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ICHIKAWA

(54) VEHICLE

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(57) **ABSTRACT**

ECU performs a process including the steps of acquiring a resistance value of an insulation resistance, determining that a battery pack having a resistance value equal to or less than a threshold value has an electric leakage, turning on the respective SMR when the resistance value is greater than the threshold value, acquiring a resistance value of the insulation resistance, and determining that an electric leakage occurs in the vehicle body when the resistance value is equal to or less than the threshold value.

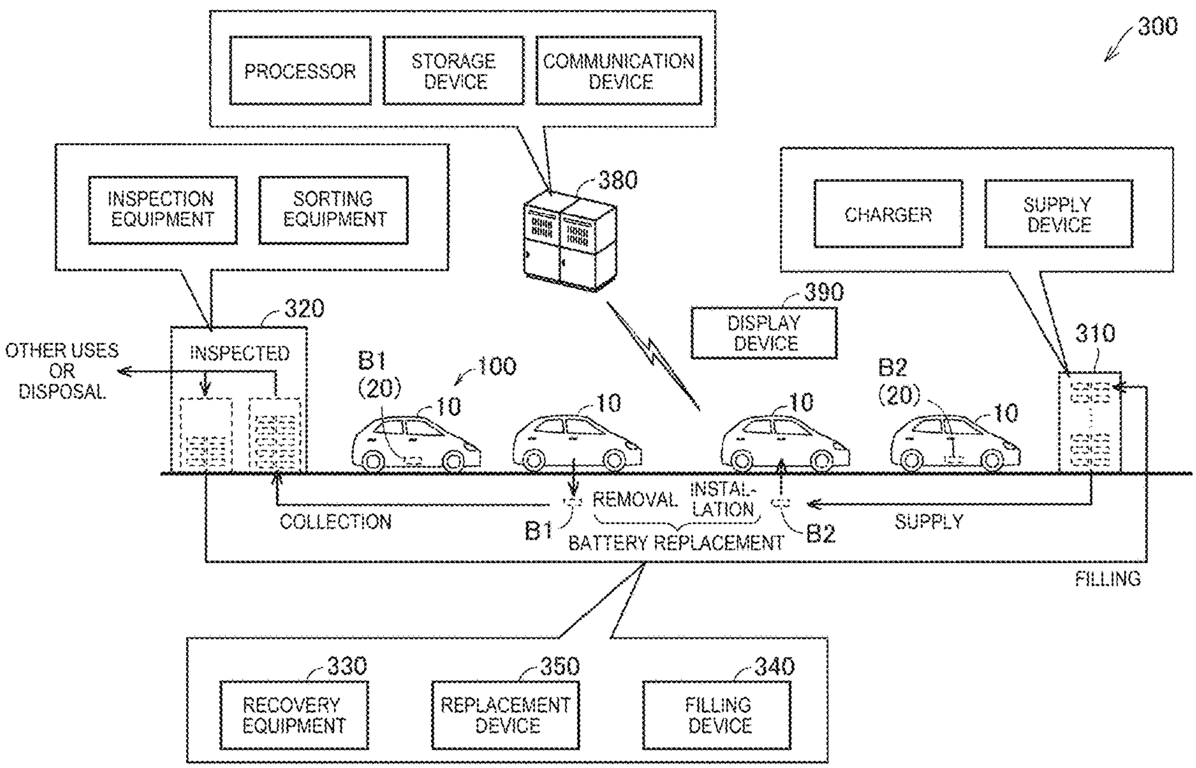
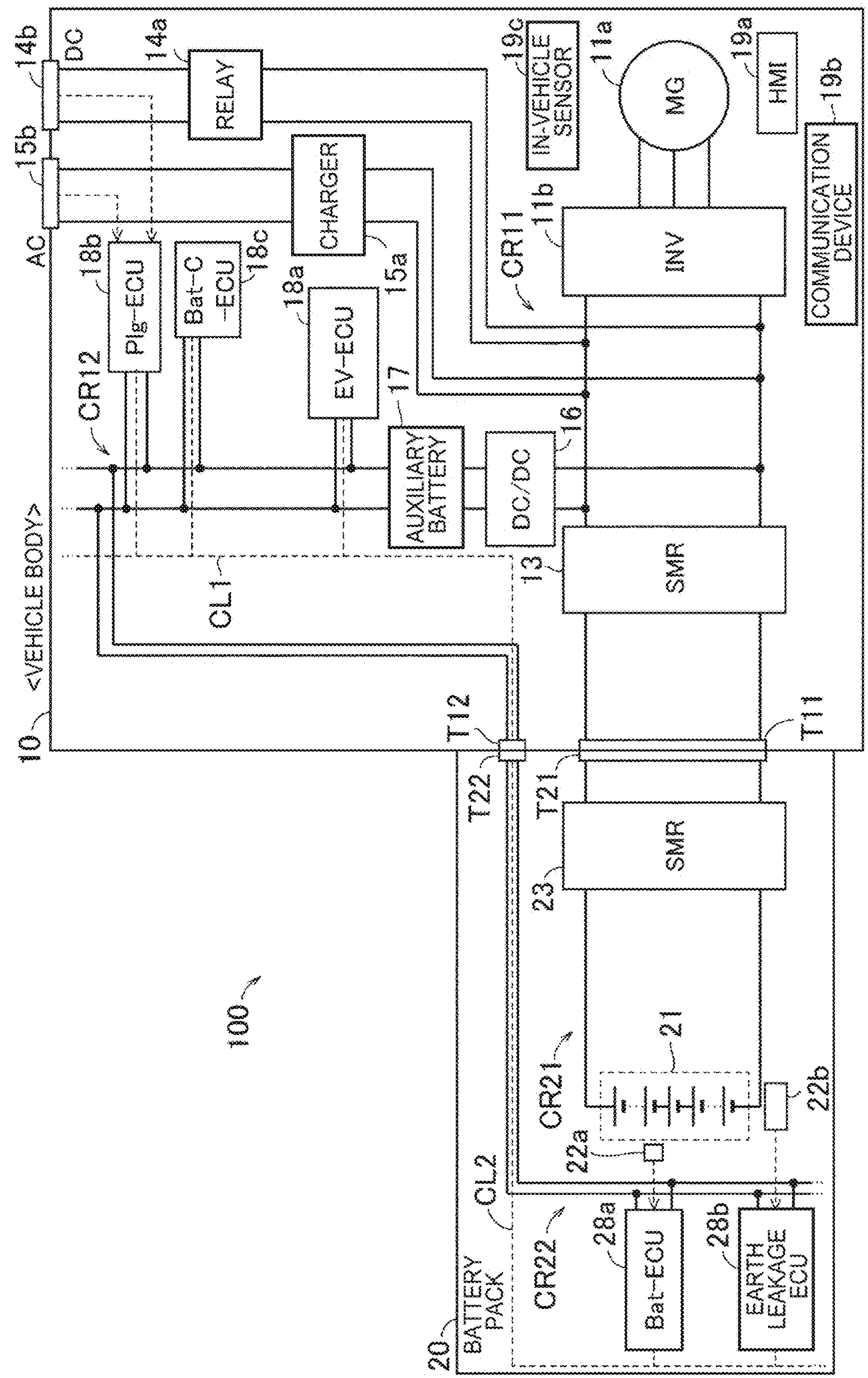


FIG. 1



<VEHICLE BODY>
10
14b
DC
14a
RELAY
15b
AC
CHARGER
15a
18b
Plg-ECU
Bat-C -ECU
18c
18a
EV-ECU
17
AUXILIARY BATTERY
16
DC/DC
CR12
CL1
13
SMR
CR11
11b
INV
11a
MG
19c
IN-VEHICLE SENSOR
19a
HMI
19b
COMMUNICATION DEVICE
T12
T11
T22
T21
23
SMR
100
21
CR21
22a
22b
CL2
CR22
28a
Bat-ECU
28b
EARTH LEAKAGE ECU
20
BATTERY PACK

FIG. 2

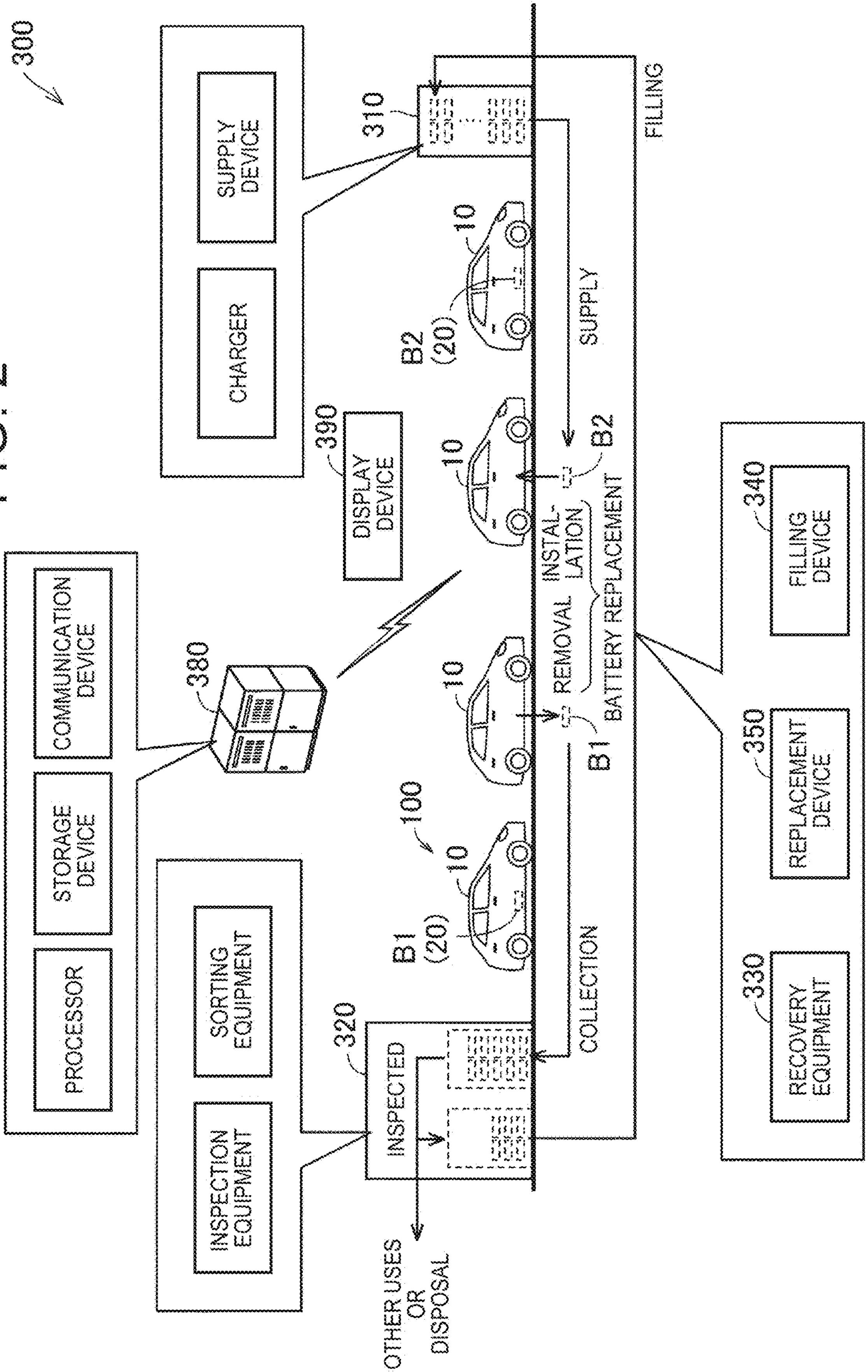

300
PROCESSOR
STORAGE DEVICE
COMMUNICATION DEVICE
380
INSPECTION EQUIPMENT
SORTING EQUIPMENT
320
INSPECTED
INSPECTED
OTHER USES OR DISPOSAL
B1 (20)
100
10
COLLECTION
B1
REMOVAL
INSTAL-LATION
BATTERY REPLACEMENT
B2
DISPLAY DEVICE
390
B2 (20)
SUPPLY
CHARGER
SUPPLY DEVICE
310
FILLING
RECOVERY EQUIPMENT
330
REPLACEMENT DEVICE
350
FILLING DEVICE
340

FIG. 3

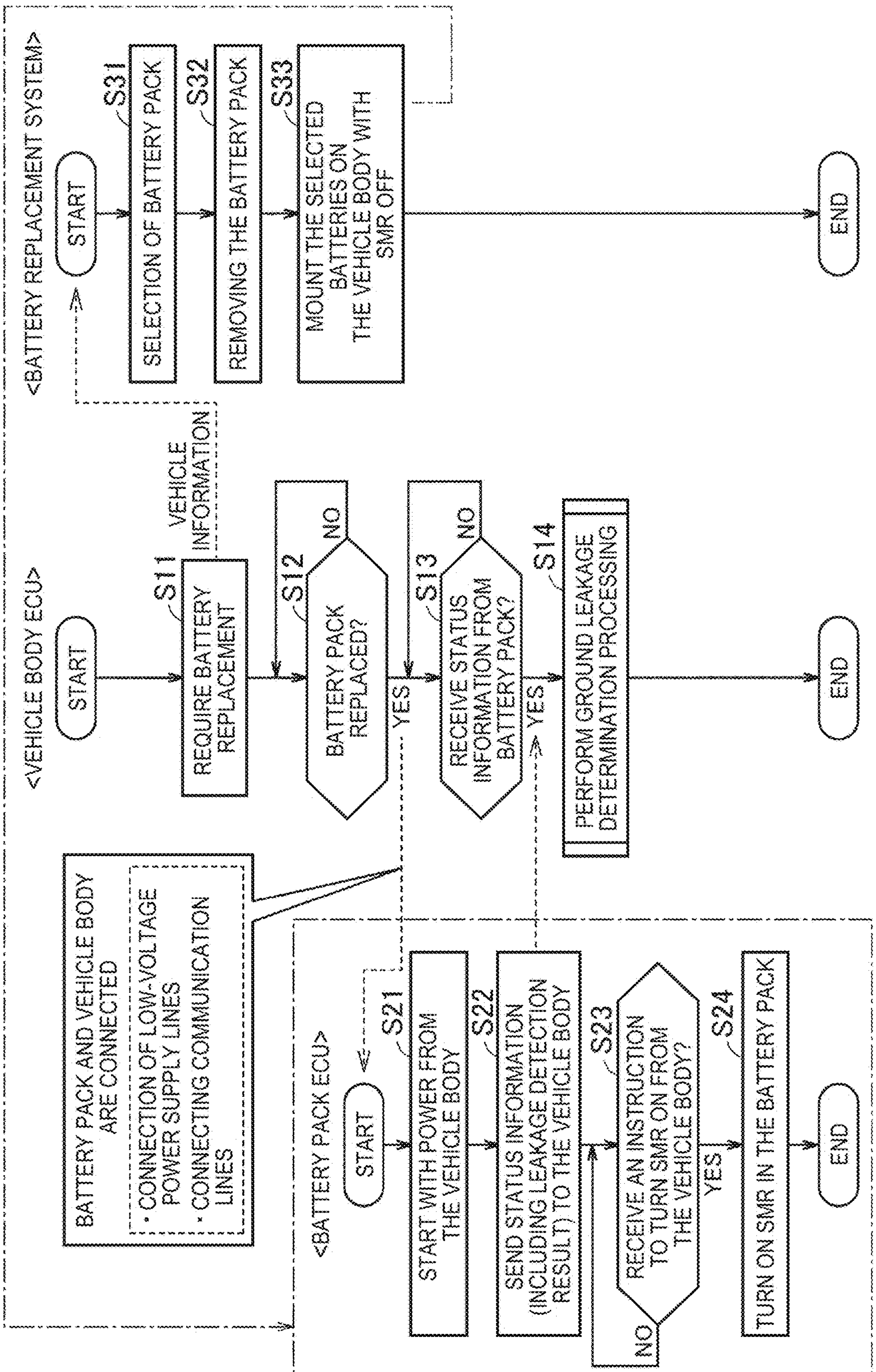

<VEHICLE BODY ECU>
START
S11
REQUIRE BATTERY REPLACEMENT
VEHICLE INFORMATION
S12
BATTERY PACK REPLACED?
NO
YES
S13
RECEIVE STATUS INFORMATION FROM BATTERY PACK?
NO
YES
S14
PERFORM GROUND LEAKAGE DETERMINATION PROCESSING
END
<BATTERY REPLACEMENT SYSTEM>
START
S31
SELECTION OF BATTERY PACK
S32
REMOVING 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

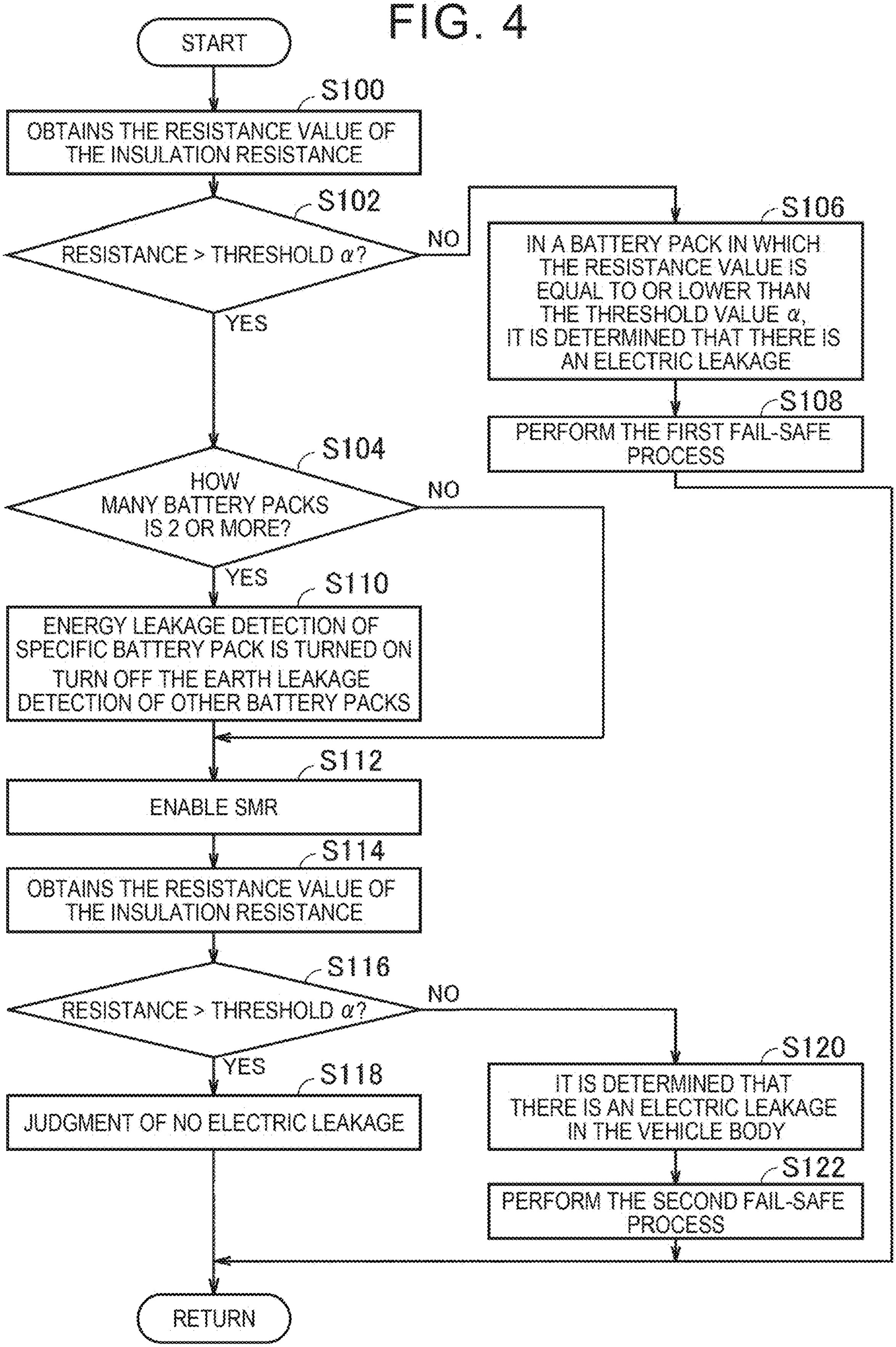
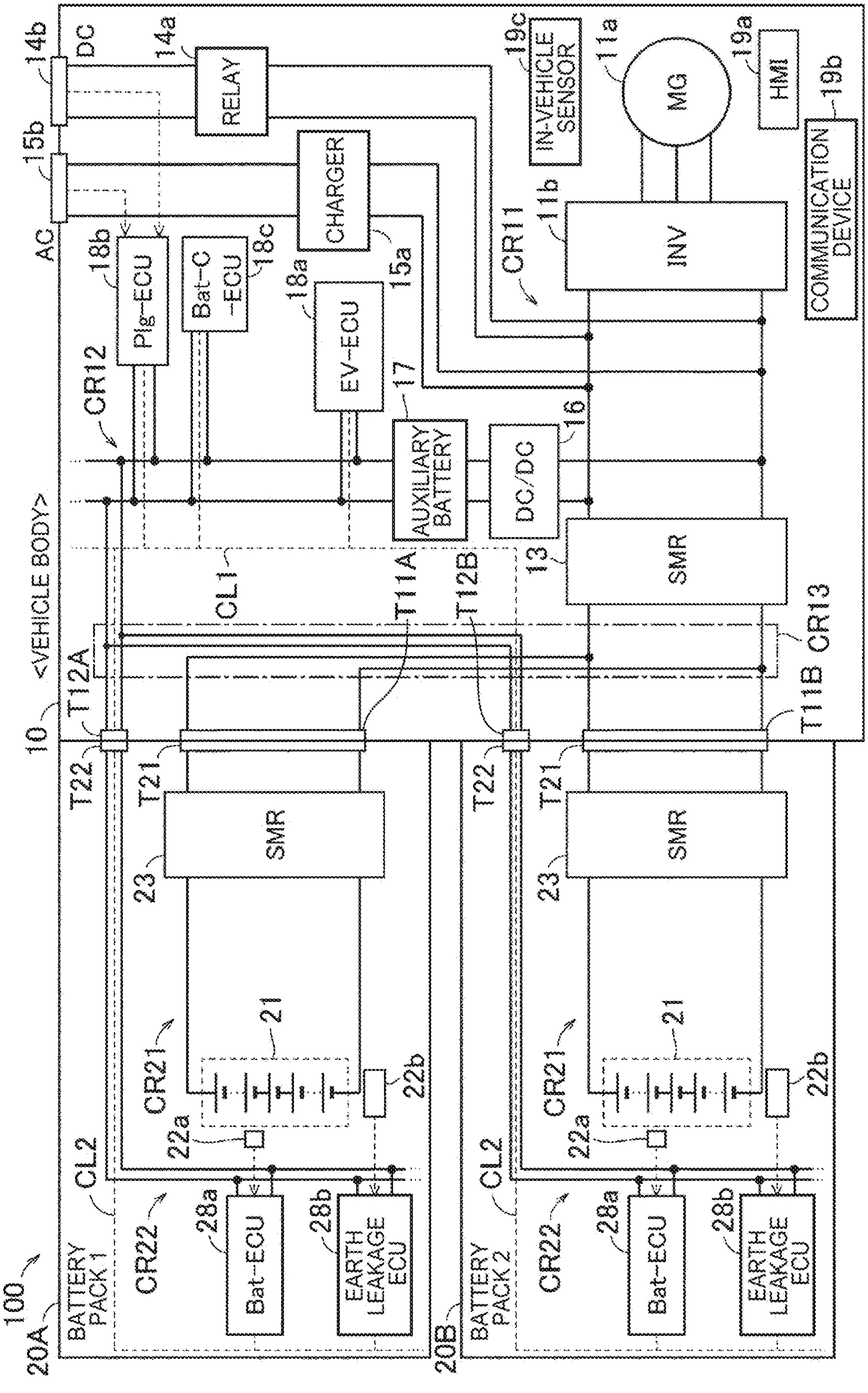

START
S100
OBTAINS THE RESISTANCE VALUE OF THE INSULATION RESISTANCE
S102
RESISTANCE > THRESHOLD α?
NO
YES
S106
IN A BATTERY PACK IN WHICH THE RESISTANCE VALUE IS EQUAL TO OR LOWER THAN THE THRESHOLD VALUE α, IT IS DETERMINED THAT THERE IS AN ELECTRIC LEAKAGE
S108
PERFORM THE FIRST FAIL-SAFE PROCESS
S104
HOW MANY BATTERY PACKS IS 2 OR MORE?
NO
YES
S110
ENERGY LEAKAGE DETECTION OF SPECIFIC BATTERY PACK IS TURNED ON
TURN OFF THE EARTH LEAKAGE DETECTION OF OTHER BATTERY PACKS
S112
ENABLE SMR
S114
OBTAINS THE RESISTANCE VALUE OF THE INSULATION RESISTANCE
S116
RESISTANCE > THRESHOLD α?
NO
YES
S118
JUDGMENT OF NO ELECTRIC LEAKAGE
S120
IT IS DETERMINED THAT THERE IS AN ELECTRIC LEAKAGE IN THE VEHICLE BODY
S122
PERFORM THE SECOND FAIL-SAFE PROCESS
RETURN

FIG. 5



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

FIG. 6

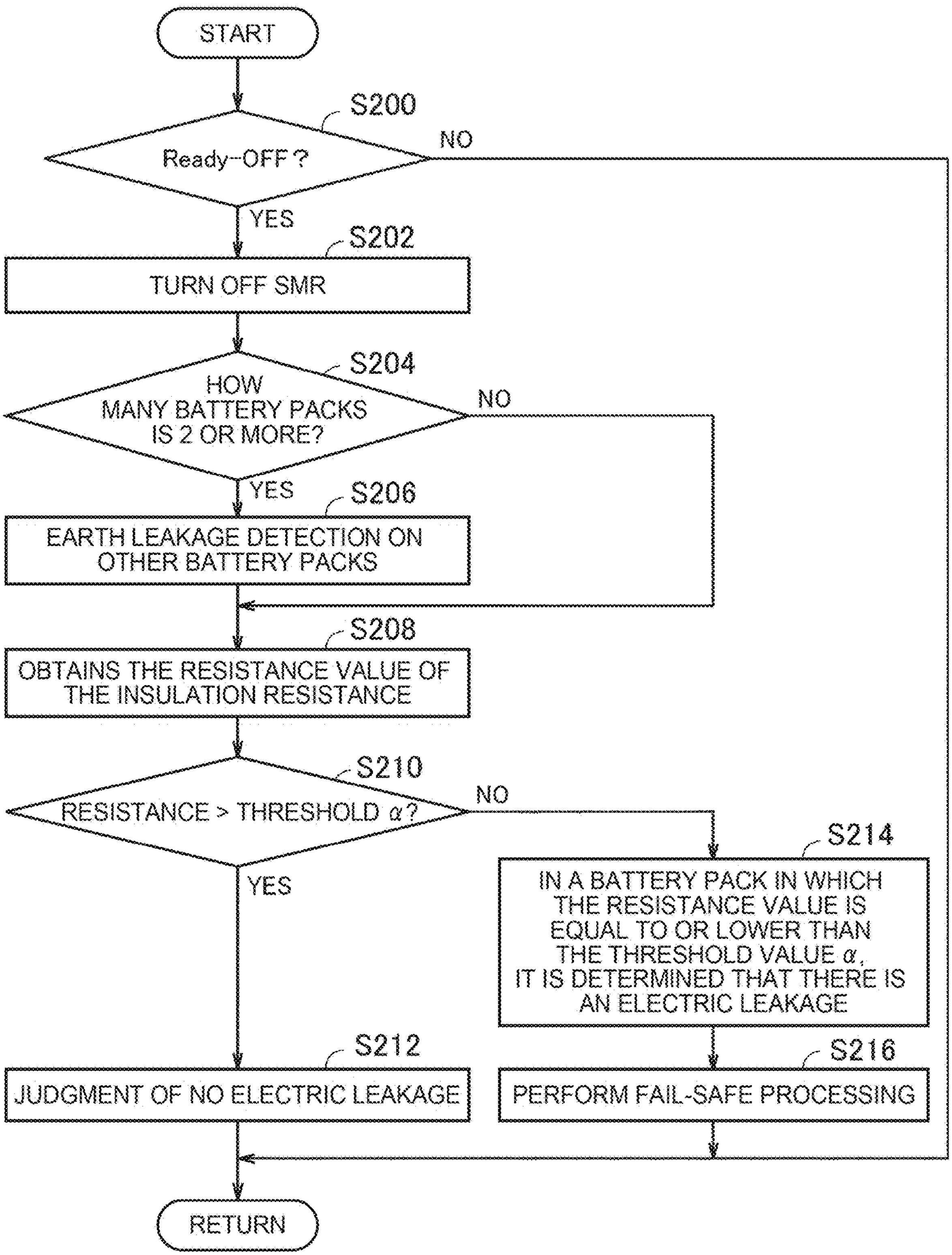
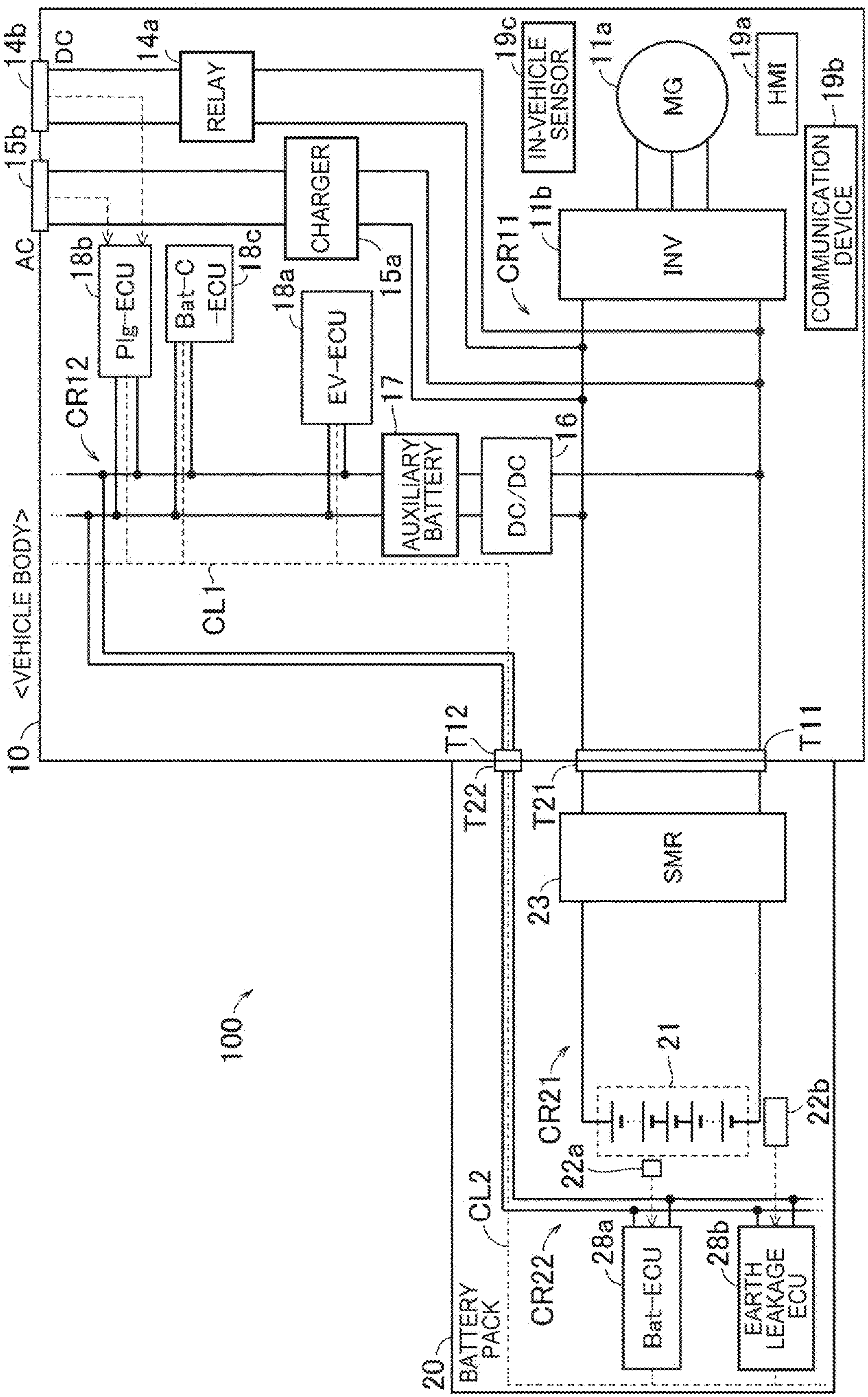

START
S200
Ready-OFF?
NO
YES
S202
TURN OFF SMR
S204
HOW MANY BATTERY PACKS IS 2 OR MORE?
NO
YES
S206
EARTH LEAKAGE DETECTION ON OTHER BATTERY PACKS
S208
OBTAINS THE RESISTANCE VALUE OF THE INSULATION RESISTANCE
S210
RESISTANCE > THRESHOLD α?
NO
YES
S214
IN A BATTERY PACK IN WHICH THE RESISTANCE VALUE IS EQUAL TO OR LOWER THAN THE THRESHOLD VALUE α, IT IS DETERMINED THAT THERE IS AN ELECTRIC LEAKAGE
S212
JUDGMENT OF NO ELECTRIC LEAKAGE
S216
PERFORM FAIL-SAFE PROCESSING
RETURN

FIG. 7



<VEHICLE BODY>
10
100
14b
DC
14a
RELAY
15b
AC
CHARGER
15a
18b
Plg-ECU
Bat-C
-ECU
18c
18a
EV-ECU
17
AUXILIARY
BATTERY
DC/DC
16
CR12
CL1
CR11
19c
IN-VEHICLE
SENSOR
11a
MG
19a
HMI
19b
COMMUNICATION
DEVICE
11b
INV
T12
T11
T22
T21
SMR
23
21
CR21
22a
22b
CL2
CR22
28a
Bat-ECU
28b
EARTH
LEAKAGE
ECU
20
BATTERY
PACK

FIG. 8

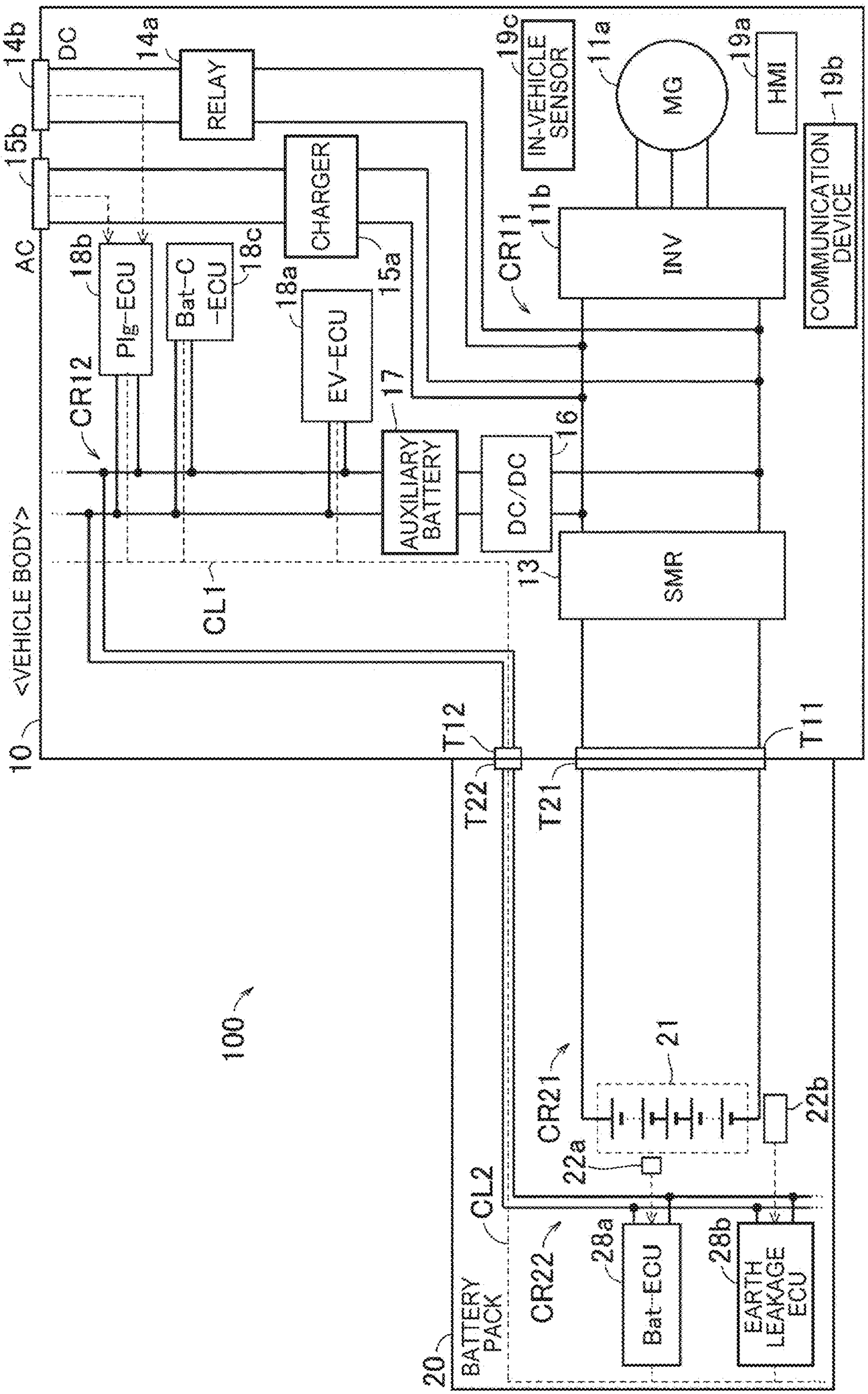
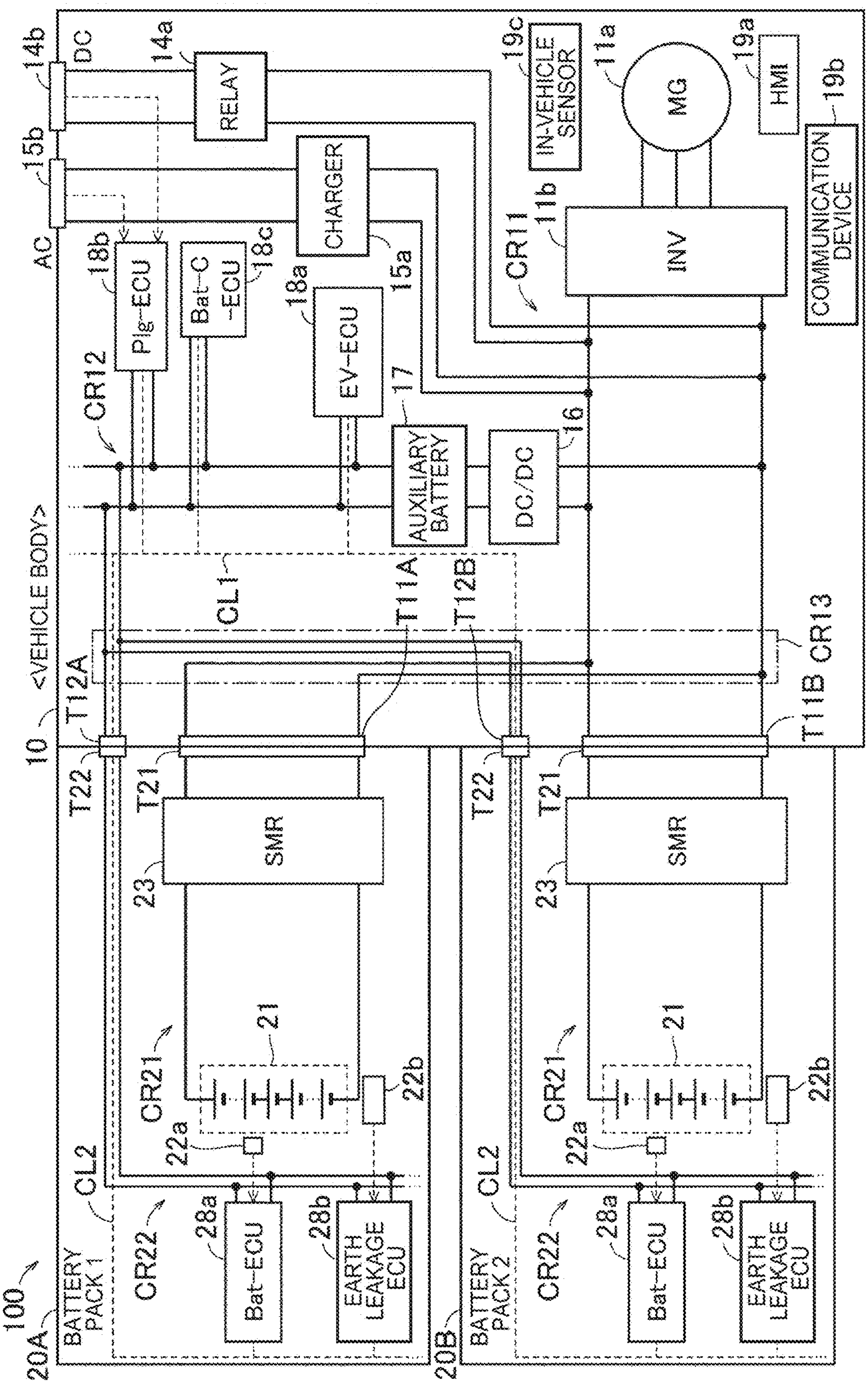
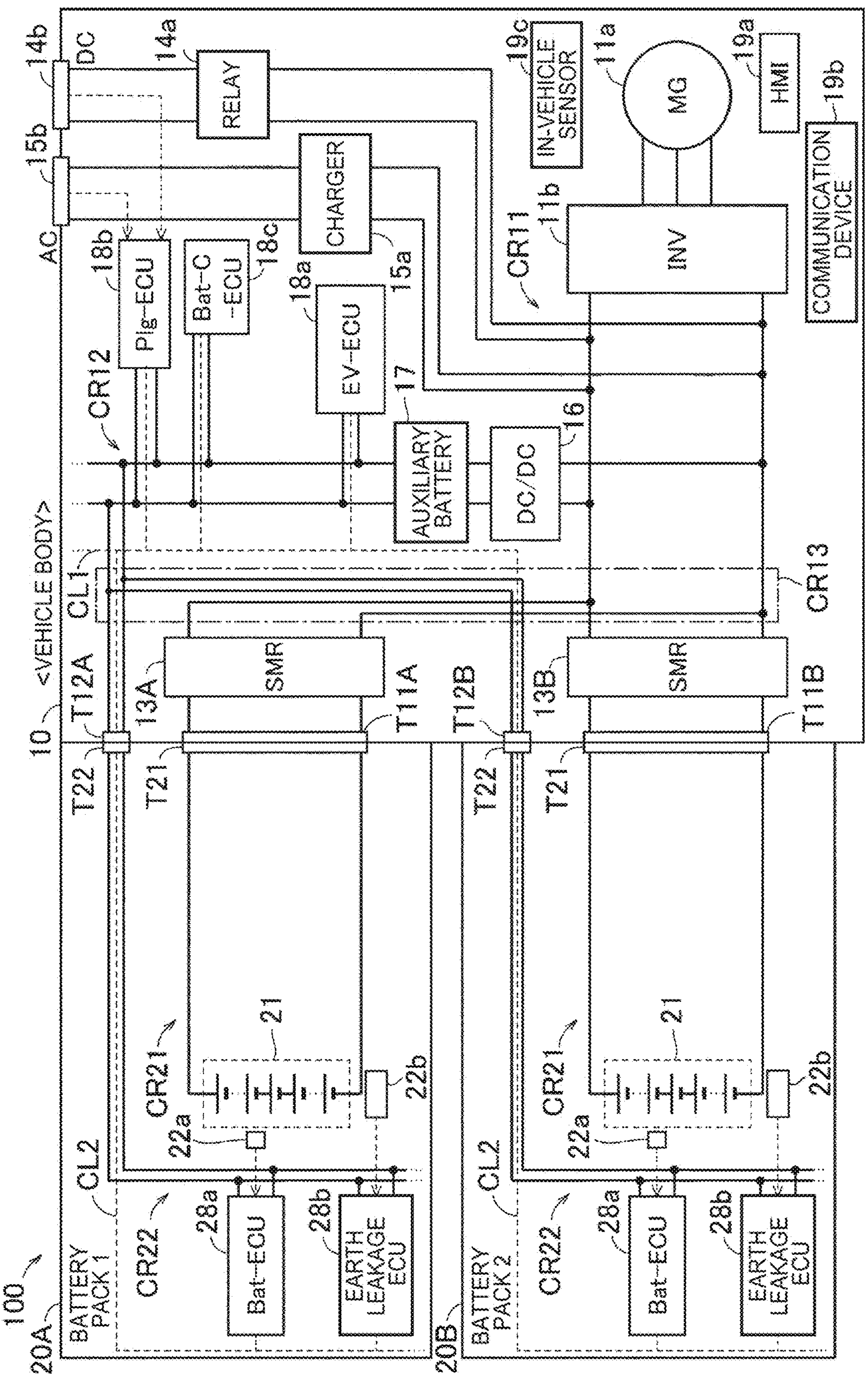

<VEHICLE BODY>
10
100
14b
DC
14a
RELAY
15b
AC
CHARGER
15a
18b
Plg-ECU
18c
Bat-C
-ECU
18a
EV-ECU
17
AUXILIARY
BATTERY
16
DC/DC
13
SMR
CR12
CL1
19c
IN-VEHICLE
SENSOR
11a
MG
19a
HMI
19b
COMMUNICATION
DEVICE
11b
INV
CR11
T12
T11
T22
T21
20
BATTERY
PACK
CL2
CR22
28a
Bat-ECU
28b
EARTH
LEAKAGE
ECU
22a
22b
CR21
21

FIG. 9



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

FIG. 10


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

VEHICLE

CROSS-REFERENCE TO RELATED APPLICATION

[0001] This application claims priority to Japanese Patent Application No. 2024-020155 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 (Translation of PCT Application) No. 2020-523576 (JP 2020-523576 A) discloses an electric leakage detection device for detecting an electric leakage using an insulation resistance value indicating an insulation state between a battery and a ground.

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 the battery and configured to detect whether an electric leakage has occurred.

[0010] 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 an electric circuit of the vehicle body are connected and a disconnected state in which the battery and the electric circuit are disconnected.

[0011] 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.

[0012] In one embodiment, the detection device may be configured to detect whether the electric leakage of the battery 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.

[0013] In this way, whether the electric leakage of the battery has occurred can be detected in the disconnected state. When the electric leakage of the battery is not detected, whether the electric leakage of the electric circuit on the vehicle body side has occurred can be detected in the conductive state.

[0014] In a further embodiment, the vehicle body may be configured such that a plurality of the batteries is mountable. In a conductive state in which each of the batteries and the electric circuit are connected, any one of a plurality of the detection devices may detect whether the electric leakage has occurred.

[0015] In this way, the occurrence of interference of the electric leakage detection among the detection devices is suppressed. Thus, it is possible to detect the electric leakage with high accuracy.

[0016] In a further embodiment, the vehicle body may be configured such that a plurality of the batteries is mountable. In a disconnected state in which each of the batteries and the electric circuit are disconnected, each of the detection devices of the batteries may detect whether the electric leakage has occurred.

[0017] In this way, it is possible to accurately determine whether the electric leakage has occurred in each of the batteries.

[0018] According to the present disclosure, it is possible to provide the vehicle that includes the detachable battery and performs appropriate electric leakage detection.

BRIEF DESCRIPTION OF THE DRAWINGS

[0019] 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:

[0020] FIG. **1** is a diagram illustrating an example of a configuration of a vehicle according to the present embodiment;

[0021] FIG. **2** is a diagram illustrating an example of a configuration of a battery replacement system for replacing a battery pack;

[0022] FIG. **3** is a flowchart illustrating an example of a method of replacing a battery pack;

[0023] FIG. **4** is a flowchart illustrating an example of the electric leakage determination process of FIG. **3**;

[0024] FIG. **5** is a diagram illustrating a first example of a configuration of a vehicle according to a modification;

[0025] FIG. **6** is a flowchart illustrating an example of the electric leakage determination process according to the modification;

[0026] FIG. **7** is a diagram illustrating a second example of a configuration of a vehicle according to a modification;

[0027] FIG. **8** is a diagram illustrating a third example of a configuration of a vehicle according to a modification;

[0028] FIG. **9** is a diagram illustrating a fourth example of a configuration of vehicles according to a modification; and

[0029] FIG. **10** is a diagram illustrating a fifth example of a configuration of a vehicle according to a modification.

DETAILED DESCRIPTION OF EMBODIMENTS

[0030] 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.

[0031] 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*. 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*. The circuit CR**21** in the battery pack **20** is provided with a BMS (Battery Management System) **22***a* and an electric leakage detector **22***b*.

[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 an SMR **13**. The battery-pack **20** includes a terminal T**21** to which the vehicle body **10** is attachable and detachable, and an 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 an 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 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**.

[0037] 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 ECUs **18***a*, **18***b*, **18***c* 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***c*, **28***a*, **28***b* from, for example, a ECU**18***a* connected to the low-voltage power supply line. "ECU" means an electronic control unit (Electronic Control Unit).

[0038] 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**28***a* corresponds to a control device (Bat-ECU) that monitors the status of the batteries **21** and controls SMR **23**. ECU**28***b* corresponds to a control device (earth leakage ECU) that monitors the earth leakage status of the circuit CR**21**. For example, ECU**28***b* detects a current between the electric circuit including the circuit CR**21** 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.

[0039] 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.

[0040] 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 SMRs **13**, **23**, and sends control commands to ECU**18***c* and ECU**28***a*.

[0041] BMS**22***a* detects the condition (current, voltage, temperature, etc.) of the battery **21**, and outputs the detected condition to ECU**28***a*. The electric leakage detector **22***b* detects a leakage condition (for example, an insulating resistor) of the circuit CR**21**, and outputs the detected condition to ECU**28***b*. ECU**18***a* acquires information (state information) indicating a battery state and an electric leakage state from ECUs **28***a*, **28***b*.

[0042] 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**.

[0043] 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**, a communication line CL**1** of the vehicle body **10** and a 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**.

[0044] 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**.

[0045] 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 from ECU**18***a* in cooperation with **18***c*.

[0046] 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 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 ECU.

[0047] In this embodiment, HMI**19***a* includes an activation switch. The user of the vehicle **100** can activate or deactivate the control system (including each ECU) of the vehicle **100** or turn the vehicle **100** Ready-ON or Ready-OFF by operating the activation switch.

[0048] 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 from the battery **21** of the battery pack **20** to the vehicle-driven device.

[0049] 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.

[0050] 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**.

[0051] 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 packs 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**.

[0052] 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). 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**.

[0053] 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 servers **380** are configured to be wirelessly communicable.

[0054] 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 servers **380**. The replacement request signal includes identification information (vehicle ID) of the vehicle **100** and specification information of respective battery packs (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**.

[0055] 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**).

[0056] Upon receiving the exchange-request signal, the server **380** starts S**33** process from S**31** of FIG. **3**.

[0057] 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**.

[0058] In S**32**, the servers **380** control 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**.

[0059] In S**33**, the servers **380** control 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 servers **380** control 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*.

[0060] 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.

[0061] 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 (circuits CR**12**, CR**22**) and a communication line (communication lines 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**.

[0062] 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**.

[0063] 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*. Note that the state information may include information about the leakage detection result (leakage state) detected by the electric leakage detector **22***b* and the leakage ECU**28***b*. 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**.

[0064] 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**.

[0065] In S**24**, ECU**28***a* switches SMR **23** from the open state (shut-off state) to the closed state (connected state).

[0066] 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 servers **380**. Accordingly, when it is determined that S**12** is YES, the process proceeds to S**13**.

[0067] 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**.

[0068] 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**.

[0069] In S**100**, ECU**18***a* acquires the resistance of the insulating resistance. For example, ECU**18***a* may acquire the resistance value of the insulation resistance from the status information received from the battery pack **20** or may acquire the resistance value of the insulation resistance from ECU**28***b*. When a plurality of battery packs is mounted, ECU**18***a* may acquire the resistance of the insulation resistance corresponding to each battery pack from each battery pack. The process is then transferred to a S**102**.

[0070] 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 a. The threshold value a is a predetermined value for determining the presence or absence of an electric leakage, and is adapted by an experiment or the like. When a plurality of battery packs is mounted, ECU**18***a* determines whether or not the resistivity of the insulating resistances of the battery packs is greater 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**102**), the process proceeds to S**104**.

[0071] In S**104**, ECU**18***a* determines whether or not the number of battery-packs mounted on the vehicle **100** is two or more. For example, ECU**18***a* determines whether or not the number of battery packs installed in the vehicles **100** is two or more by using the number of pack ID received from the battery pack, the number of attached battery packs received from the servers **380**, and the like. The process is then transferred to a S**110**. 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**106**.

[0072] In S**106**, 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 a to the ON-state. The process is then transferred to a S**108**.

[0073] 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** of the battery pack 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.

[0074] In S**110**, ECU**18**a sets the electric leakage detection of any one of the plurality of battery packs (hereinafter, referred to as a "specified battery pack") to the ON state, and sets the electric leakage detection of the other battery packs to the OFF state. More specifically, ECU**18**a is configured to detect an electric leakage by turning on a circuit for detecting a resistance of an insulation resistance of any one of the battery packs. ECU**18**a may be configured to detect an electric leakage by switching off a circuit for detecting a resistance value of an insulation resistance of another battery pack. The process is then transferred to a S**112**. If it is determined that the number of batteries is less than two (NO in S**104**), the process proceeds to S**112**.

[0075] 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** (SMR **23** of all the battery packs when a plurality of battery packs **20** are mounted). The process is then transferred to a S**114**.

[0076] In S**114**, ECU**18**a acquires the resistance of the insulating resistance. When a plurality of battery packs **20** are mounted, the resistance value of the insulation resistance is acquired from the specific battery pack. The process is then transferred to a S**116**.

[0077] In S**116**, ECU**18**a determines whether or not the resistance value of the insulating resistor is greater than a 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**116**), the process proceeds to S**118**.

[0078] In S**118**, 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 that the resistance value of the insulating resistance is equal to or less than the threshold value a (NO in S**116**), the process proceeds to S**120**.

[0079] In S**120**, 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**122**.

[0080] In S**122**, ECU**18**a performs a second fail-safe process. The second fail-safe process may include 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, and the like. The second fail-safe process may include a process of controlling SMR **23** of the battery pack (all the battery packs when a plurality of battery packs is mounted) to the off-state, a process of prohibiting the switching of SMR **23** of the battery pack to the on-state, and the like. The process is then terminated.

[0081] 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 using the detection result of whether or not the resistance value of the insulation resistance in a state in which the battery 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 and the electric circuit on the vehicle body **10** are disconnected is lower than the threshold value. Specifically, when an electric leakage is detected prior to turning on SMR **23** of the battery pack **20**, it is possible to identify that the cause of the electric leakage is caused by the battery pack **20**. In addition, when it is determined that there is no electric leakage in the battery pack 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 electric leakage is caused by the vehicle body **10**. Therefore, it is possible to provide a vehicle that performs appropriate electric leakage detection in a vehicle equipped with a detachable battery.

[0082] Modification examples will be described below.

[0083] In the above-described embodiment, the flowchart of FIG. **4** has been described as including processing assuming a case where a plurality of battery packs **20** are mounted. However, when the vehicle **100** is a vehicle in which the upper limit number of the battery packs **20** is one as illustrated in FIG. **1**, S**104** process and S**110** process in the flow chart of FIG. **4** may be omitted.

[0084] 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, an SMR **23** for connecting and disconnecting the electric circuit 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.

[0085] FIG. **5** is a diagram illustrating a first 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 battery packs **20**A, **20**B and a parallel-circuit CR**13** that connects the battery packs **20**A, **20**B to SMR **13** in parallel. The battery packs **20**A, **20**B have the same configuration as that of the battery pack **20**. Therefore, the detailed description thereof will not be repeated.

[0086] In such a configuration, when the electric leakage determination process illustrated in FIG. **4** is executed, ECU**18**a acquires (S**100**) the resistance of the insulating resistance from the respective battery packs. When the resistance value of the insulation resistance of any of the battery packs is equal to or less than the threshold value α (NO in S**102**), it is determined that there is an electric leakage in the battery pack (S**106**), and the first fail-safe process is executed (S**108**).

[0087] On the other hand, when the resistance value of the insulation resistance of the respective battery packs is larger than the threshold value α (YES in S**102**), since the number of battery packs is two or more (YES in S**104**), the electric leakage detection of the particular battery pack (for example, the battery pack **20**A) is set to the on-state. Further, the electric leakage detection of the other battery pack (battery pack **20**B) is set to the off-state (S**110**).

[0088] Thereafter, SMR **13**, SMR **23** of the battery pack **20**A, and SMR **23** of the battery pack **20**B are turned on (S**112**), and the resistivity of the insulating resistor is acquired from the battery pack **20**A (S**114**). When the obtained resistive value is larger than the threshold value a (YES in S**116**), it is determined that there is no electric leakage (S**118**). When the resistive value is equal to or less than the threshold value a, it is determined that there is an electric leakage in the vehicle body (S**120**), and the second fail-safe process is executed (S**122**).

[0089] Even in this manner, it is possible to detect the presence or absence of an electric leakage in the respective battery packs when SMR **13** is shut off in the vehicles on which the plurality of battery packs are mounted. Further, when no electric leakage is detected in the respective battery packs, it is possible to detect the presence or absence of an electric leakage in the electric circuit of the vehicle body **10** when SMR **13** is in conduction.

[0090] Further, when a plurality of batteries are mounted and SMR **23** of SMR **13** and the battery packs are set to the on-state, the electric leakage is detected only by the specified battery pack (battery pack **20**A). Therefore, it is possible to detect the electric leakage with high accuracy because the electric leakage is suppressed from occurring with the electric leakage detection device of the other battery-pack **20**B.

[0091] Further, in the above-described embodiment, when a plurality of batteries are mounted, the leakage detection of other battery packs other than the specific battery pack is set to the off state after the presence or absence of the leakage of each battery pack is first detected in the leakage determination process when the battery pack is replaced. However, for other battery packs, leakage may be detected at the time of Ready-OFF.

[0092] Hereinafter, the electric leakage determination process at the time of Ready-OFF will be described referring to FIG. **6**. FIG. **6** is a flowchart illustrating an example of the electric leakage determination process according to the modification.

[0093] 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**.

[0094] In S**202**, ECU**18***a* turns off SMR **23** of SMR **13** and the battery-packs **20**A, **20**B. The process is then transferred to a S**204**.

[0095] In S**204**, ECU**18***a* determines whether or not the number of battery packs to be mounted is two or more. Since the method of determining the number of battery packs is as described above, the detailed description thereof will not be repeated. If it is determined that the number of mounted battery-packs is two or more (YES in S**204**), the process proceeds to S**206**.

[0096] In S**206**, ECU**18***a* sets the electric leakage detection of another battery pack (battery pack **20**B) to the on-state. The process is then transferred to a S**208**. If it is determined that the number of mounted battery-packs is not two or more (NO in S**204**), the process proceeds to S**208**.

[0097] In S**208**, ECU**18***a* obtains an insulation resistance from the battery pack. When a plurality of battery packs is mounted, the insulation resistance is acquired from each battery pack in which the electric leakage detection is set to the ON state. The process is then transferred to a S**210**.

[0098] In S**210**, EUC**18***a* determines whether or not the resistance value of the insulating resistor is greater than a 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**210**), the process is transferred to S**212**.

[0099] In S**212**, 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 is equal to or less than the threshold value α (NO in S**210**), the process proceeds to S**214**.

[0100] 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**214**.

[0101] 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** of the battery pack 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.

[0102] With this configuration, it is possible to detect the presence or absence of an electric leakage in the respective battery packs when SMR **13** is shut off at the time of Ready-OFF in the vehicles on which the plurality of battery packs are mounted.

[0103] Further, the configuration of the vehicle body **10** illustrated in FIG. **1** or **5** can be changed as appropriate. For example, SMR **13** of the vehicle body **10** may be omitted, or SMR **23** of the battery-packs **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.

[0104] Specifically, the vehicle **100** may have the configuration shown in FIG. **7**. FIG. **7** is a diagram illustrating a second example of a configuration of a vehicle **100** according to a modification. The vehicle body **10** shown in FIG. **7** differs from the vehicle body **10** shown in FIG. **1** in that it does not have a SMR **13**. With regard to other configurations, the vehicle body **10** illustrated in FIG. **7** and the vehicle body **10** illustrated in FIG. **1** have the same configuration. Therefore, the detailed description thereof will not be repeated.

[0105] Further, the vehicle **100** may have the configuration shown in FIG. **8**. FIG. **8** is a diagram illustrating a third example of a configuration of a vehicle **100** according to a modification. The vehicle body **10** shown in FIG. **8** differs from the vehicle body **10** shown in FIG. **1** in that it does not have an SMR **23**. With regard to other configurations, the vehicle body **10** illustrated in FIG. **8** and the vehicle body **10** illustrated in FIG. **1** have the same configuration. Therefore, the detailed description thereof will not be repeated.

[0106] Further, the vehicle **100** may have the configuration shown in FIG. **9**. FIG. **9** is a diagram illustrating a fourth example of a configuration of a vehicle **100** according to a modification. The vehicle body **10** shown in FIG. **9** differs from the vehicle body **10** shown in FIG. **5** in that it does not have a SMR **13**. With regard to other configurations, the vehicle body **10** illustrated in FIG. **9** and the vehicle body **10** illustrated in FIG. **5** have the same configuration. Therefore, the detailed description thereof will not be repeated.

[0107] Further, the vehicle **100** may have the configuration shown in FIG. **10**. FIG. **10** is a diagram illustrating a fifth example of a configuration of a vehicle **100** according to a modification. The vehicle body **10** shown in FIG. **9** differs from the vehicle body **10** shown in FIG. **5** in that it has SMRs **13**A, **13**B instead of SMRs **13**, SMR **23**. SMR **13**A is provided in a power supply line connecting the terminal T**11**A and a branch point from a power supply line connecting the inverter **11***b* and the terminal T**11**B. SMR **13**B is provided in a power supply line between the terminal T**11**B and the branch point. With regard to other configurations, the vehicle body **10** illustrated in FIG. **10** and the vehicle body **10** illustrated in FIG. **5** have the same configuration. Therefore, the detailed description thereof will not be repeated.

[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.

What is claimed is:

1. A vehicle comprising:

a vehicle body;

a battery detachable from the vehicle body; and

a detection device provided to the battery 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 an electric circuit of the vehicle body 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 battery 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; and

in a conductive state in which each of the batteries and the electric circuit are connected, any one of a plurality of the detection devices detects whether the electric leakage has occurred.

4. The vehicle according to claim **1**, wherein:

the vehicle body is configured such that a plurality of the batteries is mountable; and

in a disconnected state in which each of the batteries and the electric circuit are disconnected, each of the detection devices of the batteries detects whether the electric leakage has occurred.

* * * * *