines whether or not the battery-pack has been replaced. While the replacement of the batteries is not completed (NO in S12), the determination of S12 is repeatedly performed.

[0045] Upon receiving the exchange-request signal, the server **380** starts S**33** process from S**31** of FIG. **3**.

[0046] In S**31**, the server **380** selects a battery pack (stock) stored in the first storage device **310** that matches the specification of the vehicle **100** indicated by the replacement request signal. When it is determined that the battery pack that meets the specifications of the vehicle **100** is not in stock, the server **380** may cause the display device **390** to display a predetermined message and stop the battery replacement process. If S**31** selects a battery pack, the process is transferred to S**32**.

[0047] In S**32**, the servers **380** control the replacement device **350** so that the battery-pack B**11**, B**12** is removed from the vehicle body **10**. Accordingly, the vehicle body **10** and the battery-pack B**11**, B**12** are separated from each other. The process is then transferred to a S**33**.

[0048] In S**33**, the servers **380** control the charger of the first storage device **310** so that the battery-pack B**21** or B**22** 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 servers **380** control the supply device of the first storage device **310** so that the battery-pack B**21** or B**22** is conveyed (supplied) from the first storage device **310** to the replacement device **350**. Subsequently, the servers **380** control the replacement device **350** so that the battery-pack B**21** or B**22** is attached to the vehicle body **10**. At this time, SMR **23** of the attached battery-pack B**21** or B**22** 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*.

[0049] 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. Removal of the battery pack and 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.

[0050] For example, when the battery pack B**21**, B**22** is attached to the vehicle body **10**, the terminal T**21**, T**22** of the battery pack B**21** are connected to the terminal T**11**A, T**12**A of the vehicle body **10**, and the terminal T**21**, T**22** of the battery pack B**22** are connected to the terminal T**11**B, T**12**B of the vehicle body **10**, so that the connection shown in FIG. **1** is established. When the battery pack B**21**, B**22** is attached to the vehicle body **10**, the circuit CR**12**, CR**22** and the communication line CL**1**, CL**2** are connected between the vehicle body **10** and each of the battery packs B**21**, B**22**. Then, in each of the battery-pack B**21**, B**22**, S**24** process is started from S**21** shown in FIG. **3**.

[0051] 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**.

[0052] 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 voltage of the battery **21** detected by BMS **22***a*. Note that the state information may include information about the leakage detection result (leakage state) detected by the leakage detector **22***b* and the leakage ECU **28***b*. The voltage of the battery **21** may vary depending on State Of Charge (SOC 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**.

[0053] 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**.

[0054] In S**24**, ECU **28***a* switches SMR **23** from the open state (shut-off state) to the closed state (connected state).

[0055] On the other hand, when the battery-pack B**21**, B**22** is attached to the vehicle body **10**, ECU **18***a* receives a replacement completion signal (S**33**) from the servers **380**. As a result, it is determined that S**12** is YES, and the process proceeds to S**13**.

[0056] In S**13**, ECU **18***a* determines whether the status data is received from ECU **28***a* of the battery-pack B**21** or B**22**. When ECU **18***a* receives the status information from the battery pack (YES in S**13**), the process is transferred to S**14**.

[0057] 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**.

[0058] In S**100**, ECU **18***a* acquires the resistance values of the respective battery-packs **20**A, **20**B and the insulation resistance of the vehicle body **10**. ECU **18***a* may acquire the resistance value of the insulation resistance from the status information received from ECU **28***a* of the battery-pack **20**A, **20**B, or may acquire the resistance value of the insulation resistance from ECU **28***b*. Further, ECU **18***a* acquires the resistance of the insulation resistance of the vehicle body **10** from ECU **18***d*. The process is then transferred to a S**102**.

[0059] In S**102**, ECU **18***a* determines whether or not the resistivity of the insulating resistances of the respective battery-packs **20**A, **20**B is greater 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. If both are determined to be greater than threshold a (YES at S**102**), then the process moves to S**104**.

[0060] In S**104**, ECU **18***a* determines whether or not the resistance value of the insulation resistance of the vehicle body **10** is larger than the threshold value α. Since the threshold value α is as described above, the detailed description thereof will not be repeated. Note that the threshold used in S**102** process may differ from the threshold used in S**104** process. If it is determined that the value is greater than the threshold value α (YES in S**104**), the process proceeds to S**110**. When at least one of the resistivity values of the insulating resistances of the battery-pack B**21**, B**22** is equal to or less than the threshold value α (NO in S**102**), the process is transferred to S**106**.

[0061] In S**106**, ECU **18***a* determines that there is an electric leakage in the battery pack in which the resistance value of the insulating resistance of the battery pack **20**A, **20**B is equal to or less than the threshold value α. ECU **18***a* sets, for example, a flag associated with the pack ID of the battery pack in which the resistance value of the insulation resistance is equal to or less than the threshold value α to the ON-state. The process is then transferred to a S**108**.

[0062] In S**108**, 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 **23** of the battery pack of the pack ID corresponding to the flag of the ON state to the OFF state, a process of prohibiting the switching of SMR **23** to the ON state, a process of controlling SMR **13** to the OFF state, and a process of prohibiting the switching of SMR **13** to the ON state. The process is then terminated.

[0063] In S**110**, ECU **18***a* sets the electric leakage detection of the battery-pack **20**A, **20**B to the off-state. Specifically, ECU **18***a* switches off the circuit (leakage detector **22***b*) for detecting the resistivity of the insulating resistor of each of the battery-pack **20**A, **20**B and sets the circuit to a state in which the leakage cannot be detected (detection stopped state). The process is then transferred to a S**112**.

[0064] In S**112**, ECU **18***a* sets SMR to the on-state. ECU **18***a* transmits a SMR on-command to SMR **13** and SMR **23** of the battery-pack **20**A, **20**B. The process is then terminated. When it is determined that the resistance value of the insulation resistance of the vehicle body **10** is equal to or less than the threshold value α (NO in S**104**), the process proceeds to S**114**.

[0065] In S**114**, 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**116**.

[0066] In S**116**, ECU **18***a* performs a second fail-safe process. The second fail-safe process may include 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 prohibiting the switching of SMR **23** of the battery-pack **20**A, **20**B to the on state, and the like. The process is then terminated.

[0067] Note that ECU **18***a* may detect leakage at the time of Ready-OFF in the respective battery packs.

[0068] Hereinafter, the electric leakage determination process at the time of Ready-OFF will be described referring to FIG. **5**. FIG. **5** is a flow chart illustrating an exemplary leakage determination process at the time of Ready-OFF.

[0069] In S**200**, ECU **18***a* determines whether or not it is at the time of Ready-OFF. ECU **18***a* may determine that it is at the time of Ready-OFF after the operation (off operation) of the start switch is accepted at the time of Ready-ON and when the operation (on operation) of the start switch is not accepted thereafter. If it is determined that the time is Ready-OFF time (YES in S**200**), the process proceeds to S**202**.

[0070] In S**202**, ECU **18***a* turns off SMR **23** of SMR **13** and the battery-pack **20**A, **20**B. The process is then transferred to a S**204**.

[0071] In S**204**, ECU **18***a* sets the electric leakage detection of the respective battery-packs **20**A, **20**B to the on-state. The process is then transferred to a S**206**.

[0072] In S**206**, ECU **18***a* acquires the resistance of the insulating resistance from the respective battery-packs **20**A, **20**B. The process is then transferred to a S**208**.

[0073] In S**208**, ECU **18***a* determines whether or not the resistivity of the insulating resistances of the respective battery-packs **20**A, **20**B is greater than the threshold value α. If it is determined that the value is greater than the threshold value α (YES in S**208**), the process proceeds to S**210**.

[0074] In S**210**, ECU **18***a* determines that all of the battery-pack **20**A, **20**B have no electric leakage. The process is then transferred to a S**212**.

[0075] In S**212**, ECU **18***a* sets the ground fault detection to the off-state. The process is then terminated. If it is determined that at least one of the resistance values of the insulation resistance of the battery-pack **20**A, **20**B is equal to or less than the threshold value a (NO in S**208**), the process proceeds to S**214**.

[0076] In S**214**, ECU **18***a* determines that there is an electric leakage in the battery pack in which the resistance value of the insulation resistance is equal to or less than the threshold value α. ECU **18***a* sets, for example, a flag associated with the pack ID of the battery pack in which the resistance value of the insulation resistance is equal to or less than the threshold value α to the ON-state. The process is then transferred to a S**216**.

[0077] At S**216**, ECU **18***a* performs a fail-safe process. The fail-safe process may include at least one of a process of controlling SMR **23** of the battery pack of the pack ID corresponding to the flag of the ON state to the OFF state, a process of prohibiting the switching of SMR **23** to the ON state, a process of controlling SMR **13** to the OFF state, and a process of prohibiting the switching of SMR **13** to the ON state. The process is then terminated.

[0078] In this way, the presence or absence of an electric leakage can be detected in the respective battery-packs **20**A, **20**B when SMR **13** is shut off at the time of Ready-OFF in the vehicle **100**.

[0079] Various types of information are communicated between the vehicle body **10** and each battery pack. Specifically, ECU **28***a* transmits, to ECU **18***a* of the vehicle body **10**, information on whether the electric leakage detection of the respective battery packs is in the on-state or the off-state, and information on the resistance of the insulation resistance. On the other hand, ECU **18***a* transmits to ECU **28***a* one of a request to set the leakage detection to the ON state and a request to set the leakage detection to the OFF state. ECU **28***a* of the batteries sets the leakage detection to either the on-state or the off-state in response to a request from ECU **18***a*. In the following, referring to FIG. **6**, an exemplary process in which ECU **18***a* (vehicle body ECU) requests ECU **28***a* (battery ECU) of the respective battery packs to execute the leakage detection will be described. FIG. **6** is a flowchart illustrating an example of a process of setting a state of electric leakage detection.

[0080] As shown in "A" of FIG. **6**, for example, when ECU **18***a* is activated and ECU **28***a* is activated as shown in "a" of FIG. **6**.

[0081] As illustrated in "B" of FIG. **6**, ECU **18***a* sets the electric leakage detection of the vehicle body **10** to the ON state (the leakage detector **12** is in the ON state), and starts communication with ECU **28***a*. As illustrated in "b" of FIG.

6, ECU **28***a* sets the leakage detection of the battery pack **20** to the ON state, and transmits an execution state indicating that the leakage detection is the ON state to ECU **18***d* as illustrated in "c" of FIG. **6**.

[0082] As illustrated in "C" of FIG. **6**, when the execution status is received in ECU **18***a*, as illustrated in "D" of FIG. **6**, ECU **28***a* is required to turn off the electric leakage detection of the battery pack **20**.

[0083] As illustrated in "d" of FIG. **6**, a detection-request determination process is executed in ECU **28***a*. Detection request determination process, as shown in the left flow chart of FIG. **6**, a step of determining whether there is a leakage detection ON request (S**300**), when there is a request for leakage detection ON (YES in S**300**), a step of setting the leakage detection ON to the ON state (S**302**), if there is no request for leakage detection ON (NO in S**300**), a step of determining whether there is a leakage detection OFF request (S**304**), if there is a leakage detection OFF request (YES in S**304**), and a step of setting the leakage detection to the OFF state (S**306**). Therefore, when an off-request for the electric leakage detection is received from ECU **18***a*, the electric leakage detection is set to the off-state.

[0084] As illustrated in "e" of FIG. **6**, when the execution status indicating that the leakage detection is in the off-state is transmitted from ECU **28***a*, the execution status is received in ECU **18***a* as illustrated in "E" of FIG. **6**. Thereafter, when SMR **13** is set to the off-state at the time of Ready-OFF or the like, ECU **28***a* is required to turn on the electric leakage detection in the battery pack **20** as illustrated in "F" of FIG. **6**.

[0085] As illustrated in "f" of FIG. **6** and "g" of FIG. **6**, the detection-request determination process is executed in ECU **28***a*, the leakage detection is set to the ON state, and ECU **28***a* is turned to the OFF state after the leakage detection is performed. On the other hand, in ECU **18***a*, as illustrated in "G" of FIG. **6** and "H" of FIG. **6**, the termination sequence is executed, and ECU **18***a* is turned off. ECU **18***a* can prevent the leakage detection from interfering between the battery pack **20**A, **20**B and between the battery pack **20** and the vehicle body **10** by setting the timing at which the leakage detection of the battery pack **20**A, **20**B is turned on by using the execution status. For example, ECU **18***a* transmits the above-described demand to ECU **28***a* at the timing of turning on/off the leakage detection in the flow charts of FIGS. **3** and **4**. ECU **18***a* may request the change of the state of the electric leakage detection of the battery-pack **20**A, **20**B by using the state of the electric leakage detection of the vehicle body **10**.

[0086] As described above, according to the vehicle **100** of the present embodiment, the presence or absence of electric leakage between the battery pack **20**A, **20**B and the electric device of the vehicle body **10** is detected by ECU **28***b* and ECU **18***d* while the battery pack **20**A, **20**B and the electric device of the vehicle body **10** are electrically disconnected from each other. Therefore, the presence or absence of an electric leakage is accurately detected in each of the battery-pack **20**A, **20**B and the vehicle body **10**. Furthermore, the presence or absence of an electric leakage between the battery pack **20**A, **20**B and the electric device of the vehicle body **10** is detected by ECU **18***d* while the battery pack **20**A, **20**B and the electric device of the vehicle body **10** are electrically connected to each other. Since the electric leakage detection of the battery pack **20**A, **20**B is set to the off-state, it is possible to detect the presence or absence of an electric leakage in a state in which the battery pack **20**A, **20**B and the electric device of the vehicle body **10** are connected, while avoiding interference between the electric leakage detection using ECU **28***b* of the battery pack **20** and the electric leakage detection using ECU **18***d*. As described above, since the electric leakage is detected in accordance with the state of attachment and detachment of the battery-pack **20**A, **20**B, it is possible to identify the location where the electric leakage occurs while avoiding the interference. Therefore, it is possible to provide a vehicle that appropriately detects an electric leakage when a plurality of electric leakage detection devices is mounted.

[0087] Modification examples will be described below.

[0088] In the embodiments described above, although the vehicles **100** are shown as one case of mounting two battery pack **20**A, **20**B, the number of mounting battery packs may be one or three or more.

[0089] Furthermore, in the above-described embodiment, the case where the execution subject of the leakage determination process is ECU **18***a* has been described as an example, but the execution subject of the leakage determination process or the switching subject of SMR **13**, **23** is not limited to ECU **18***a*, and may be, for example, ECU **18***d* or another ECU mounted on the vehicle body **10**.

[0090] Further, the configuration of the vehicle body shown in FIG. **1** 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** 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 (Vehicle to Everything: V2X) using the electric power outputted from the attached battery pack.

[0091] All or some of the above-mentioned modified examples may be combined for implementation.

[0092] 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.

What is claimed is:

1. A vehicle comprising:

a vehicle body;

a battery detachable from the vehicle body;

a first detection device provided in the battery to detect presence or absence of an electric leakage; and

a second detection device provided on the vehicle body to detect presence or absence of an electric leakage, wherein

each of the first detection device and the second detection device detects the presence or absence of the electric leakage when in a first state in which the battery and an electric device of the vehicle body are electrically disconnected from each other, and

the second detection device detects the presence or absence of the electric leakage when in a second state in which the battery and the electric device are electrically connected to each other.

2. The vehicle according to claim **1**, wherein the second detection device detects the presence or absence of the electric leakage when in the second state and while detection of the presence or absence of the electric leakage by the first detection device is stopped.

3. The vehicle according to claim **1**, further comprising a control device that acquires information about a detection result of the presence or absence of the electric leakage from the first detection device and the second detection device, wherein:

when in the second state, the control device acquires an execution status of detection of the electric leakage; and

the control device either requests detection of the electric leakage by the first detection device or requests stop of detection of the electric leakage using the acquired execution status.

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