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Takahashi

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(54) **VEHICLE AND COMMUNICATION CONTROL METHOD FOR THE SAME**

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B60L 53/66 (2019.01)
B60L 58/12 (2019.01)

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CPC ***H04W 52/0225*** (2013.01); ***B60L 53/66*** (2019.02); ***B60L 58/12*** (2019.02); *B60L 2240/70* (2013.01)

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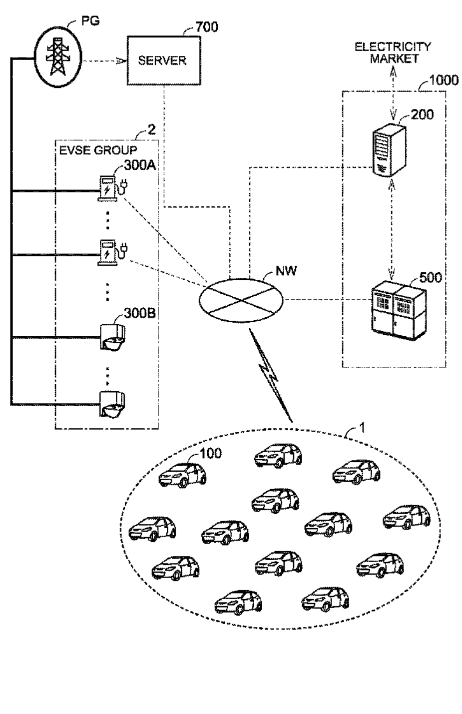
(57) **ABSTRACT**

A vehicle includes: a first energy storage device that is electrically connectable to an external power supply; a wireless communication device; a second energy storage device that supplies power to the wireless communication device, and a control device that communicates with a management device outside the vehicle through the wireless communication device. The first energy storage device is configured to supply power to the second energy storage device. The control device is configured to restrict wireless communication by the wireless communication device when a communication restriction condition set using a cumulative number of communications of the wireless communication device is satisfied. The communication restriction condition when the external power supply and the vehicle are not electrically connected to each other is set to be more easily satisfied than the communication restriction condition when the external power supply and the vehicle are electrically connected to each other.

8 Claims, 11 Drawing Sheets



(58) **Field of Classification Search**

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USPC 455/575

See application file for complete search history.

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FIG. 1

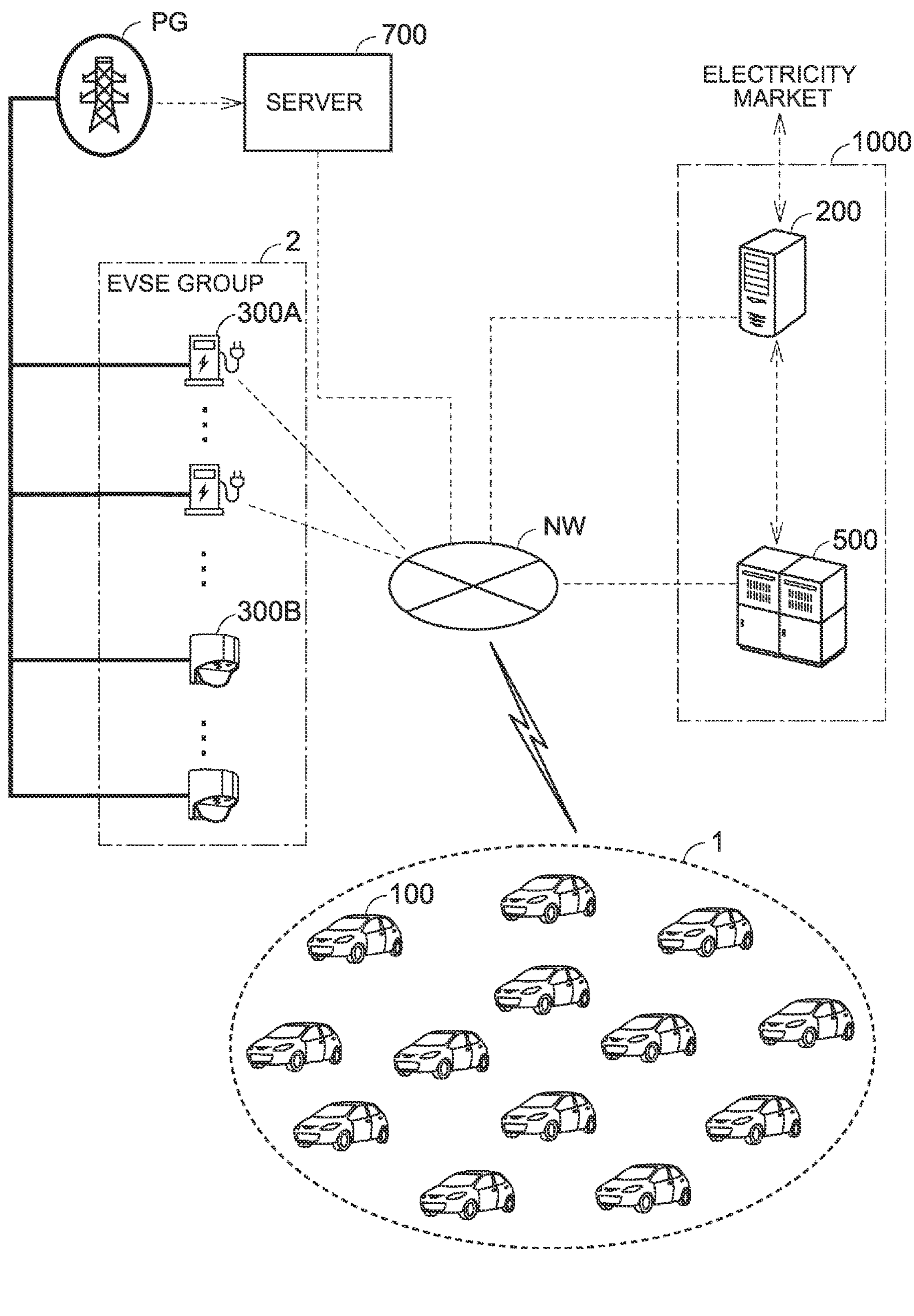

PG
700
SERVER
ELECTRICITY MARKET
1000
200
2
EVSE GROUP
300A
NW
500
300B
1
100

FIG. 2

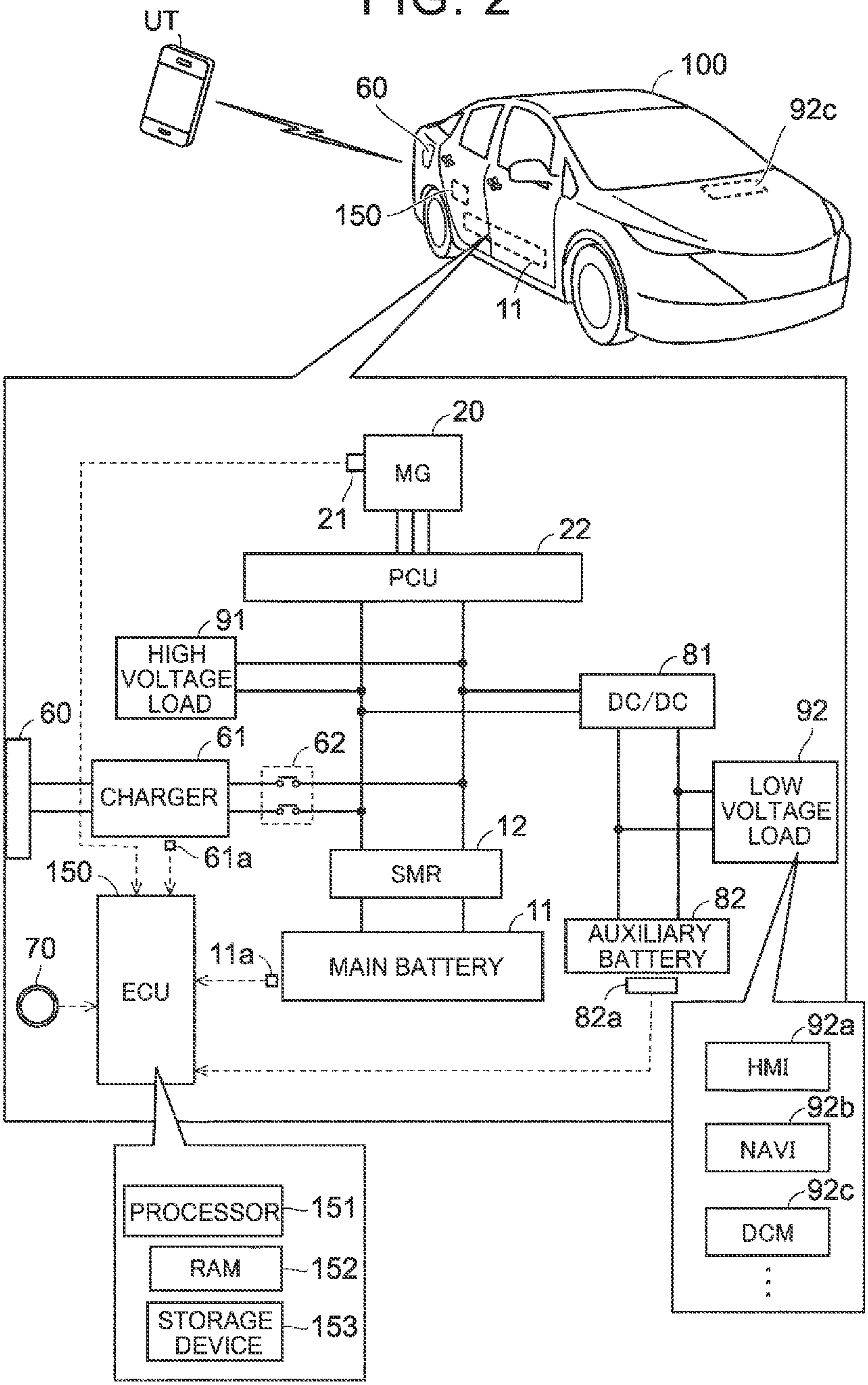

UT
60
100
92c
150
11
20
MG
21
22
PCU
91
HIGH VOLTAGE LOAD
81
DC/DC
92
60
61
CHARGER
62
LOW VOLTAGE LOAD
12
61a
150
SMR
11
82
70
AUXILIARY BATTERY
11a
ECU
MAIN BATTERY
82a
92a
HMI
92b
NAVI
92c
DCM
PROCESSOR
151
RAM
152
STORAGE DEVICE
153

FIG. 3

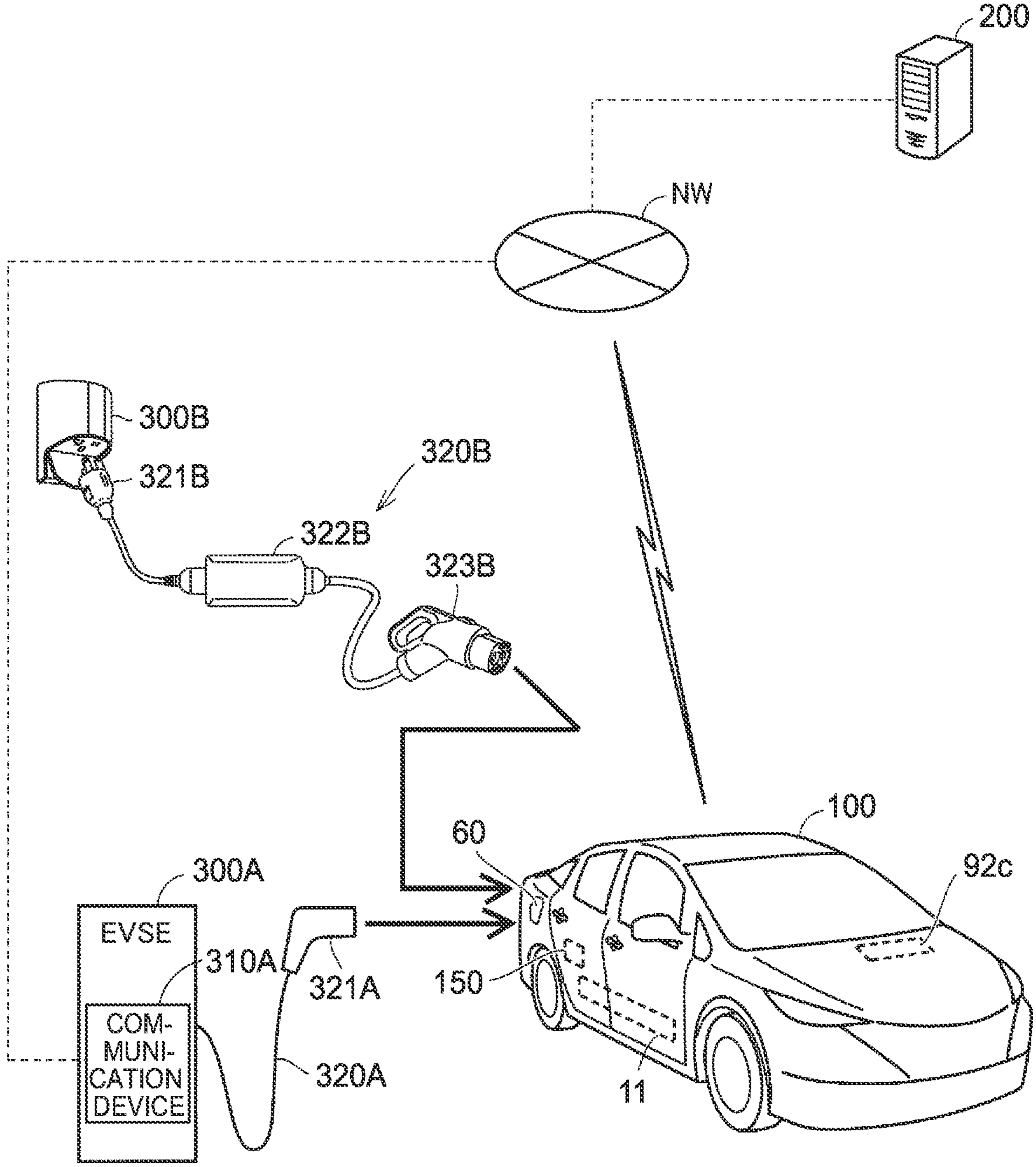

200
NW
300B
321B
320B
322B
323B
100
60
92c
300A
EVSE
310A
321A
150
COM-
MUNI-
CATION
DEVICE
320A
11

FIG. 4

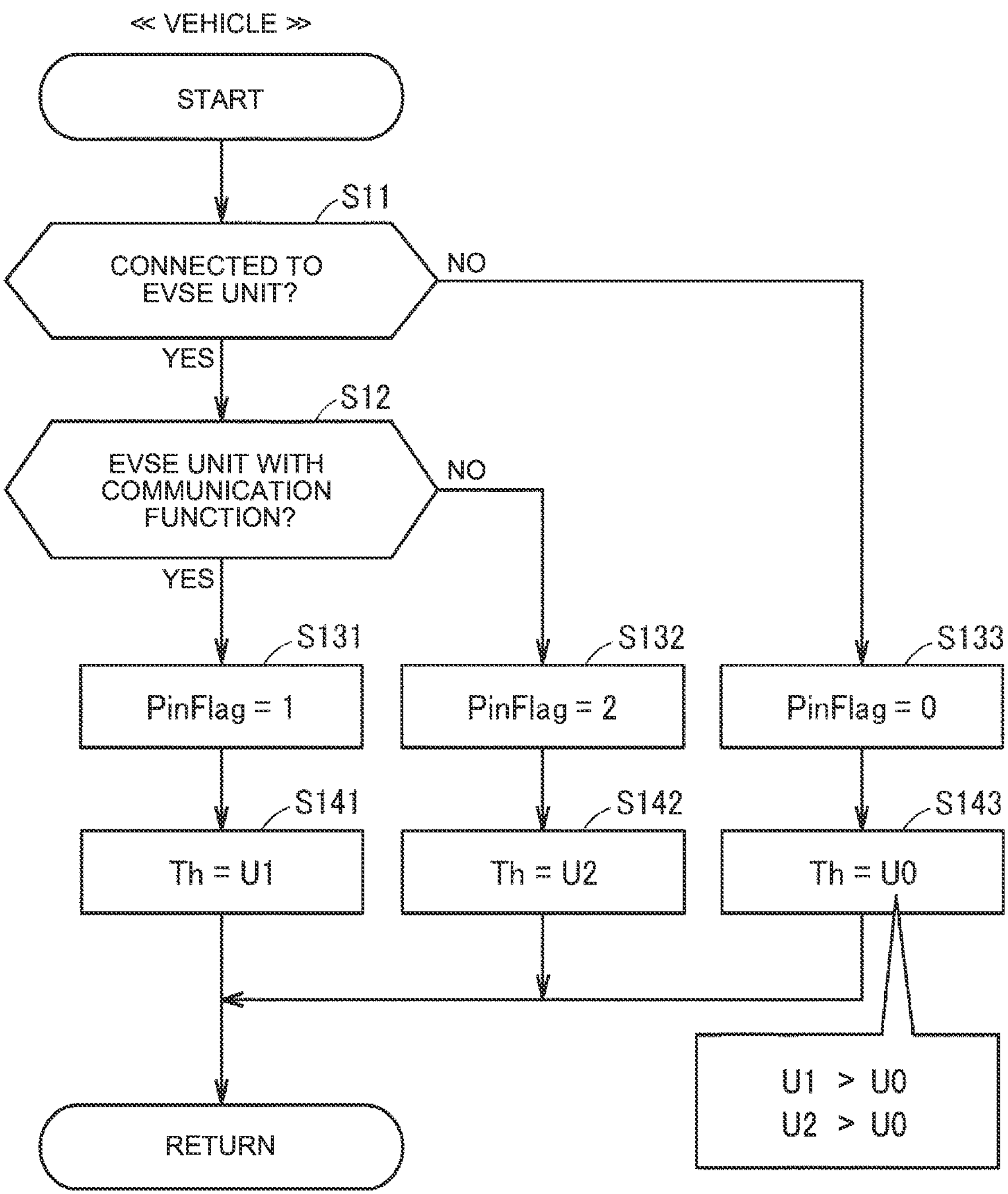
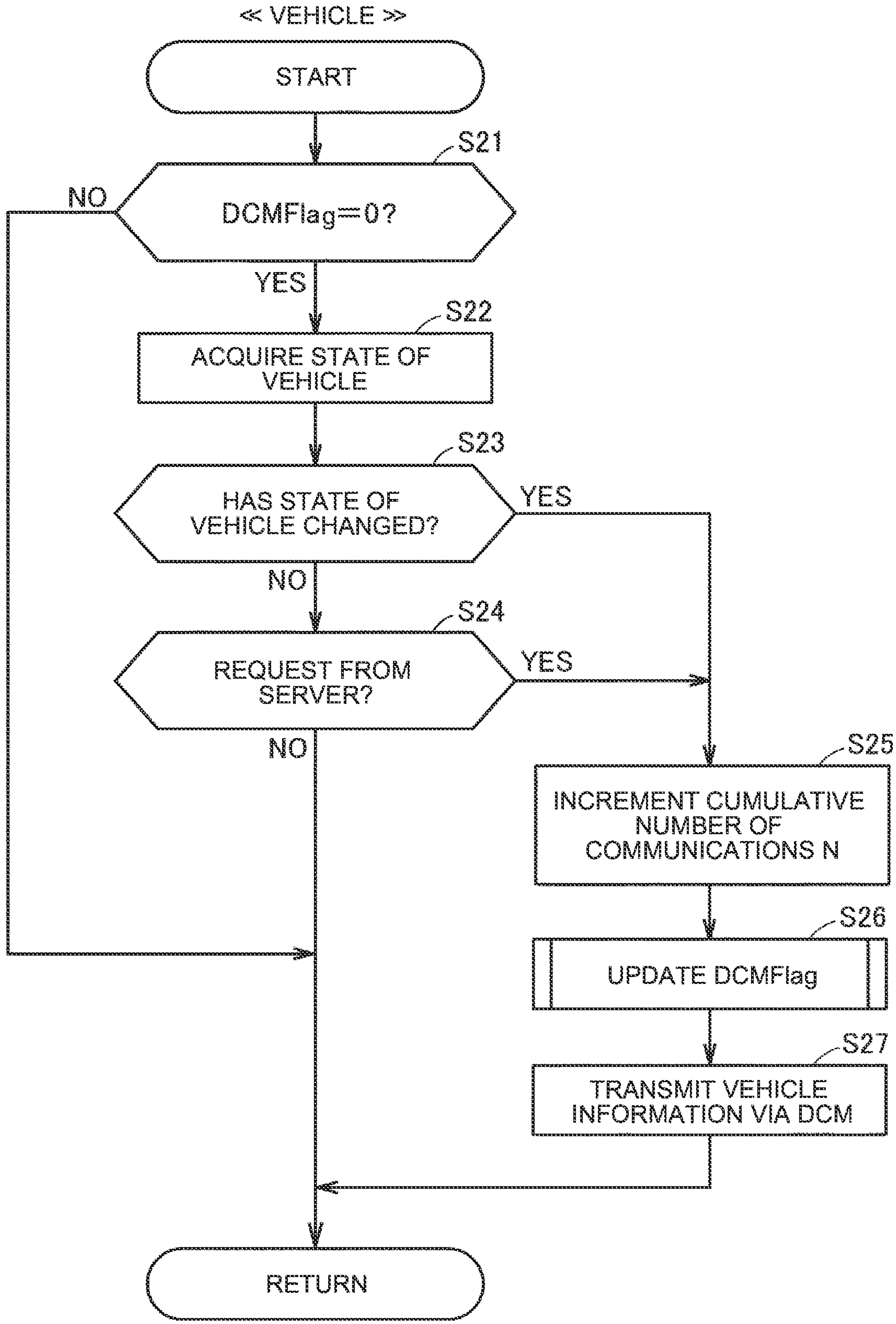

≪ VEHICLE ≫
START
S11
CONNECTED TO EVSE UNIT?
NO
YES
S12
EVSE UNIT WITH COMMUNICATION FUNCTION?
NO
YES
S131
PinFlag = 1
S132
PinFlag = 2
S133
PinFlag = 0
S141
Th = U1
S142
Th = U2
S143
Th = U0
U1 > U0
U2 > U0
RETURN

FIG. 5



≪ VEHICLE ≫
START
S21
DCMFlag=0?
NO
YES
S22
ACQUIRE STATE OF VEHICLE
S23
HAS STATE OF VEHICLE CHANGED?
YES
NO
S24
REQUEST FROM SERVER?
YES
NO
S25
INCREMENT CUMULATIVE NUMBER OF COMMUNICATIONS N
S26
UPDATE DCMFlag
S27
TRANSMIT VEHICLE INFORMATION VIA DCM
RETURN

FIG. 6

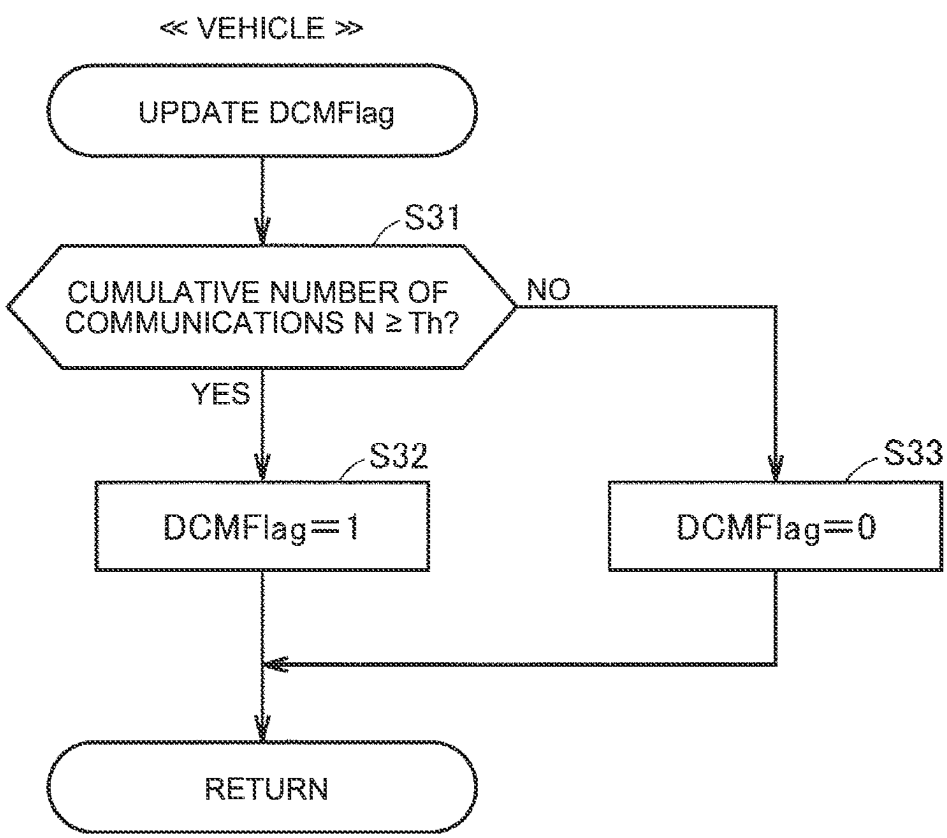

≪ VEHICLE ≫
UPDATE DCMFlag
S31
CUMULATIVE NUMBER OF COMMUNICATIONS N ≥ Th?
NO
YES
S32
DCMFlag=1
S33
DCMFlag=0
RETURN

FIG. 7

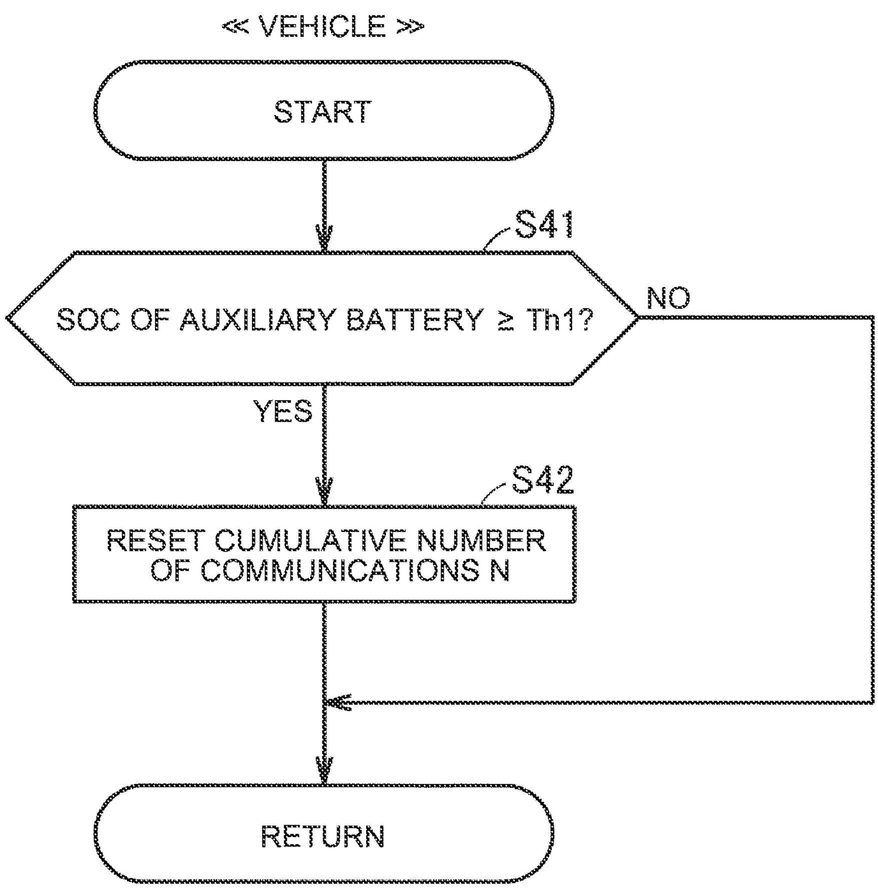
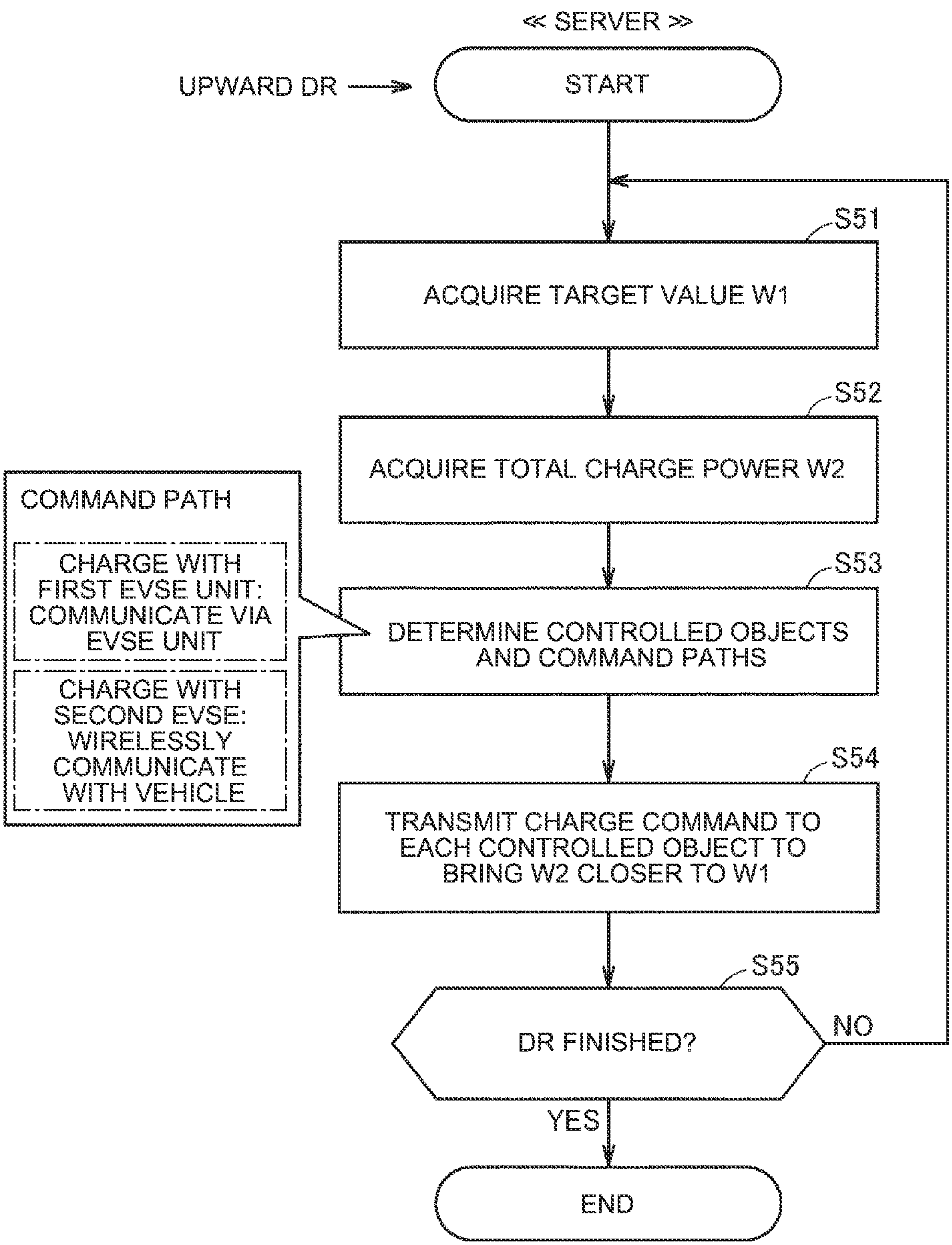

≪ VEHICLE ≫
START
S41
SOC OF AUXILIARY BATTERY ≥ Th1?
NO
YES
S42
RESET CUMULATIVE NUMBER OF COMMUNICATIONS N
RETURN

FIG. 8



≪ SERVER ≫
UPWARD DR
START
S51
ACQUIRE TARGET VALUE W1
S52
ACQUIRE TOTAL CHARGE POWER W2
COMMAND PATH
CHARGE WITH FIRST EVSE UNIT: COMMUNICATE VIA EVSE UNIT
CHARGE WITH SECOND EVSE: WIRELESSLY COMMUNICATE WITH VEHICLE
S53
DETERMINE CONTROLLED OBJECTS AND COMMAND PATHS
S54
TRANSMIT CHARGE COMMAND TO EACH CONTROLLED OBJECT TO BRING W2 CLOSER TO W1
S55
DR FINISHED?
NO
YES
END

FIG. 9

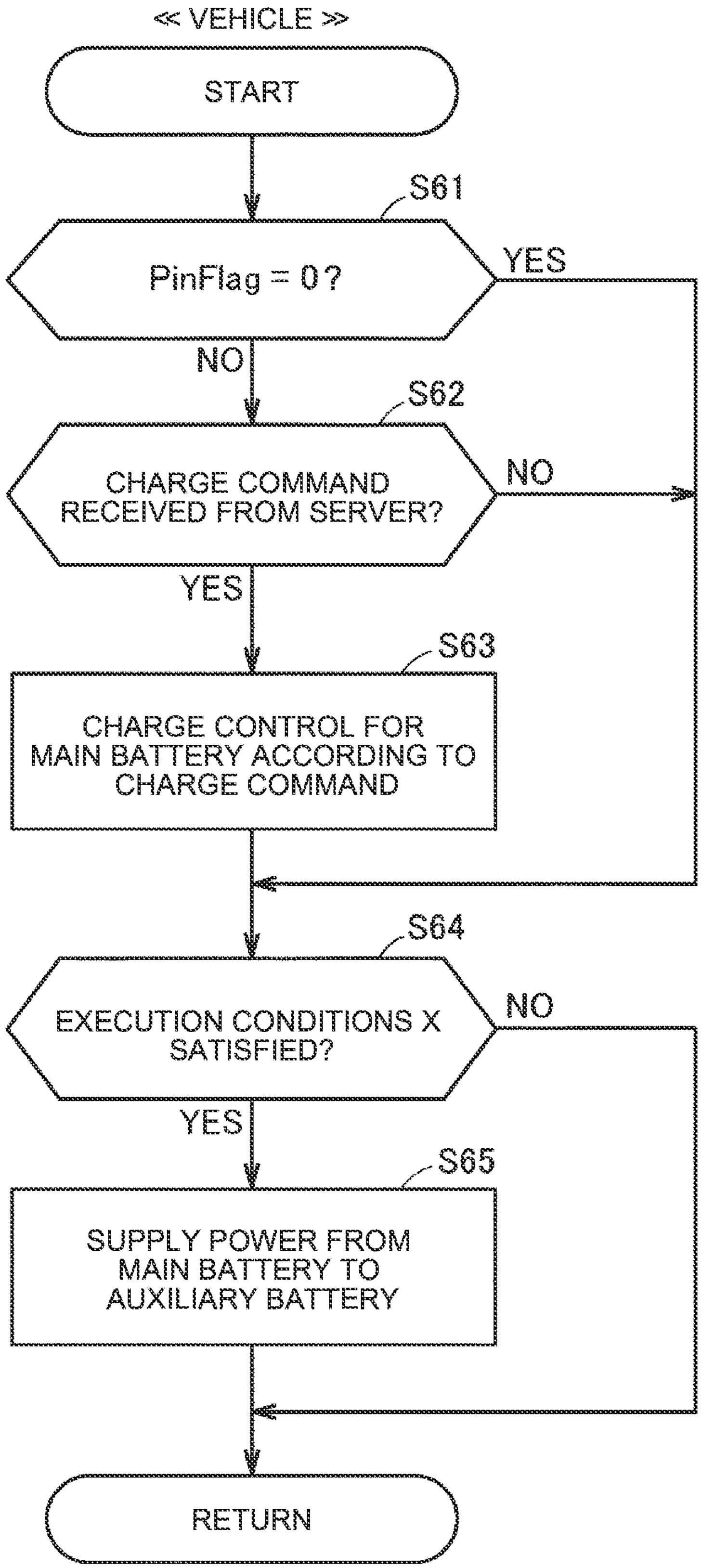
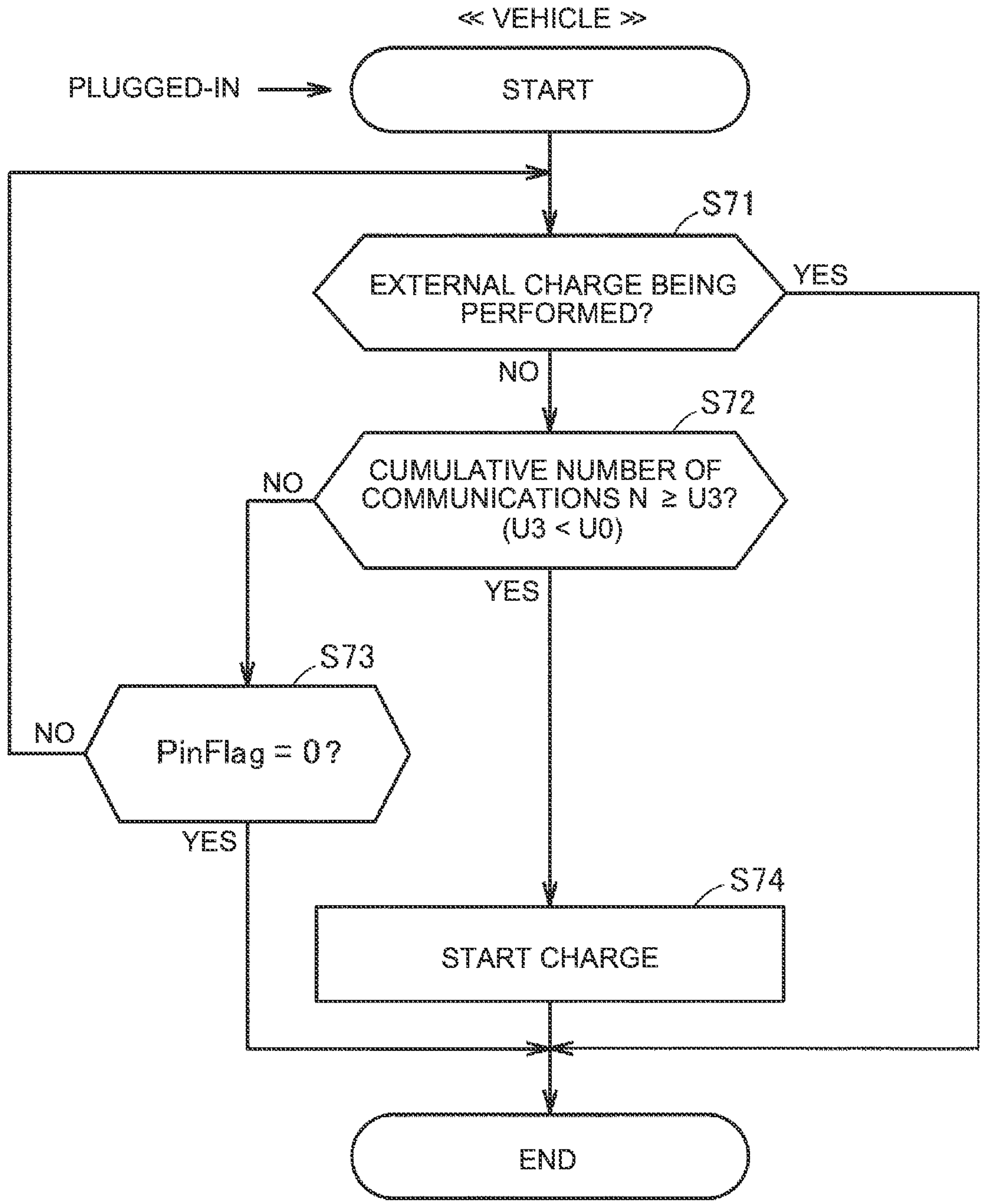
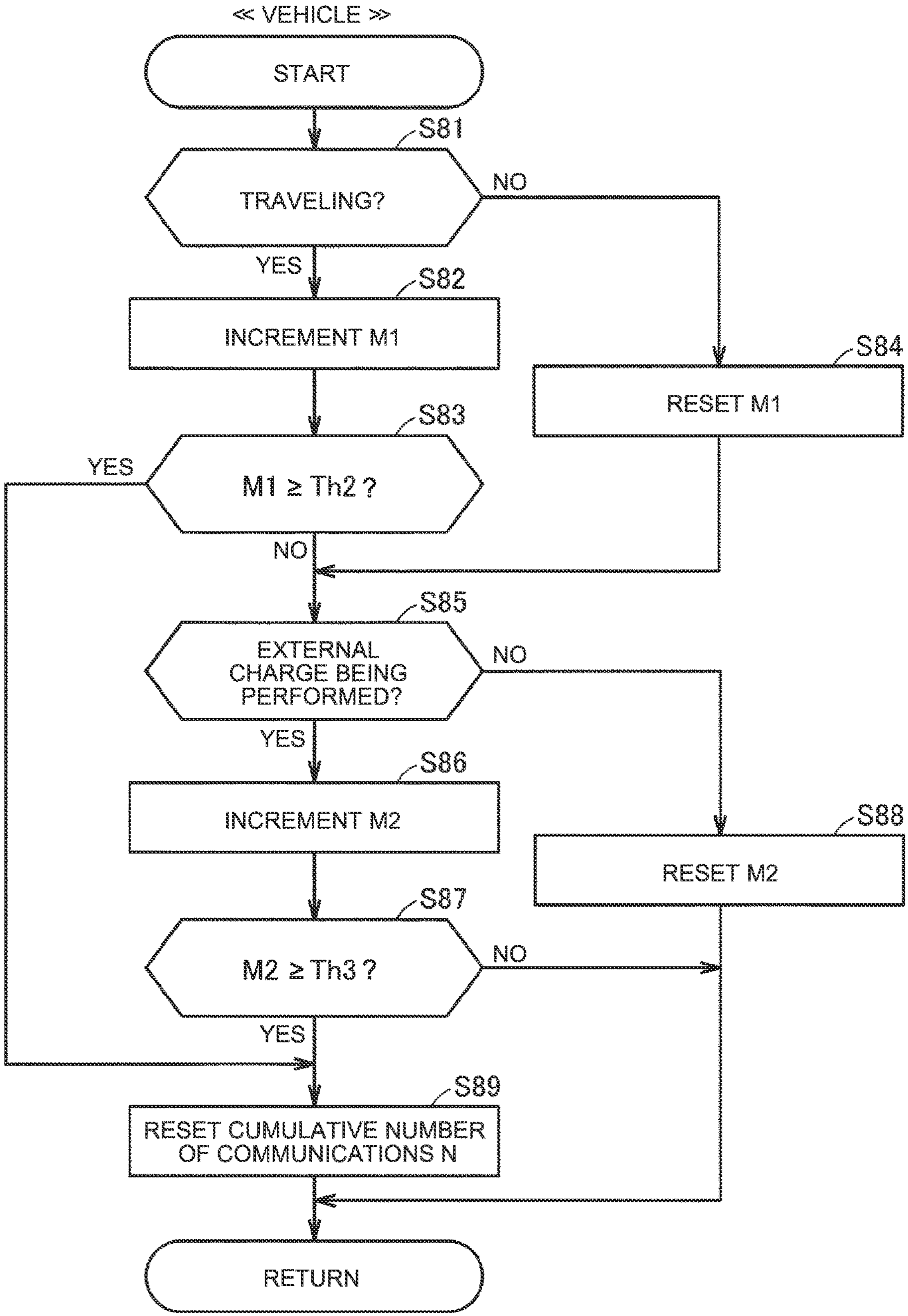

≪ VEHICLE ≫
START
S61
PinFlag = 0 ?
YES
NO
S62
CHARGE COMMAND RECEIVED FROM SERVER?
NO
YES
S63
CHARGE CONTROL FOR MAIN BATTERY ACCORDING TO CHARGE COMMAND
S64
EXECUTION CONDITIONS X SATISFIED?
NO
YES
S65
SUPPLY POWER FROM MAIN BATTERY TO AUXILIARY BATTERY
RETURN

FIG. 10



≪ VEHICLE ≫
PLUGGED-IN
START
S71
EXTERNAL CHARGE BEING PERFORMED?
YES
NO
S72
CUMULATIVE NUMBER OF COMMUNICATIONS N ≥ U3? (U3 < U0)
NO
YES
S73
PinFlag = 0 ?
NO
YES
S74
START CHARGE
END

FIG. 11



≪ VEHICLE ≫
START
S81
TRAVELING?
NO
YES
S82
INCREMENT M1
S84
RESET M1
S83
M1 ≥ Th2 ?
YES
NO
S85
EXTERNAL CHARGE BEING PERFORMED?
NO
YES
S86
INCREMENT M2
S88
RESET M2
S87
M2 ≥ Th3 ?
NO
YES
S89
RESET CUMULATIVE NUMBER OF COMMUNICATIONS N
RETURN

VEHICLE AND COMMUNICATION CONTROL METHOD FOR THE SAME

CROSS-REFERENCE TO RELATED APPLICATION

This application claims priority to Japanese Patent Application No. 2022-041478 filed on Mar. 16, 2022, incorporated herein by reference in its entirety.

BACKGROUND

1. Technical Field

The present disclosure relates to vehicles and communication control methods for the same.

2. Description of Related Art

In recent years, electric utilities have been known that bundle a plurality of distributed energy resources (hereinafter also referred to as "DERs") and provide an energy management service (hereinafter referred to as "aggregators"). For example, Japanese Unexamined Patent Application Publication No. 2020-156149 (JP 2020-156149 A) discloses a technique for an aggregator to operate power devices according to an operation plan. The charge and discharge performance of the power devices can vary depending on the environment (e.g., temperature). Therefore, in JP 2020-156149, the aggregator acquires the charge and discharge performance of the power devices corrected by environmental information.

SUMMARY

In recent years, a technique for a server outside a vehicle to remotely control the vehicle has been attracted attention. Such a remote control technique can be used for power balancing (energy management) of an external power supply. For example, a server remotely controls a vehicle equipped with a wireless communication device and an energy storage device by wireless communication to perform charge and discharge control of the energy storage device for power balancing of the external power supply. However, when the wireless communication device is used frequently, an auxiliary battery that supplies power to the wireless communication device may run short of power.

The present disclosure provides a vehicle and a communication control method for the vehicle that facilitates power balancing of an external power source through wireless communication and that makes it less likely that an energy storage device that supplies power to a wireless communication device will run short of power.

A vehicle according to a first aspect of the present disclosure includes: a first energy storage device configured to be electrically connected to an external power supply; a wireless communication device; a second energy storage device configured to supply power to the wireless communication device; and a control device configured to communicate with a management device outside the vehicle through the wireless communication device. The first energy storage device is configured to supply power to the second energy storage device. The control device is configured to restrict wireless communication of the wireless communication device when a communication restriction condition set using a cumulative number of communications of the wireless communication device is satisfied. The communication restriction condition when the external power supply and the vehicle are not electrically connected to each other is set to be more easily satisfied than the communication restriction condition when the external power supply and the vehicle are electrically connected to each other.

According to the above configuration, wireless communication of the wireless communication device is restricted when the communication restriction condition is satisfied. This reduces power consumption of the second energy storage device (e.g., an auxiliary battery), so that the second energy storage device is less likely to run short of power. The higher the cumulative number of communications by the wireless communication device, the greater the power consumption of the second energy storage device tends to be. Therefore, the use of the cumulative number of communications of the wireless communication device facilitates appropriate setting of the communication restriction condition. In the above configuration, the communication restriction condition is less easily satisfied when the external power supply and the vehicle are electrically connected to each other than when the external power supply and the vehicle are not electrically connected to each other. This makes it easier for the management device to remotely control the vehicle by wireless communication to perform vehicle control for power balancing of the external power supply (i.e., charge control or discharge control of the first energy storage device). When the external power supply and the vehicle are electrically connected to each other, the second energy storage device can receive power supplied form the external power supply via the first energy storage device.

The cumulative number of communications of the wireless communication device may be updated by the control device. The control device may increment the cumulative number of communications every time the wireless communication device performs wireless communication, and may reset the cumulative number of communications to an initial value (e.g., zero) when a predetermined reset condition is satisfied.

The external power supply may be a power grid that supplies power to a predetermined area (e.g., a microgrid or a large-scale electrical network developed as an infrastructure). The external power supply may be a smart grid. The external power supply may supply alternating current (AC) power or direct current (DC) power. Power balancing may be frequency control or may be supply-demand balancing.

The management device may be one computer, or may be composed of a plurality of computers that can communicate with each other. The vehicle may be an electrified vehicle (xEV) that runs on power stored in the first energy storage device. Electrified vehicles (xEVs) include battery electric vehicles (BEVs), plug-in hybrid electric vehicles (PHEVs), and fuel cell electric vehicles (FCEVs).

The communication restriction condition may not be satisfied when a state of charge (SOC) of the second energy storage device is equal to or greater than a first threshold. In such a configuration, wireless communication of the wireless communication device is not restricted when the SOC of the second energy storage device is sufficiently high. This facilitates power balancing of the external power supply through wireless communication. The SOC indicates the remaining capacity of the energy storage device. For example, the SOC is the ratio of the available capacity to the capacity in the fully charged state and varies between 0% and 100%.

The control device may be configured to prohibit wireless communication of the wireless communication device when the communication restriction condition is satisfied by the cumulative number of communications of the wireless communication device reaching a first upper limit value with the external power supply and the vehicle not being electrically connected to each other. The control device may be configured to prohibit wireless communication of the wireless communication device when the communication restriction condition is satisfied by the cumulative number of communications of the wireless communication device reaching a second upper limit value that is greater than the first upper limit value with the external power supply and the vehicle being electrically connected to each other.

In the above configuration, the first upper limit is smaller than the second upper limit. Accordingly, the communication restriction condition when the external power supply and the vehicle are not electrically connected to each other is more easily satisfied than the communication restriction condition when the external power supply and the vehicle are electrically connected to each other. Moreover, since wireless communication of the wireless communication device is prohibited when the cumulative number of communications by the wireless communication device reaches the upper limit value (first or second upper limit value), the second energy storage device is less likely to run short of power.

The second energy storage device may be configured to be charged while the vehicle is traveling. The control device may be is configured to reset the cumulative number of communications of the wireless communication device when a continuous travel distance or travel time of the vehicle becomes equal to or greater than a second threshold value.

When the vehicle travels continuously for a long period of time, the SOC of the second energy storage device is estimated to be sufficiently increased by the power supplied from the first energy storage device. In the above configuration, when the continuous travel distance or travel time of the vehicle becomes greater than a predetermined value (second threshold), the cumulative number of communications of the wireless communication device is reset, and the wireless communication device becomes available. Wireless communication of the wireless communication device that has been prohibited is resumed. This facilitates power balancing of the external power supply through wireless communication.

The first energy storage device may be configured to supply power to the second energy storage device while the first energy storage device is being charged with power supplied from the external power supply. The control device may be configured to reset the cumulative number of communications of the wireless communication device when an amount of charge power or charge duration due to a continuous charge of the first energy storage device becomes equal to or greater than a third threshold.

When the first energy storage device continues to be charged for a long period of time, the SOC of the second energy storage device is estimated to be sufficiently increased by the power supplied from the first energy storage device. In the above configuration, when the amount of charge power or charge duration due to a continuous charge of the first energy storage device becomes equal to or greater than a predetermined value (third threshold), the cumulative number of communications of the wireless communication device is reset, and the wireless communication device becomes available. Wireless communication of the wireless communication device that has been prohibited is resumed. This facilitates power balancing of the external power supply through wireless communication.

The wireless communication device may be configured to transmit a state of the vehicle to the management device as needed. The control device may be configured to start a charge of the first energy storage device using power supplied from the external power supply when the cumulative number of communications of the wireless communication device reaches a predetermined value that is smaller than the first upper limit with no charge of the first energy storage device being performed with the vehicle being electrically connected to the external power supply.

Depending on the charge condition for the first energy storage device set in the vehicle by the user, the first energy storage device may not be charged even when the vehicle is electrically connected to the external power supply, and the vehicle may be left for a long period of time without the first energy storage device being charged. When the wireless communication of such a vehicle is used frequently, the second energy storage device that supplies power to the wireless communication device tends to run short of power. In this regard, according to the above configuration, a charge of the first energy storage device is started when the cumulative number of communications of the wireless communication device becomes equal to or greater than the predetermined value that is smaller than the first upper limit. The first energy storage device can therefore supply power to the second energy storage device, and the second energy storage device is less likely to run short of power. Since the management device receives the state of the vehicle as needed, the management device can more easily appropriately control the vehicle for power balancing of the external power supply.

The control device may be configured to charge the first energy storage device according to a charge command received from the management device with the external power supply and the first energy storage device being electrically connected together.

According to the above configuration, power balancing of the external power supply is performed by charging the first energy storage device. Since the first energy storage device is charged, power can be supplied from the first energy storage device to the second energy storage device, and the second energy storage device is therefore less likely to run short of power during power balancing of the external power supply.

The control device may be configured to distinguish between first power supply equipment with a function to communicate with the management device and second power supply equipment without a function to communicate with the management device. The control device may be configured to communicate with the management device through the first power supply equipment when the control device charges the first energy storage device according to the charge command using power supplied from the external power supply to the vehicle via the first power supply equipment. The control device may be configured to communicate with the management device through the wireless communication device when the control device charges the first energy storage device according to the charge command using power supplied from the external power supply to the vehicle via the second power supply equipment.

When the control device performs power balancing of the external power supply (i.e., a charge according to the charge command from the management device) using the first power supply equipment with a function to communicate with the management device, the control device communicates with the management device through the first power supply equipment rather than through the wireless communication device. This reduces power consumption of the second energy storage device, so that the second energy storage device is less likely to run short of power. On the other hand, when the control device performs power balancing of the external power supply using the second power supply equipment, the control device communicates with the management device through the wireless communication device (in-vehicle communication device). Power balancing of the external power supply can thus be performed using the power supply equipment without a function to communicate with the management device (second power supply equipment).

A communication control method for a vehicle according to a second aspect of the present disclosure is a method for controlling communication of a vehicle described below. The method includes a transmission step, a first prohibition step, and a second prohibition step.

The vehicle includes: a first energy storage device that is electrically connectable to an external power supply; a wireless communication device; a second energy storage device that supplies power to the wireless communication device; and a control device that communicates with a management device outside the vehicle via the wireless communication device.

In the transmission step, the control device receives a control command for power balancing of the external power supply from the management device via the wireless communication device. In the first prohibition step, the control device prohibits wireless communication of the wireless communication device when a cumulative number of communications of the wireless communication device reaches a first upper limit value with the external power supply and the vehicle not being electrically connected to each other. In the second prohibition step, the control device prohibits wireless communication of the wireless communication device when the cumulative number of communications of the wireless communication device reaches a second upper limit value that is greater than the first upper limit value with the external power supply and the vehicle being electrically connected to each other.

Like the vehicle described above, this communication control method also facilitates power balancing of the external power supply using the first energy storage device, and makes it less likely that the second energy storage device that supplies power to the wireless communication device will run short of power.

The present disclosure provides a vehicle and a communication control method for the vehicle that facilitates power balancing of an external power source through wireless communication and that makes it less likely that an energy storage device that supplies power to a wireless communication device will run short of power.

BRIEF DESCRIPTION OF THE DRAWINGS

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

FIG. **1** shows a schematic configuration of a management system according to an embodiment of the present disclosure;

FIG. **2** shows a configuration of a vehicle shown in FIG. **1**;

FIG. **3** illustrates a configuration of an EVSE unit shown in FIG. **1**;

FIG. **4** is a flowchart of a plugged-in determination process that is performed by a control device of the vehicle shown in FIG. **2**;

FIG. **5** is a flowchart of a process for wireless communication with a management device that is performed by the vehicle shown in FIG. **2**;

FIG. **6** is a flowchart showing in detail a process of restricting wireless communication shown in FIG. **5**;

FIG. **7** is a flowchart of a process for resetting the cumulative number of communications of a wireless communication device in a communication control method according to the embodiment of the present disclosure;

FIG. **8** is a flowchart of a process for controlling a vehicle group for power balancing of an external power supply that is performed by the management device according to the embodiment of the present disclosure;

FIG. **9** is a flowchart of a process that is periodically performed by the vehicle according to the embodiment of the present disclosure;

FIG. **10** is a flowchart of a process for charge start control that is performed by the vehicle according to the embodiment of the present disclosure; and

FIG. **11** is a flowchart of a modification of the process shown in FIG. **7**.

DETAILED DESCRIPTION OF EMBODIMENTS

An embodiment of the present disclosure will be described in detail with reference to the drawings. The same or corresponding parts are denoted by the same signs throughout the drawings, and description thereof will not be repeated.

FIG. **1** shows a schematic configuration of a management system according to an embodiment of the present disclosure. Referring to FIG. **1**, the management system according to the present embodiment includes a vehicle group **1**, an EVSE group **2**, a server **700**, and a management device **1000**. The management device **1000** includes servers **200**, **500**. EVSE stands for electric vehicle supply equipment.

Each of the servers **200**, **500**, and **700** is, for example, a computer equipped with a Human Machine Interface (HMI) and a communication interface (I/F). Each computer includes a processor and a storage device. The storage device stores, in addition to programs to be executed by the processor, information to be used in the programs (e.g., maps, mathematical formulas, and various parameters). The HMI includes an input device and a display device. The HMI may be a touch panel display.

A power grid PG is an electrical network that supplies electric power to a predetermined area. The power grid PG is formed by power transmission and distribution equipment. A plurality of power plants is connected to the power grid PG. Electric power is supplied from the power plants to the power grid PG. In the present embodiment, an electric power company maintains and manages the power grid PG (commercial power supply). The electric power company is a transmission system operator (TSO) (grid operator). The power grid PG supplies alternating current (AC) power (e.g., three-phase AC power). The server **700** is a computer belonging to the TSO. The server **700** may include a central load dispatching center system and a simple command system. The power grid PG according to the present embodiment is an example of the “external power supply” according to the present disclosure.

The server **500** periodically communicates with each vehicle in the vehicle group **1**. Each vehicle in the vehicle group **1** is an electrified vehicle (xEV), and is operable as a balancing power for the power grid PG. Each vehicle in the vehicle group **1** is, for example, a privately owned vehicle (POV). The number of vehicles in the vehicle group **1** may be 5 or more and less than 100, or may be 100 or more. It is assumed in the present embodiment that the vehicle group **1** includes 30 or more and less than 100 vehicles. The vehicle group **1** includes a vehicle **100** having the configuration that will be described below (see FIG. **2**). The vehicle **100** may have the same configuration as or a different configuration from the other vehicles in the vehicle group **1**.

The EVSE group **2** includes a plurality of EVSE units that is supplied with electric power from the power grid PG. The EVSE group **2** includes EVSE units **300**A, **300**B having the configuration that will be described later (see FIG. **3**). The EVSE unit **300**A is first power supply equipment having a function to communicate with the server **200** (hereinafter also referred to as "first EVSE unit"). The EVSE unit **300**B is second power supply equipment that does not have a function to communicate with the server **200** (hereinafter also referred to as "second EVSE unit"). The EVSE group **2** may include any number and types of EVSE units.

The management device **1000**, the vehicle group **1**, and the first EVSE unit included in the EVSE group **2** are configured to communicate with each other via a communication network NW. The server **700** communicates with the server **200** via the communication network NW. In the management device **1000**, the servers **200**, **500** are configured to communicate with each other. The communication network NW is a wide area network formed by, for example, the Internet and wireless base stations. Each vehicle in the vehicle group **1** is configured to access the communication network NW by wireless communication. The first EVSE unit is connected to the communication network NW via, for example, a communication line. The second EVSE unit is not connected to the communication network NW. The form of communication is not limited to the above and can be changed as appropriate. For example, the first EVSE unit may be connected to the communication network NW by wireless communication.

FIG. **2** shows the configuration of the vehicle **100**. Referring to FIG. **2** together with FIG. **1**, the vehicle **100** includes a main battery **11**, a system main relay (SMR) **12**, a motor generator (MG) **20**, a power control unit (PCU) **22**, an inlet **60**, and an electronic control unit (ECU) **150**.

The ECU **150** includes a processor **151**, a random access memory (RAM) **152**, and a storage device **153**. The ECU **150** may be a computer. The processor **151** may be a central processing unit (CPU). The RAM **152** temporarily stores data to be processed by the processor **151**. The storage device **153** is configured to save stored information. The storage device **153** stores, in addition to programs, information to be used in the programs (e.g., maps and various parameters). In the present embodiment, various controls in the ECU **150** (e.g., charge control for the main battery **11**) are performed as the processor **151** executes the program stored in the storage device **153**. The ECU **150** is an example of the "control device" according to the present disclosure.

The main battery **11** stores electric power for moving the vehicle **100**. The vehicle **100** is configured to run on the electric power stored in the main battery **11**. The vehicle **100** according to the present embodiment is a battery electric vehicle (BEV) without an engine (internal combustion engine). The main battery **11** may be a known energy storage device for vehicles (e.g., a liquid secondary battery, an all-solid-state secondary battery, or an assembled battery). Examples of a secondary battery for vehicles include a lithium-ion battery and a nickel metal hydride battery.

The vehicle **100** further includes a monitoring module **11***a* that monitors the state of the main battery **11**. The monitoring module **11***a* includes various sensors that detect the state of the main battery **11** (e.g., voltage, current, and temperature). The monitoring module **11***a* outputs the detection results to the ECU **150**. The monitoring module **11***a* may be a battery management system (BMS) having a state of charge (SOC) estimation function, a state of health (SOH) estimation function, a cell voltage equalization function, a diagnostic function, and a communication function, in addition to the above sensor function. The ECU **150** can acquire the state of the main battery **11** (e.g., temperature, current, voltage, SOC, and internal resistance) based on the output of the monitoring module **11***a*.

The vehicle **100** further includes a charger **61** (in-vehicle charger) and a charging relay **62**. The charger **61** and the charging relay **62** are located between the inlet **60** and the main battery **11**. The charger **61** and the charging relay **62** are controlled by the ECU **150**. In the present embodiment, a charging line including the inlet **60**, the charger **61**, and the charging relay **62** is connected between the SMR **12** and the PCU **22**. However, the present disclosure is not limited to this, and the charging line may be connected between the main battery **11** and the SMR **12**.

The charger **61** charges the main battery **11** with power (e.g., AC power) input from outside the vehicle **100** to the inlet **60**. The charger **61** includes a power converter circuit. The power converter circuit may be configured to convert alternating current (AC) to direct current (DC). The power converter circuit may include at least one of the following: a power factor correction (PFC) circuit, an inverter, an isolation circuit (e.g., isolation transformer), and a rectifier circuit. The charging relay **62** connects and disconnects the electrical path from the inlet **60** to the main battery **11**. The vehicle **100** further includes a monitoring module **61***a* that monitors the state of the charger **61** (e.g., charging power). The monitoring module **61***a* includes various sensors that detect the state of the charger **61** (e.g., current sensor and voltage sensor), and outputs the detection results to the ECU **150**.

The MG **20** is, for example, a three-phase AC motor generator. The MG **20** functions as a traction motor of the vehicle **100**. The MG **20** is driven by the PCU **22** and rotates drive wheels of the vehicle **100**. The PCU **22** drives the MG **20** using power supplied from the main battery **11**. The SMR **12** connects and disconnects the electrical path from the main battery **11** to the PCU **22**. The SMR **12** and the PCU **22** are controlled by the ECU **150**. The PCU **22** includes, for example, an inverter and a converter, and performs power conversion as instructed by the ECU **150**. The SMR **12** is closed (connected) when the vehicle **100** is traveling. The SMR **12** is also closed when power is transferred between the main battery **11** and the inlet **60** (and outside the vehicle).

The MG **20** generates regenerative power and supplies the generated regenerative power to the main battery **11**. When the vehicle **100** is traveling, the main battery **11** is regeneratively charged with the power generated by the MG **20**. The vehicle **100** further includes a motor sensor **21** that monitors the state of the MG **20**. The motor sensor **21** includes various sensors that detect the state of the MG **20** (e.g., current sensor, voltage sensor, and temperature sensor), and output the detection results to the ECU **150**. The vehicle **100** may include any desired number of traction motors. The vehicle **100** may include one traction motor, two traction motors, or three or more traction motors. The traction motor may be an in-wheel motor.

The vehicle **100** further includes a direct current-to-direct current (DC-to-DC) converter **81**, an auxiliary battery **82**, a monitoring module **82***a*, a high voltage load **91**, and a low voltage load **92**. The high voltage load **91** is high voltage auxiliaries. The low voltage load **92** is low voltage auxiliaries. The driving voltage for the low voltage load **92** is lower than that for the high voltage load **91**. The DC-to-DC converter **81** steps down the voltage of the power supplied from the main battery **11** and outputs the resultant voltage to the auxiliary battery **82** and the low voltage load **92**. The auxiliary battery **82** is a low voltage in-vehicle battery, and supplies power to the low voltage load **92**. The capacity of the auxiliary battery **82** is smaller than that of the main battery **11**. The auxiliary battery **82** may be a lead-acid battery. The SMR **12** is closed when the main battery **11** supplies power to at least one of the following: the high voltage load **91**, the low voltage load **92**, and the auxiliary battery **82**. The main battery **11** and the auxiliary battery **82** are an example of the "first energy storage device" and the "second energy storage device" according to the present disclosure, respectively.

The monitoring module **82***a* includes various sensors that detect the state of the auxiliary battery **82** (e.g., voltage, current, and temperature), and outputs the detection results to the ECU **150**. The ECU **150** can acquire the state of the auxiliary battery **82** (e.g., temperature, current, voltage, SOC, and internal resistance) based on the output of the monitoring module **82***a*. The auxiliary battery **82** is configured to be charged while the vehicle **100** is traveling. The monitoring module **82***a* constantly monitors the voltage across the terminals of the auxiliary battery **82** or the SOC of the auxiliary battery **82** while the vehicle **100** is traveling. The ECU **150** charges the auxiliary battery **82** so that the voltage across the terminals of the auxiliary battery **82** or the SOC of the auxiliary battery **82** becomes equal to or higher than a predetermined value. For example, the auxiliary battery **82** is charged with the power stored in the main battery **11** or the power generated by the MG **20**.

Each of the high voltage load **91** and the low voltage load **92** receives an operation from a user. Each of the high voltage load **91** and the low voltage load **92** includes a power supply circuit that generates driving power according to the user's operation. When the user operates the high voltage load **91**, the ECU **150** controls the SMR **12** and the high voltage load **91** according to the user's operation. When the user operates the low voltage load **92**, the ECU **150** controls the SMR **12**, the DC-to-DC converter **81**, and the low voltage load **92** according to the user's operation. In the present embodiment, the high voltage load **91** includes air conditioning equipment. The air conditioning equipment may include a built-in inverter. The low voltage load **92** includes a Human-Machine Interface (HMI) **92***a*, a navigation system (hereinafter also referred to as "NAVI") **92***b*, and a Data Communication Module (DCM) **92***c*. The low voltage load **92** may further include a lighting device.

The HMI **92***a* includes an input device and a display device. The HMI **92***a* may include a touch panel display. The HMI **92***a* may take reservations for a timer charge that will be described later. The HMI **92***a* may include a meter panel and/or a head-up display. The HMI **92***a* may include a smart speaker that receives voice input.

The NAVI **92***b* includes a touch panel display, a Global Positioning System (GPS) module, and a storage device (none of which are shown). The storage device stores map information. The touch panel display receives input from the user and displays a map and other information. The GPS module is configured to receive signals from GPS satellites, not shown (hereinafter referred to as "GPS signals"). The NAVI **92***b* detects the location of the vehicle **100** using the GPS signals. The NAVI **92***b* is configured to display the location of the vehicle **100** in real time on the map. The NAVI **92***b* performs a route search for finding an optimal route (e.g., shortest route) from the current location of the vehicle **100** to the destination by referring to the map information. The NAVI **92***b* may update that map information by Over The Air (OTA) as needed.

The DCM **92***c* is a wireless communication device that can access the communication network NW. The DCM **92***c* is configured to communicate with the management device **1000** by wireless communication. The ECU **150** communicates with devices located outside the vehicle (e.g., management device **1000**) via the DCM **92***c*. In the present embodiment, the vehicle **100** receives commands or notifications from the servers **200**, **500** by the DCM **92***c*. The DCM **92***c* may include a communication I/F compatible with the fifth or sixth generation mobile communication system (5G or 6G).

The vehicle **100** is electrically connected to the power grid PG via the EVSE unit when the EVSE unit is electrically connected to the vehicle **100** in a parked state via a charging cable (hereinafter also referred to as "plugged-in state"). The vehicle **100** is not electrically connected to the EVSE unit and the power grid PG while, for example, the vehicle **100** is traveling (hereinafter also referred to as "plugged-out state"). The inlet **60** of the vehicle **100** is connectable to both of the EVSE units **300**A, **300**B that will be described below.

FIG. **3** illustrates the configuration of the EVSE units **300**A, **300**B. Referring to FIG. **3** together with FIGS. **1** and **2**, the EVSE units **300**A, **300**B are equipped with charging cables **320**A, **320**B, respectively. The EVSE units **300**A, **300**B can be electrically connected to the vehicle **100** via the charging cables **320**A, **320**B, respectively. The EVSE units **300**A, **300**B are configured to convert the power (e.g., AC power) supplied from the power grid PG (FIG. **1**) to power suitable for supply to the vehicle **100** and supply the resultant power to the vehicle **100**.

In the present embodiment, the EVSE unit **300**A is installed in the workplace of the user of the vehicle **100**. The EVSE unit **300**A includes a communication device **310**A. The communication device **310**A includes a communication I/F for communication with the server **200**. The charging cable **320**A is connected to the body of the EVSE unit **300**A. The charging cable **320**A includes a connector **321**A (plug) at its distal end, and includes a communication line and a power line inside. The EVSE unit **300**A further includes a first control device and a first power converter circuit (both not shown) as its built-in components. The first control device communicates with the vehicle **100** and the server **200**. The first control device communicates with the server **200** through the communication device **310**A. The first control device communicates with the vehicle **100** via the communication line inside the charging cable **320**A.

The connector **321**A can be connected to and disconnected from the inlet **60** of the vehicle **100**. The vehicle **100** is electrically connected to the power grid PG via the EVSE unit **300**A when the connector **321**A is connected to the inlet **60** of the vehicle **100** (hereinafter also referred to as "first plugged-in state"). In the first plugged-in state, the first control device controls the first power converter circuit based on a command from the vehicle **100** or the server **200** and outputs supply power (e.g., AC power) to the connector **321**A.

In the present embodiment, the EVSE unit **300**B is installed in the home of the user of the vehicle **100**. The power grid PG (FIG. **1**) may supply 100V or 200V power to the EVSE unit **300**B via a residential distribution board, not shown (i.e., a distribution board connected to house wires). The charging cable **320**B is connected to the EVSE unit **300**B. The charging cable **320**B includes a plug **321**B, a control box **322**B, and a connector **323**B, and includes a communication line and a power line inside. The EVSE unit **300**B includes an outlet to and from which the plug **321**B can be connected and disconnected. The plug **321**B is connected to the outlet of the EVSE unit **300**B and receives AC power from this outlet. The AC power output from the EVSE unit **300**B to the plug **321**B (input end) is output to the connector **323**B (output end) through the control box **322**B.

The control box **322**B includes a second control device and a second power converter circuit (both not shown) as its built-in components. The second control device communicates with the vehicle **100** via the communication line inside the charging cable **320**B. The second control device does not communicate with the server **200**. The AC power adjusted to an appropriate voltage and current by the second power converter circuit in the control box **322**B is output from the connector **323**B. The connector **323**B can be connected to and disconnected from the inlet **60** of the vehicle **100**. The vehicle **100** is electrically connected to the power grid PG via the EVSE unit **300**B when the plug **321**B is connected to the outlet of the EVSE unit **300**B and the connector **323**B is connected to the inlet **60** of the vehicle **100** (hereinafter also referred to as "second plugged-in state"). In the second plugged-in state, the second control device controls the second power converter circuit based on a command from the vehicle **100** and outputs supply power (e.g., AC power) to the connector **323**B.

The configuration of each EVSE unit **300**A, **300**B is not limited to the configuration described above. For example, either or both of the EVSE units **300**A, **300**B may output DC power. The inlet **60** may have separate connection units for the EVSE units **300**A, **300**B, namely a first connection unit to which the EVSE unit **300**A is connected, and second connection unit to which the EVSE unit **300**B is connected. The charger **61** may perform separate power conversions on first power input from the first connection unit and second power input from the second connection unit. The vehicle **100** may include a plurality of inlets so as to be compatible with a plurality of types of power supply methods (e.g., AC and DC methods).

When the vehicle **100** goes into the first plugged-in state, a first cable connection signal (signal indicating identification information of the EVSE unit **300**A) is sent from the first control device of the EVSE unit **300**A to the ECU **150**. When the vehicle **100** goes into the second plugged-in state, a second cable connection signal (signal indicating identification information of the EVSE unit **300**B) is sent from the second control device of the EVSE unit **300**B to the ECU **150**. The ECU **150** according to the present embodiment determines whether the vehicle **100** is in the first plugged-in state, the second plugged-in state, or the plugged-out state based on the cable connection signal. This determination process is also referred to as the "plugged-in discrimination process."

FIG. **4** is a flowchart of the plugged-in determination process that is performed by the ECU **150**. In the following description, the term "step" in the flowchart is abbreviated as "S."

Referring to FIG. **4** together with FIGS. **1** to **3**, the ECU **150** determines in S**11** whether the vehicle **100** is electrically connected to an EVSE unit. Specifically, when the ECU **150** has received a first or second cable connection signal, the ECU **150** determines that the vehicle **100** is electrically connected to an EVSE unit (YES in S**11**). When the ECU **150** has not received any cable connection signal, the ECU **150** determines that the vehicle **100** is not electrically connected to any EVSE unit (NO in S**11**). The ECU **150** having received a cable connection signal means that the vehicle **100** is electrically connected to an EVSE unit (i.e., the vehicle is in the plugged-in state).

When YES in S**11**, the ECU **150** determines in S**12** whether the EVSE unit electrically connected to the vehicle **100** is a first EVSE unit (e.g., the EVSE unit **300**A shown in FIG. **3**). Specifically, when the ECU **150** has received a first cable connection signal, the ECU **150** determines that the vehicle **100** is electrically connected to a first EVSE unit. When the ECU **150** has received a second cable connection signal, the ECU **150** determines that the vehicle **100** is electrically connected to a second EVSE unit (e.g., the EVSE unit **300**B shown in FIG. **3**). The ECU **150** can thus distinguish between a first EVSE unit (first power supply equipment having a function to communicate with the management device **1000**) and a second EVSE unit (second power supply equipment that does not have a function to communicate with the management device **1000**).

The ECU **150** sets PinFlag and Th based on the determination results in S**11** and S**12**. Specifically, PinFlag and Th are stored in, for example, the storage device **153**. PinFlag is a flag indicating the result of the plugged-in identification process. PinFlag has values (1, 2, and 0) corresponding to the first plugged-in state, the second plugged-in state, and the plugged-out state. Th is an upper limit value of the cumulative number of communications N that will be described below (see S**31** in FIG. **6**). As will be described in detail later, when the cumulative number of communications N reaches Th, a communication restriction condition is satisfied, and wireless communication of the DCM **92***c* is prohibited. The smaller the Th, the more easily the communication restriction condition is satisfied.

When the vehicle **100** is electrically connected to a first EVSE unit (YES in S**12**), the ECU **150** sets PinFlag to "1" (value corresponding to the first plugged-in state) in S**131**, and sets Th to an upper limit value U1 (hereinafter sometimes simply referred to as "U1") in S**141**. When the vehicle **100** is electrically connected to a second EVSE unit (NO in S**12**), the ECU **150** sets PinFlag to "2" (value corresponding to the second plugged-in state) in S**132**, and sets Th to an upper limit value U2 (hereinafter sometimes simply referred to as "U2") in S**142**. When NO in S**11**, the ECU **150** sets PinFlag to "0" (value corresponding to the plugged-out state) in S**133**, and sets Th to an upper limit value U0 (hereinafter sometimes simply referred to as "U0") in S**143**.

U0 is Th in the plugged-out state, and is an example of the "first upper limit value" according to the present disclosure. Each of U1 and U2 is Th in the plugged-in state, and is an example of the "second upper limit value" according to the present disclosure. U1 and U2 are greater than U0. In the present embodiment, U1 and U2 are the same value. However, the present disclosure is not limited to this, and U1 and U2 may be different values. For example, in the second plugged-in state, the vehicle **100** cannot communicate with the server **200** through an EVSE unit. Therefore, U2 may be set to a value greater than U1 so that the vehicle **100** is more likely to communicate with the server **200** through the DCM **92***c*.

When the ECU **150** finishes setting PinFlag and Th in S**131** to S**133** and S**141** to S**143**, the routine returns to the first step (S**11**). The series of steps shown in FIG. **4** is repeatedly performed in a predetermined cycle. PinFlag and Th are updated as needed by the series of steps shown in FIG. **4**.

The method for detecting connection of a charging cable is not limited to the above method using a cable connection signal, and any desired method may be used. For example, the inlet **60** may be equipped with a sensor that detects connection of a charging cable (e.g., limit switch, proximity sensor, or photoelectric sensor). The inlet **60** may be equipped with a connection detection circuit that detects connection of a charging cable based on a voltage change that occurs when a charging cable is connected to the inlet **60**. The connection detection circuit may be configured so that the electrical resistance (e.g., partial resistance) varies among when the charging cable of a first EVSE unit is connected to the inlet **60**, when the charging cable of a second EVSE unit is connected to the inlet **60**, and when no charging cable is connected to the inlet **60**.

Referring back to FIG. **2** together with FIG. **1**, the vehicle **100** in the plugged-in state can perform an external charge (i.e., a charge of the main battery **11** with power from outside the vehicle). The vehicle **100** can perform power balancing of the power grid PG (FIG. **1**) by the external charge. For example, the power for the external charge is supplied from the power grid PG to the inlet **60** through an EVSE unit. The charging relay **62** is closed (connected) when the external charge is performed. The charging relay **62** is opened (disconnected) when the external charge is not performed.

The ECU **150** is configured so that the charge end time and target SOC (SOC at the end of charging) for a timer charge can be set in the ECU **150**. The ECU **150** with the charge end time and target SOC set therein performs a timer charge. A timer charge is a charge that is performed according to the reserved charge schedule. Specifically, in a timer charge of the vehicle **100**, the ECU **150** performs charge control of the main battery **11** (controls the charger **61**) so that the SOC of the main battery **11** reaches the target SOC at the scheduled charge end time.

Each vehicle in the vehicle group **1** is configured to take reservations for a timer charge from the user and perform a scheduled timer charge. Each vehicle in the vehicle group **1** sends charge reservation information to the server **500**. The charge reservation information indicates whether a timer charge is scheduled for the vehicle. The charge reservation information also indicates the set charge end time and target SOC for the vehicle. Each vehicle in the vehicle group **1** may send charge reservation information to the server **500** when a timer charge reservation is made. Those vehicles in the vehicle group **1** for which a timer charge is not scheduled perform an immediate charge. An immediate charge is an external charge that is started as soon as the vehicle goes into the plugged-in state. The vehicle **100** also starts a charge as instructed by the user. For example, the user of the vehicle **100** can instruct the ECU **150** to start a charge by operating a mobile terminal UT.

In the present embodiment, those vehicles in the vehicle group **1** for which a timer charge is scheduled permit the server **200** to remotely control the energy storage device. On the other hand, those vehicles in the vehicle group **1** for which a timer charge is not scheduled do not permit the server **200** to remotely control the energy storage device. However, the condition for permitting remote control is not limited to the above condition, and can be changed as appropriate.

The mobile terminal UT is a terminal carried by the user of the vehicle **100**. In the present embodiment, the mobile terminal UT is a smartphone with a touch panel display. The smartphone includes a built-in computer. The vehicle **100** further includes a communication I/F for direct communication with the mobile terminal UT located inside the vehicle or within a range around the vehicle. The vehicle **100** and the mobile terminal UT may perform short-range communication such as wireless local area network (LAN), near field communication (NFC), or Bluetooth (registered trademark). The mobile terminal UT may be any desired mobile terminal such as laptop, tablet terminal, wearable device (e.g., smart watch or smart glasses), or electronic key. Any communication method can be used for communication between the vehicle **100** and the mobile terminal UT.

A vehicle system including the ECU **150** (system that controls the vehicle **100**) is turned on (operated) and off (stopped) when the user operates a start switch **70**. For example, the start switch **70** is mounted in the vehicle cabin of the vehicle **100**. The vehicle system is started when the start switch **70** is turned on. The vehicle system is stopped when the start switch **70** is turned off while the vehicle system is in operation. An operation of turning off the start switch **70** is prohibited while the vehicle **100** is traveling. The start switch of the vehicle is commonly referred to as "power switch" or "ignition switch."

Referring back to FIG. **1**, the server **200** is a computer that belongs to an aggregator. An aggregator is an electric utility that bundles a plurality of distributed energy resources (DERs) to provide an energy management service. The server **200** is configured to control the vehicle group **1**. Each vehicle in the vehicle group **1** includes an energy storage device that can be electrically connected to the power grid PG (external power supply). Each vehicle in the vehicle group **1** can thus function as a DER. The server **200** may cause the DERs (e.g., each vehicle in the vehicle group **1**) to function as a virtual power plant (VPP) by remotely and integratively controlling the DERs. The server **500** may belong to the aggregator, or may belong to an automaker.

The server **200** may perform demand response (DR) for each DER in order to integratively control the DERs as a VPP. Power balancing of the power grid PG is requested to the DERs by DR. The server **200** may use DR to cause a plurality of DERs (e.g., each vehicle in the vehicle group **1**) to perform power balancing of the power grid PG requested from the server **700** or power balancing of the power grid PG successfully won on the electricity market.

By participating in DR (power balancing), the DERs can give flexibility and adequacy to the power grid PG. Administrators of the DERs participating in DR (e.g., vehicle users) permit the server **200** to remotely control the DERs. In the situation where remote control of the DERs by the server **200** is permitted, the server **200** can remotely control the DERs to cause the DERs to perform a charge or discharge for power balancing of the power grid PG. For example, in the vehicle **100**, the ECU **150** controls the charger **61** according to a command from the server **200**. However, even when the server **200** sends commands to the DERs, the DERs cannot perform power balancing by remote control when the DERs are not ready for power balancing.

Any desired type of power balancing can be performed by the DERs. Power balancing may be, for example, supply and demand balancing, power supply stabilization, load following, or frequency balancing. The DERs may operate as balancing forces or reserve powers for the power grid PG by remote control. DR is broadly classified into upward DR and downward DR. Upward DR is basically DR that requests an increase in demand. However, when the DERs receiving a request are power generating equipment, upward DR may request supply curtailment to the DERs. Downward DR is DR that requests reduction in demand or backfeeding.

In the present embodiment, the server **500** holds information on each vehicle in the vehicle group **1** (hereinafter also referred to as "vehicle information"). The server **200** performs vehicle control (remote control) for power balancing of the power grid PG by using the vehicle information acquired from the server **500**.

The vehicle information held by the server **500** is distinguished by vehicle IDs (vehicle identification information). The vehicle information includes, for example, a charging location, the specifications of an EVSE unit installed at the charging location, location information of the vehicle, the SOC of the in-vehicle battery, charge reservation information, the state (ON/OFF) of the vehicle system, information set in the navigation system (e.g., travel route to the destination), vehicle trip history data (e.g., data in which the location of the vehicle is associated with time for vehicle's daily trips), PinFlag and Th shown in FIG. **4**, and DCMFlag (FIG. **6**). When each vehicle has different specifications, the specifications of each vehicle (e.g., specifications related to charging) may be registered in advance in the server **500**. The locations of the home and workplace of the user of the vehicle **100** may be registered in advance as charging locations for the vehicle **100** in the server **500**.

The vehicle information is saved in the storage device of the server **500** and is updated as needed. The server **500** periodically communicates with each vehicle in the vehicle group **1** and receives the vehicle information from each vehicle as needed. The server **500** updates the vehicle information in the storage device based on the received latest vehicle information.

FIG. **5** is a flowchart of a process related to wireless communication of the vehicle **100** with the server **500**. The process in this flowchart is repeatedly performed in a predetermined cycle.

Referring to FIG. **5** together with FIGS. **1** to **3**, the ECU **150** determines in S**21** whether DCMFlag is "0." For example, DCMFlag is stored in the storage device **153**. DCMFlag is a flag indicating whether the communication restriction condition is satisfied. DCMFlag being "1" means that the communication restriction condition is satisfied. DCMFlag being "0" means that the communication restriction condition is not satisfied.

When the communication restriction condition is not satisfied (YES in S**21**), the ECU **150** acquires the state of the vehicle **100** in S**22**. In the present embodiment, the ECU **150** acquires, in S**22**, the location of the vehicle **100**, the SOC of the main battery **11**, the charge reservation information, the set parameters in the NAVI **92***b*, and the values of PinFlag and Th (see FIG. **4**). However, the present disclosure is not limited to this, and the state of the vehicle **100** to be acquired in S**22** can be set as desired. The ECU **150** may further acquire the detection values from various sensors mounted on the vehicle **100** in S**22**.

Thereafter, in S**23**, the ECU **150** determines whether the state of the vehicle **100** acquired in S**22** has changed from the previous value. Specifically, the ECU **150** compares the state acquired in S**22** of the current routine with the state acquired in S**22** of the previous routine. When the amount of change in state from the previous routine to the current routine is greater than a predetermined level, the ECU **150** determines in S**23** that the state of the vehicle **100** has changed from the previous value (YES in S**23**). When the amount of change in state from the previous routine to the current routine is not greater than the predetermined level, the ECU **150** determines in S**23** that the state of the vehicle **100** has not changed from the previous value (NO in S**23**). For example, since the location of the vehicle **100** and the SOC of the main battery **11** change significantly while the vehicle **100** is traveling, the ECU **150** determines in S**23** that the state of the vehicle **100** has changed from the previous value (YES in S**23**). Since the SOC of the main battery **11** changes significantly during an external charge, the ECU **150** determines in S**23** that the state of the vehicle **100** has changed from the previous value (YES in S**23**). Moreover, when the charge reservation information (e.g., charge end time and target SOC for a timer charge) has been changed, the ECU **150** determines in S**23** that the state of the vehicle **100** has changed from the previous value (YES in S**23**). When the set parameters in the NAVI **92***b* (e.g., destination) have been changed, the ECU **150** determines in S**23** that the state of the vehicle **100** has changed from the previous value (YES in S**23**). When either PinFlag or Th has been changed, the ECU **150** determines in S**23** that the state of the vehicle **100** has changed from the previous value (YES in S**23**).

When the amount of change in state of the vehicle **100** is small (NO in S**23**), the ECU **150** determines in S**24** whether the ECU **150** has received a request for vehicle information from the management device **1000** (e.g., server **200** or **500**). When the amount of change in state of vehicle **100** is large (YES in S**23**), or when the management device **1000** has requested vehicle information from the vehicle **100** (YES in S**24**), the routine proceeds to S**25**.

In S**25**, the ECU **150** increments the cumulative number of communications N. The cumulative number of communications N is thus increased by one (counted up). In other words, the cumulative number of communications N is updated to the current value plus one. The cumulative number of communications N is stored in, for example, the storage device **153**. The cumulative number of communications N is a parameter indicating the cumulative number of communications of the DCM **92***c*. In the present embodiment, the ECU **150** increments the cumulative number of communications N (S**25**) every time the DCM **92***c* performs wireless communication (YES in S**23** or S**24**). When a predetermined reset condition is satisfied (YES in S**41** in FIG. **7** that will be described later), the ECU **150** resets the cumulative number of communications N to the initial value (zero).

Thereafter, in S**26**, the ECU **150** updates DCMFlag based on the cumulative number of communications N FIG. **6** is a flowchart showing the details of S**26**.

Referring to FIG. **6** together with FIGS. **1** to **3**, the ECU **150** determines in S**31** whether the cumulative number of communications N is equal to or greater than Th. Th is set in S**141** to S**143** in FIG. **4**. In other words, Th is set to one of U0, U1, or U2. When the cumulative number of communications N is equal to or greater than Th (YES in S**31**), the ECU **150** sets DCMFlag to "1" in S**32**. When the cumulative number of communications N is less than Th (NO in S**31**), the ECU **150** sets DCMFlag to "0" in S**33**. After DCMFlag is set in S**32** or S**33**, the routine proceeds to S**27** in FIG. **5**.

Referring back to FIG. **5** together with FIGS. **1** to **3**, the ECU **150** transmits predetermined vehicle information to the server **500** via the DCM **92***c* (wireless communication device) in S**27**. In other words, the DCM **92***c* performs wireless communication in S27. In the present embodiment, the predetermined vehicle information that is transmitted in S27 includes the value of DCMFlag (0 or 1) in addition the state of the vehicle 100 acquired in S22. In the present embodiment, DCMFlag is updated (S26) before the DCM 92c transmits the vehicle information (S27). Therefore, the management device 1000 can be notified of the fact that wireless communication of the DCM 92c has been prohibited (DCMFlag is set to 0). The vehicle information that is transmitted in S27 is not limited to the above information, and can be changed as appropriate.

After S27 is performed, the routine returns to the first step (S21). When DCMFlag is "0," the vehicle 100 transmits the latest state of the vehicle 100 to the server 500 by wireless communication (S27) every time the state of the vehicle 100 changes by an amount greater than the predetermined level (YES in S23). When the vehicle 100 has received a request from the management device 1000 (YES in S24), the vehicle 100 also transmits the latest state of the vehicle 100 to the server 500 by wireless communication (S27). The DCM 92c is thus configured to transmit the state of the vehicle 100 to the management device 1000 as needed.

When NO in both S23 and S24, wireless communication of the DCM 92c (S27) is not performed, and the routine returns to the first step (S21). When DCMFlag is "1" (NO in S21), wireless communication of the DCM 92c (S27) is also not performed, and S21 is repeated. As described above, when DCMFlag is "1" (NO in S21), wireless communication of the DCM 92c is prohibited.

As described above, in the plugged-out state (when the power grid PG and the vehicle 100 are not electrically connected), the communication restriction condition is satisfied (S32 in FIG. 6) when the cumulative number of communications N of the DCM 92c reaches the first upper limit value (U0 in S143 in FIG. 4) (YES in S31 in FIG. 6). The ECU 150 then prohibits wireless communication of the DCM 92c. In the plugged-in state (when the power grid PG and the vehicle 100 are electrically connected), the communication restriction condition is satisfied (S32 in FIG. 6) when the cumulative number of communications N of the DCM 92c reaches the second upper limit value that is greater than the first upper limit value (U1 or U2 in S141 or S142 in FIG. 4) (YES in S31 in FIG. 6). The ECU 150 then prohibits wireless communication of the DCM 92c.

FIG. 7 is a flowchart of a process for resetting the cumulative number of communications N. The process in this flowchart is repeatedly performed in a predetermined cycle. The series of steps shown in FIG. 7 is performed in parallel with the series of steps shown in FIGS. 4 and 5.

Referring to FIG. 7 together with FIGS. 1 to 3, the ECU 150 determines in S41 whether the SOC of the auxiliary battery 82 is equal to or greater than a predetermined first threshold (hereinafter referred to as "Th1"). When the SOC of the auxiliary battery 82 is equal to or greater than Th1 (YES in S41), the ECU 150 resets the cumulative number of communications N to the initial value (zero) in S42. The routine then returns to the first step (S41). When the SOC of the auxiliary battery 82 is less than Th1 (NO in S41), the cumulative number of communications N is be reset, and the routine returns to the first step (S41). As described above, when the SOC of the auxiliary battery 82 is Th1 or higher, the cumulative number of communications N is reset. Therefore, the communication restriction condition is not satisfied.

The vehicle group 1 in the present embodiment is configured to perform power balancing of the power grid PG in response to a request from the server 200. FIG. 8 is a flowchart of a process for controlling the vehicle group 1 for power balancing of the power grid PG. This process is performed by the server 200. For example, when the server 200 starts the series of steps shown in FIG. 8 described below when it receives a request to increase demand from the server 700. In the present embodiment, upward DR for the vehicle group 1 is performed by the series of steps shown in FIG. 8.

Referring to FIG. 8 together with FIGS. 1 to 3, the server 200 acquires a target value for charge control (hereinafter referred to as "target value W1") in S51. For example, the server 200 may acquire the target value W1 from the server 700. The server 700 may determine the target value W1 for power balancing of the power grid PG and request the server 200 to bring the total charge power W2 described below (S52) closer to the target value W1.

Thereafter, in S52, the server 200 acquires the total charge power of the vehicle group 1 (hereinafter referred to as "total charge power W2"). The charge power of the energy storage device of each vehicle in the vehicle group 1 (more specifically, the charge power of the energy storage devices using the power supplied from the power grid PG) may be measured by a watt-hour meter installed at the charging location, and may be sent to the server 200. The watt-hour meter installed at the charging location may be a smart meter installed at a network connection point, or may be a built-in watt-hour meter of an EVSE unit. The total charge power W2 is the total value of the charge power of the vehicle group 1 as measured by the watt-hour meters installed at each charging location.

Subsequently, in S53, the server 200 determines a controlled object for power balancing and a command path to the controlled object. Specifically, the server 200 acquires the current state (vehicle information) of each vehicle in the vehicle group 1 from the server 500. The server 200 then selects controlled objects from the vehicle group 1. The server 200 selects those vehicles that meet predetermined requirements (hereinafter also referred to as "standby requirements") (i.e., a vehicle that is ready for power balancing) as controlled objects.

The standby requirements for the vehicle 100 according to the present embodiment include the following requirements: PinFlag is "1" or "2" (first SBY requirement), the SOC of the main battery 11 is within a predetermined SOC range (second SBY requirement), DCMFlag is "0" (third SBY requirement), and a timer charge is scheduled for the vehicle 100 (fourth SBY requirement). In order to meet the standby requirements, the vehicle 100 needs to meet all of the first to fourth SBY requirements.

Meeting the first SBY requirement means that the vehicle 100 is electrically connected to the power grid PG. The vehicle 100 in the plugged-in state is electrically connected to the power grid PG via the first or second EVSE unit. Meeting the second SBY requirement means that the current remaining capacity of the main battery 11 is within a range suitable for the requested power balancing. For example, the predetermined SOC range is set by the server 200. Meeting the third SBY requirement means that wireless communication of the DCM 92c is permitted. The vehicle 100 that meets the third SBY requirement transmits the state of the vehicle 100 to the server 500 as needed (see FIG. 5). This makes it easier for the server 200 to accurately grasp the state of the vehicle 100 that meets the third SBY requirement. Meeting the fourth SBY requirement means that remote control of the vehicle 100 by the server 200 is permitted. The server 200 performs remote control to cause the controlled objects to perform power balancing of the power grid PG in S54 that will be described later. The standby requirements are not limited to the above requirements, and can be changed as appropriate. For example, either or both of the second and third SBY requirements may be omitted. In forms in which each vehicle has different specifications, different standby requirements may be set for each vehicle.

In S**53**, the server **200** selects either a first path or a second path as a command path for each controlled object according to whether the controlled object is connected to a first EVSE unit or a second EVSE unit. The first path is a communication path from the server **200** to the controlled object through a first EVSE unit. The second path is a communication path that directly connects the server **200** and the controlled object by wireless communication without through a second EVSE unit. For example, when a vehicle **100** connected to a first EVSE unit (PinFlag="1") is selected as a controlled object, the first path is selected as a command path for this vehicle **100**. When a vehicle **100** connected to a second EVSE unit (PinFlag="2") is selected as a controlled object, the second path is selected as a command path for this vehicle **100**. It is not essential that the controlled objects be connectable to both a first EVSE unit and a second EVSE unit. The controlled objects may only be connectable to either a first EVSE unit or a second EVSE unit.

Once the controlled objects and command paths for each controlled object are determined in S**53**, the server **200** then controls the controlled objects to bring the total charge power W2 closer to the target value W1 in SM. Specifically, the server **200** determines the charge power to be allocated to the controlled objects (hereinafter referred to as "requested charge power") based on the target value W1 and the total charge power W2, and sends a charge command indicating the requested charge power to the controlled objects. The charge command is sent from the server **200** to the controlled objects through the command paths (first or second paths) determined in S**53**. The server **200** determines the requested charge power for each controlled object, and sends a charge command to each controlled object. The controlled objects having received a charge command from the server **200** perform charge control of the energy storage device according to the charge command. In other words, the controlled objects control the in-vehicle charger so that the charge power of the energy storage device gets closer to the requested charge power.

Instead of the requested charge power, the server **200** may determine a charge command for ON (execute) or OFF (stop) for each controlled object. The server **200** may perform charge ON-OFF control on each controlled object so as to bring the total charge power W2 closer to the target value W1. The server **200** may determine the charge schedule for each controlled object by using the charge reservation information of each controlled object so that power balancing (e.g., upward DR) of the power grid PG is performed while meeting the requirements for the charge end time and target SOC for a timer charge. The server **200** may then send a charging command to each controlled object to meet the determined charge schedule. The server **200** may predict movement of each controlled object by using the vehicle information acquired from the server **500**, and may change the schedule (charge start time and charge end time) for the reserved timer charge based on the movement prediction results. For example, when a controlled object is in a predetermined charge mode, the controlled object may permit the server **200** to change the charge schedule.

Thereafter, the server **200** determines in S**55** whether the DR is finished. The server **200** determines whether the DR is finished based on whether the period of power balancing requested by the server **700** (DR period) has passed. When DR is not finished (NO in S**55**), the routine returns to the first step (S**51**). While the DR continues (within the DR period), S**51** to S**54** are repeatedly performed so that the controlled objects perform power balancing of the power grid PG.

When the DR is finished (YES in S**55**), the series of steps shown in FIG. **8** ends. After the DR is finished, the aggregator may give an incentive to the users of the vehicles that performed power balancing (controlled objects).

FIG. **9** is a flowchart of a process that is periodically performed by the vehicle **100**. Referring to FIG. **9** together with FIGS. **1** to **3**, the ECU **150** determines in S**61** whether PinFlag is "0." When PinFlag is not "0" (NO in S**61**), the routine proceeds to S**62**. When PinFlag is "0" (YES in S**61**), the routine proceeds to S**64**.

When PinFlag is not "0" (i.e., the vehicle **100** is in the plugged-in state), the ECU **150** determines in S**62** whether the ECU **150** has received a charge command (S**54** in FIG. **8**) from the server **200**. When the vehicle **100** has received a charge command from the server **200** (YES in S**62**), the ECU **150** performs an external charge of the main battery **11** according to the received charge command in S**63**. During the external charge of the main battery **11**, the power grid PG and the main battery **11** are electrically connected and the charger **61** is controlled by the ECU **150**.

When the ECU **150** performs an external charge of the main battery **11** according to a charge command from the server **200** by using the power supplied from the power grid PG to the vehicle **100** through the EVSE unit **300**A (FIG. **3**), the ECU **150** communicates with the server **200** through the first path (S**53** in FIG. **8**). In other words, the ECU **150** communicates with the server **200** through the EVSE unit **300**A. Power balancing of the power grid PG is performed by this external charge of the main battery **11** that is performed according to the charge command.

When the ECU **150** performs an external charge of the main battery **11** according to a charge command from the server **200** by using the power supplied from the power grid PG to the vehicle **100** through the EVSE unit **300**B (FIG. **3**), the ECU **150** communicates with the server **200** through the second path (S**53** in FIG. **8**). In other words, the ECU **150** communicates with the server **200** through the DCM **92***c*. The DCM **92***c* is thus configured to receive a charge command for power balancing of the power grid PG from the management device **1000** by wireless communication. Power balancing of the power grid PG is performed by this external charge of the main battery **11** that is performed according to the charge command (remote control of the vehicle **100** by the server **200**).

After the charge control (S**63**), the routine proceeds to S**64**. When NO in S**62**, the routine skips S**63** and proceeds to S**64**. In S**64**, the ECU **150** determines whether predetermined execution conditions (hereinafter also referred to as "execution conditions X") are satisfied. The execution conditions X are charge execution conditions for the auxiliary battery **82**. In the present embodiment, the execution conditions X include the following conditions: the SOC of the main battery **11** is equal to or greater than a predetermined first SOC value (first SOC requirement), and the SOC of the auxiliary battery **82** is equal to or less than a predetermined second SOC value (second SOC requirement). In order for the execution conditions X to be satisfied, both the first SOC requirement and the second SOC requirement need be met. However, the present disclosure is not limited to this, and the execution conditions X can be set as desired.

When the execution conditions X are satisfied (YES in S**64**), the ECU **150** controls the SMR **12** and the DC-to-DC converter **81** so that power is supplied from the main battery **11** to the auxiliary battery **82** in S**65**. The main battery **11** is thus configured to supply power to the auxiliary battery **82**.

After the auxiliary battery **82** is charged as described above (S**65**), the routine returns to the first step (S**61**). When the execution conditions X are not satisfied (NO in S**64**), the auxiliary battery **82** will not be charged (S**65**), and the routine returns to the first step (S**61**). The series of steps shown in FIG. **9** is repeatedly performed in a predetermined cycle.

FIG. **10** is a flowchart of a process for charge start control that is performed by the vehicle **100**. The process shown in this flowchart is started when the vehicle **100** goes into the plugged-in state.

Referring to FIG. **10** together with FIGS. **1** to **3**, the ECU **150** determines in S**71** whether an external charge of the main battery **11** is being performed. When a timer charge is not scheduled for the vehicle **100**, an immediate charge is performed. When an immediate charge has been performed, the ECU **150** determines that an external charge of the main battery **11** is being performed (YES in S**71**), and the series of steps shown in FIG. **10** ends. When an immediate charge is not performed, the ECU **150** determines that an external charge of the main battery **11** is not being performed (NO in S**71**), and the routine proceeds to S**72**.

In S**72**, the ECU **150** determines whether the cumulative number of communications N of the DCM **92***c* is equal to or greater than a predetermined value (hereinafter referred to as "U3") that is smaller than U0 (FIG. **4**). The cumulative number of communications N is updated by the process of FIG. **5** described above. When the cumulative number of communications N is less than U3 (NO in S**72**), the ECU **150** determines in S**73** whether the vehicle **100** has gone into the plugged-out state (PinFlag="0"). When the vehicle **100** remains in the plugged-in state (NO in S**73**), the routine returns to the first step (S**71**). On the other hand, when the vehicle **100** goes into the plugged-out state (YES in S**73**), the series of steps shown in FIG. **10** ends.

When the cumulative number of communications N of the DCM **92***c* reaches U3 (YES in S**72**) with no charge of the main battery **11** being performed (NO in S**71**) with the vehicle **100** being electrically connected to the power grid PG, the ECU **150** starts an external charge of the main battery **11** in S**74**. In S**74**, the main battery **11** is charged with the power supplied from the power grid PG.

After S**74** is performed, the series of steps shown in FIG. **10** ends, and charge control, not shown, is started. Although details of the charge control will be omitted, the external charge of the main battery **11** continues until a predetermined end condition is satisfied. When the end condition is satisfied, the ECU **150** stops the external charge. For example, the end condition may be satisfied when the SOC of the main battery **11** becomes equal to or greater than a predetermined SOC value. The predetermined SOC value for the end condition may be set by the user.

As described above, the communication control method according to the present embodiment includes the processes shown in FIGS. **4** to **10**. When the vehicle **100** (controlled object) is in the second plugged-in state, a charge command is sent from the server **200** to the vehicle **100** through the second path in S**54** in FIG. **8**. The vehicle **100** receives a control command (charge command) for power balancing of the power grid PG (external power supply) from the management device **1000** through the DCM **92***c* (wireless communication. When the vehicle **100** receives a control command, the ECU **150** determines in S**62** in FIG. **9** that the ECU **150** has received a charge command from the server **200** (YES in S**62**). When the cumulative number of communications N of the DCM **92***c* (S**25** in FIG. **5**) reaches U0 (S**143** in FIG. **4**) with the power grid PG and the vehicle **100** not electrically connected to each other (S**133** in FIG. **4**) (YES in S**31** in FIG. **6**), the vehicle **100** prohibits wireless communication of the DCM **92***c* (NO in S**21** in FIG. **5**). When the cumulative number of communications N of the DCM **92***c* (S**25** in FIG. **5**) reaches U1 or U2 that is greater than U0 (S**141** or S**142** in FIG. **4**) with the power grid PG and the vehicle **100** electrically connected to each other (S**131** or S**132** in FIG. **4**) (YES in S**31** in FIG. **6**), the vehicle **100** prohibits wireless communication of the DCM **92***c* (NO in S**21** in FIG. **5**).

According to the above communication control method, the communication restriction condition is satisfied when the cumulative number of communications N reaches a predetermined value (U0, U1, or U2). Wireless communication of the DCM **92***c* is restricted when the communication restriction condition is satisfied. This reduces power consumption of the auxiliary battery **82**, so that the auxiliary battery **82** is less likely to run short of power. When the communication restriction condition is satisfied, the ECU **150** may control a power supply circuit for the DCM **92***c* so as to reduce generation of driving power for the DCM **92***c*. In the above communication control method, the communication restriction condition is less easily satisfied when the power grid PG and the vehicle **100** are electrically connected to each other than when the power grid PG and the vehicle **100** are not electrically connected to each other. This makes it easier for the management device **1000** (e.g., server **200**) to remotely control the vehicle **100** by wireless communication to perform vehicle control for power balancing of the power grid PG (e.g., charge control of the main battery **11**).

The processes shown in FIGS. **4** to **10** can be changed as appropriate. For example, the process for restricting wireless communication is not limited to prohibition of wireless communication, and may be a process for limiting the frequency of wireless communications to a predetermined frequency or less. The ECU **150** may perform a series of steps shown in FIG. **11** instead of the process shown in FIG. **7**.

FIG. **11** is a flowchart of a modification of the process shown in FIG. **7**. In the vehicle **100** according to this modification as well, the main battery **11** supplies power to the auxiliary battery **82** while the main battery **11** is being charged with the power supplied from the power grid PG by the process shown in FIG. **10** described above. The auxiliary battery **82** is charged while the vehicle **100** is traveling. For example, when the vehicle **100** is traveling, the main battery **11** is regeneratively charged with the power generated by the MG **20**. When the SOC of the auxiliary battery **82** becomes less than a predetermined value while the vehicle **100** is traveling, power is supplied from the main battery **11** to the auxiliary battery **82**.

Referring to FIG. **11** together with FIGS. **1** to **3**, the ECU **150** determines in S**81** whether the vehicle **100** is traveling. When the vehicle **100** is traveling (YES in S**81**), the ECU **150** increments cumulative travel time M1 in S**82**. A predetermined unit time is thus added to the cumulative travel time M1. The cumulative travel time M1 is continuous travel time of the vehicle **100**, and is stored in, for example, in the storage device **153**. Thereafter, the ECU **150** determines in S**83** whether the cumulative travel time M1 is equal to or greater than a second threshold (hereinafter referred to as "Th**2**"). When the vehicle **100** is not traveling (NO at S**81**), the ECU **150** resets the cumulative travel time M**1** to the initial value (zero seconds) in S**84**.

When the cumulative travel time M**1** is equal to or greater than Th**2** (YES in S**83**), the routine proceeds to S**89**. YES in S**83** means that a condition for resetting the cumulative number of communications N is satisfied. When the cumulative travel time M**1** is less than Th**2** (NO in S**83**), the routine proceeds to S**85**.

In S**85**, the ECU **150** determines whether the vehicle **100** is performing an external charge. When the vehicle **100** performing an external charge (YES in S**85**), the ECU **150** increments cumulative charge time M**2** in S**86**. A predetermined unit time is thus added to the cumulative charge time M**2**. The cumulative charge time M**2** is charge duration of the main battery **11** and is stored in, for example, the storage device **153**. Thereafter, the ECU **150** determines in S**87** whether the cumulative charge time M**2** is equal to or greater than a third threshold (hereinafter referred to as "Th**3**"). When the vehicle **100** is not performing an external charge (NO in S**85**), the ECU **150** resets the cumulative charge time M**2** to the initial value (zero seconds) in S**88**.

When the cumulative charge time M**2** is equal to or greater than Th**3** (YES in S**87**), the routine proceeds to S**89**. YES in S**87** means that a condition for resetting the cumulative number of communications N is satisfied. When the cumulative charge time M**2** is less than Th**3** (NO in S**87**), the routine skips S**89** and returns to the first step (S**81**).

When the condition for resetting the cumulative number of communications N is satisfied (YES in S**83** or S**87**), the ECU **150** reset the cumulative number of communications N to the initial value (zero) in S**89**. After S**89** is performed, the routine returns to the first step (S**81**). The series of steps shown in FIG. **11** is repeatedly performed in a predetermined cycle.

In the vehicle **100** according to the above modification, the ECU **150** resets the cumulative number of communications N of the DCM **92***c* (S**89**) when the continuous travel time (cumulative travel time M**1**) of the vehicle **100** becomes equal to or greater than the second threshold (Th**2**) (YES in S**83**). When the vehicle **100** travels continuously for a long period of time, the SOC of the auxiliary battery **82** is estimated to be sufficiently increased by the power supplied from the main battery **11**. The ECU **150** also resets the cumulative number of communications N of the DCM **92***c* (S**89**) when the charge duration of the main battery **11** (cumulative charge time M**2**) becomes equal to or greater than the third threshold (Th**3**) (YES in S**87**). When the main battery **11** continues to be charged for a long period of time, the SOC of the auxiliary battery **82** is estimated to be sufficiently increased by the power supplied from the main battery **11**. The monitoring module **82***a* may not always be able to detect the SOC of the auxiliary battery **82** accurately. In this respect, the above configuration (see FIG. **11**) makes it possible to appropriately reset the cumulative number of communications N even in a form in which the SOC of the auxiliary battery **82** cannot be detected accurately. The DCM **92***c* (wireless communication device) becomes available when the cumulative number of communications N is reset.

In the process shown in FIG. **11** (particularly S**82** to S**84**), a parameter indicating a continuous travel distance (km) of the vehicle **100** may be used instead of the cumulative travel time M**1**. In the process shown in FIG. **11** (particularly S**86** to S**88**), a parameter indicating the amount of charge power (kWh) due to a continuous charge of the main battery **11** may be used instead of the cumulative charge time M**2**.

In the above embodiment, the vehicle **100** (ECU **150**) distinguishes the first and second EVSE units from each other. However, the present disclosure is not limited to this, and the server **200** or **500** may determine whether the EVSE unit electrically connected to the vehicle **100** is the EVSE unit **300**A (first EVSE unit) or the EVSE unit **300**B (second EVSE unit) based on the charging location (i.e., the location of the vehicle **100** in the plugged-in state). For example, the server **200** or **500** may determine that the vehicle **100** is electrically connected to the EVSE unit **300**A when the charging location is the workplace of the user of the vehicle **100**. The server **200** or **500** may determine that the vehicle **100** is electrically connected to the EVSE unit **300**B when the charging location is the home of the user of the vehicle **100**. The charging location is not limited to the home and workplace, but can be changed as needed.

The power grid PG (external power supply) is not limited to a large-scale AC grid provided by an electric power company, and may be a microgrid or a direct current (DC) grid. The configuration of the management system is not limited to the configuration shown in FIG. **1**. Another server (e.g., a server of a higher-level aggregator) may be provided between the server **700** and the server **200**. The server **200** may communicate with the server **700** via other server. The functions of the server **500** may be implemented in the server **200** and the server **500** may be omitted. The server **200** may wirelessly communicate directly with the vehicle group **1**. In the above embodiment, the on-premise servers (servers **200**, **500** shown in FIG. **1**) function as computers that manage the vehicle group **1**. However, the present disclosure is not limited to this, and the functions of the servers **200**, **500** (particularly the functions related to vehicle group management) may be implemented in a cloud by cloud computing. The management device **1000** may belong to other electric utility (e.g., a transmission system operator (TSO)) rather than the aggregator.

The configuration of the vehicle is not limited to the configuration described above (see FIG. **2**). The vehicle may include a charger and discharger (charge and discharge circuit) that functions as both a charge circuit and a discharge circuit, instead of the charger **61**. The inlet **60** may function as both a charge port and a discharge port. The vehicle may include an inlet that is only connectable to either the first power supply equipment or the second power supply equipment. The vehicle may output the power discharged from the in-vehicle battery to an external power supply via a discharge connector rather than via an EVSE unit. The in-vehicle battery may be replaceable. The vehicle may be an xEV other than a BEV (PHEV, FCEV, range extender EV, etc.).

The number of wheels is not limited to four, and may be three or may be five or more. The vehicle may be contactlessly rechargeable. The vehicle may equipped with a solar panel. The vehicle may be configured to perform autonomous driving or may have a flying function. The vehicle is not limited to a passenger car, and may be a bus or a truck. The vehicle may be a Mobility-as-a-Service (MaaS) vehicle. MaaS vehicles are vehicles that are managed by a MaaS operator. The vehicle may be an unmanned vehicle (e.g., a robotaxi, an automated guided vehicle (AGV), or an agricultural machine). The vehicle may be an unmanned or single-seater small-sized BEV (e.g., a micropallet).

The embodiment disclosed herein should be considered to be illustrative and not restrictive in all respects. The scope of the present disclosure is shown by the claims rather than by the above description of the embodiment and is intended to include all modifications within the meaning and scope equivalent to the claims.

What is claimed is:

1. A vehicle comprising:

a first energy storage device configured to be electrically connected to an external power supply;

a wireless communication device;

a second energy storage device configured to supply power to the wireless communication device; and

a control device configured to communicate with a management device outside the vehicle through the wireless communication device, wherein:

the first energy storage device is configured to supply power to the second energy storage device;

the control device is configured to restrict wireless communication of the wireless communication device when a communication restriction condition set using a cumulative number of communications of the wireless communication device is satisfied;

the communication restriction condition when the external power supply and the vehicle are not electrically connected to each other is set to be more easily satisfied than the communication restriction condition when the external power supply and the vehicle are electrically connected to each other; and

the communication restriction condition is not satisfied when a state of charge of the second energy storage device is equal to or greater than a first threshold.

2. The vehicle according to claim 1, wherein:

the control device is configured to prohibit wireless communication of the wireless communication device when the communication restriction condition is satisfied by the cumulative number of communications of the wireless communication device reaching a first upper limit value with the external power supply and the vehicle not being electrically connected to each other; and

the control device is configured to prohibit wireless communication of the wireless communication device when the communication restriction condition is satisfied by the cumulative number of communications of the wireless communication device reaching a second upper limit value that is greater than the first upper limit value with the external power supply and the vehicle being electrically connected to each other.

3. The vehicle according to claim 2, wherein:

the second energy storage device is configured to be charged while the vehicle is traveling; and

the control device is configured to reset the cumulative number of communications of the wireless communication device when a continuous travel distance or travel time of the vehicle becomes equal to or greater than a second threshold.

4. The vehicle according to claim 2, wherein:

the first energy storage device is configured to supply power to the second energy storage device while the first energy storage device is being charged with power supplied from the external power supply; and

the control device is configured to reset the cumulative number of communications of the wireless communication device when an amount of charge power or charge duration due to a continuous charge of the first energy storage device becomes equal to or greater than a third threshold.

5. The vehicle according to claim 2, wherein:

the wireless communication device is configured to transmit a state of the vehicle to the management device as needed; and

the control device is configured to start a charge of the first energy storage device using power supplied from the external power supply when the cumulative number of communications of the wireless communication device reaches a predetermined value that is smaller than the first upper limit with no charge of the first energy storage device being performed with the vehicle being electrically connected to the external power supply.

6. The vehicle according to claim 1, wherein the control device is configured to charge the first energy storage device according to a charge command received from the management device with the external power supply and the first energy storage device being electrically connected together.

7. The vehicle according to claim 6, wherein:

the control device is configured to distinguish between first power supply equipment with a function to communicate with the management device and second power supply equipment without a function to communicate with the management device;

the control device is configured to communicate with the management device through the first power supply equipment when the control device charges the first energy storage device according to the charge command using power supplied from the external power supply to the vehicle via the first power supply equipment; and

the control device is configured to communicate with the management device through the wireless communication device when the control device charges the first energy storage device according to the charge command using power supplied from the external power supply to the vehicle via the second power supply equipment.

8. A communication control method for a vehicle, the vehicle including a first energy storage device that is electrically connectable to an external power supply, a wireless communication device, a second energy storage device that supplies power to the wireless communication device, and a control device that communicates with a management device outside the vehicle via the wireless communication device, the method comprising:

receiving, by the control device, a control command for power balancing of the external power supply from the management device via the wireless communication device;

prohibiting, by the control device, wireless communication of the wireless communication device when a cumulative number of communications of the wireless communication device reaches a first upper limit value with the external power supply and the vehicle not being electrically connected to each other; and

prohibiting, by the control device, wireless communication of the wireless communication device when the cumulative number of communications of the wireless communication device reaches a second upper limit value that is greater than the first upper limit value with the external power supply and the vehicle being electrically connected to each other.

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