



- (51) **International Patent Classification:** Not classified
- (21) **International Application Number:** PCT/IB2014/001411
- (22) **International Filing Date:** 30 July 2014 (30.07.2014)
- (25) **Filing Language:** English
- (26) **Publication Language:** English
- (30) **Priority Data:**
2013-166533 9 August 2013 (09.08.2013) JP
- (71) **Applicant:** TOYOTA JIDOSHA KABUSHIKI KAISHA [JP/JP]; 1, Toyota-cho, Toyota-shi, Aichi-ken, 471-8571 (JP).
- (72) **Inventor:** SUGIYAMA, Yoshinobu; c/o TOYOTA JIDOSHA KABUSHIKI KAISHA, of 1, Toyota-cho, Toyota-shi, Aichi-ken, 471-8571 (JP).
- (81) **Designated States** (*unless otherwise indicated, for every kind of national protection available*): AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM,

DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT,
HN, HR, HU, ID, IL, IN, IR, IS, KE, KG, KN, KP, KR,
KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME,
MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ,
OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA,
SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM,
TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM,
ZW

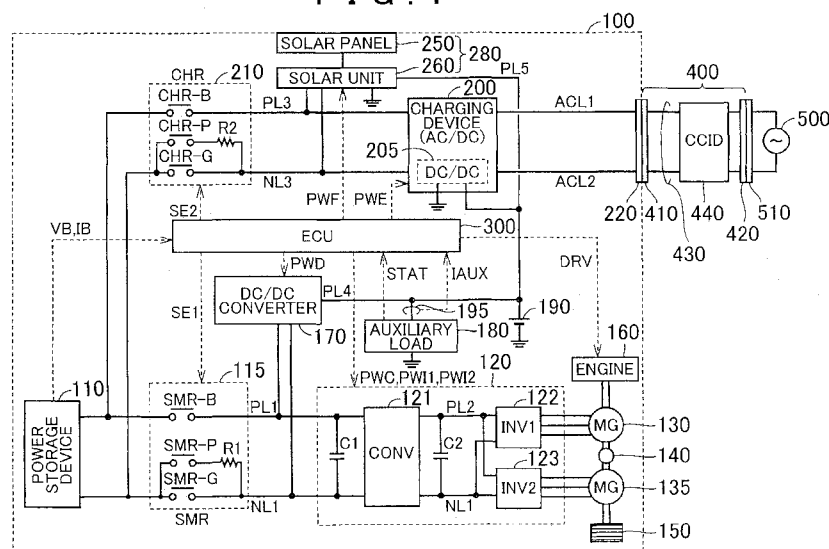
- (84) Designated States** (*unless otherwise indicated, for every kind of regional protection available*): ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Published:

without international search report and to be republished upon receipt of that report (Rule 48.2(g))

- (54) Title:** VEHICLE AND METHOD FOR CONTROLLING THE VEHICLE

FIG. 1



- (S7) Abstract:** A vehicle including an auxiliary load, an auxiliary battery, at least one electric power output unit, and a controller is provided. The auxiliary battery supplies electric power to the auxiliary load. The at least one electric power output unit supplies electric power to the auxiliary load. The controller predicts a maximum electric power consumption of the auxiliary load based on a usage state of the auxiliary load. When the predicted maximum electric power consumption exceeds a threshold value, the controller supplies the electric power from the electric power output unit, in addition to the electric power from the auxiliary battery, to the auxiliary load.

VEHICLE AND METHOD FOR CONTROLLING THE VEHICLE

BACKGROUND OF THE INVENTION

5 1. Field of the Invention

[0001] The invention relates to a vehicle and a method for controlling the vehicle, and more particularly relates to electric power supply control for supplying electric power to an auxiliary load installed on the vehicle.

10 2. Description of Related Art

[0002] In recent years, vehicles (electric vehicles) each installed with a power storage device (such as a secondary battery or a capacitor) and adapted to run using driving force generated from electric power stored in the power storage device have been attracting attention, as environmentally-friendly vehicles. These vehicles include, for example, 15 electric automobiles, hybrid automobiles, and fuel cell vehicles. Technologies for charging the power storage device installed on these vehicles by use of a commercial power supply having a high power generation efficiency have been proposed.

SUMMARY OF THE INVENTION

20 [0003] In the electric vehicles, electric power used for driving the auxiliary load installed on the vehicle is generally supplied from an auxiliary battery. However, as described in Japanese Patent Application Publication No. 2013-018420 (JP 2013-018420 A), some vehicles are arranged to lower the voltage of electric power from a high-voltage power storage device (main battery) for generating driving force, via a DC/DC converter, 25 and supply the resulting electric power to the auxiliary load or auxiliary machines.

[0004] In the vehicle in which the auxiliary load can be driven with the electric power from the main battery, as described above, it may be considered to reduce the size of the auxiliary battery as compared with the conventional one, from a cost-cutting standpoint, and make the battery capacity relatively small.

[0005] In the meantime, electric power consumption of a particular auxiliary load, such as a power steering, or an electronically controlled brake (ECB) system, varies according to the amount of operation by the user. Therefore, large electric power may be temporarily needed depending on operating conditions. At this time, if the electric power
5 required by the entire auxiliary system exceeds the maximum output power determined from electric power that can be generated from the auxiliary battery and the DC/DC converter, the auxiliary load may not be appropriately operated due to reduction of the voltage of the auxiliary system, or the auxiliary battery may run out. When the size of the auxiliary battery is reduced, this situation is more likely to occur.

10 [0006] The invention provides a vehicle in which appropriate electric power is supplied to an auxiliary system even when required electric power of the auxiliary system is temporarily increased, and a method of controlling the vehicle.

[0007] A first aspect of the invention is concerned with a vehicle including an auxiliary load, an auxiliary battery, at least one electric power output unit, and a controller.

15 The auxiliary battery is configured to supply electric power to the auxiliary load. The electric power output unit is configured to supply electric power to the auxiliary load. The controller is configured to predict a maximum electric power consumption of the auxiliary load based on a usage state of the auxiliary load and supply the electric power from the electric power output unit, in addition to the electric power from the auxiliary
20 battery, to the auxiliary load, when the predicted maximum electric power consumption exceeds a threshold value.

[0008] With the above arrangement, even when electric power consumption of the auxiliary load temporarily becomes excessively large, and it is thus predicted that the electric power supplied to the auxiliary load becomes insufficient, electric power supplied
25 from the electric power output unit can make up for the shortage of electric power.

[0009] The vehicle according to the above aspect of the invention may further include a power storage device, a drive unit, and a first power conversion device that is different from the electric power output unit. The drive unit is configured to generate driving force for running the vehicle, using electric power from the power storage device.

The first power conversion device is configured to convert electric power from the power storage device and supply the electric power to the auxiliary load. The threshold value is determined as a sum of a maximum value of electric power that can be generated from the auxiliary battery, and a maximum value of electric power that can be generated from the first power conversion device.

[0010] With the above arrangement, when it is predicted, in the electric vehicle, that electric power that exceeds the sum of the maximum output power of the auxiliary battery and the maximum output power of the power conversion device for supplying electric power to the auxiliary load is needed, electric power from the electric power output unit can be additionally supplied to the auxiliary load.

[0011] The vehicle as described above may further include a charging device. The charging device is configured to convert electric power from an external power supply provided outside the vehicle, and perform external charging for supplying charging power to the power storage device. The charging device may include a second power conversion device. Also, the charging device may be used as the electric power output unit. The second power conversion device may be configured to lower a voltage of one of the converted electric power from the external power supply and the electric power from the power storage device, and supply the electric power to the auxiliary load.

[0012] With the above arrangement, in the electric vehicle capable of external charging, electric power can be additionally supplied from the power conversion device included in the charging device, to the auxiliary load.

[0013] The vehicle as described above may further include a solar power generation system configured to generate electric power using solar light, and supply the generated electric power to the auxiliary load. Then, at least one of the second power conversion device and the solar power generation system is used as the electric power output unit.

[0014] With the above arrangement, electric power can be additionally supplied from at least one of the power conversion device included in the charging device and the solar power generation system to the auxiliary load.

[0015] In the vehicle as described above, when the predicted maximum electric power consumption exceeds the threshold value during execution of the external charging, the controller may be configured to use the electric power from the second power conversion device at a higher priority than the electric power from the solar power generation system. Since the charging device has already been started during external charging, it will not be necessary to additionally start another device or system if the power conversion device in the charging device is used.

[0016] In the vehicle as described above, the controller may be configured to operate in one of a running mode for running the vehicle, and a charging mode for executing the external charging. The controller may be configured to, when operating in the running mode, set a sum of a maximum value of electric power that can be generated from the auxiliary battery and a maximum value of electric power that can be generated from the first power conversion device, as the threshold value, and use at least one of the second power conversion device and the solar power generation system as the electric power output unit. The controller may be configured to, when operating in the charging mode, set a sum of the maximum value of electric power that can be generated from the auxiliary battery and a maximum value of electric power that can be generated from the second power conversion device as the threshold value, and use the solar power generation system as the electric power output unit.

[0017] When the controller operates in the charging mode, the first power conversion device is generally not started. Therefore, when the electric power from the second power conversion device in the charging device and the electric power from the auxiliary battery are supplied to the auxiliary load, the sum of the maximum value of electric power that can be generated from the auxiliary battery and the maximum value of electric power that can be generated from the second power conversion device is set as the threshold value, and the solar power generation system is used as the electric power output unit. This arrangement makes it possible to appropriately make up for a shortage of electric power.

[0018] In the vehicle as described above, the controller may be configured to

operate in one of a running mode for running the vehicle, and a charging mode for executing the external charging. The controller may be configured to, when operating in the running mode, set a sum of a maximum value of electric power that can be generated from the auxiliary battery and a maximum value of electric power that can be generated from the first power conversion device, as the threshold value. The controller may be configured to, when operating in the charging mode, set the maximum value of electric power that can be generated from the auxiliary battery as the threshold value.

[0019] When the controller unit operates in the charging mode, no electric power is supplied from the first power conversion device to the auxiliary load. Therefore, when only the electric power from the auxiliary battery is supplied, the maximum value of electric power that can be generated from the auxiliary battery is set as the threshold value, so that a shortage of electric power can be appropriately made up for.

[0020] The vehicle according to the first aspect of the invention may further include a solar power generation system that is used as the electric power output unit. The solar power generation system may be configured to generate electric power using solar light, and supply the generated electric power to the auxiliary load.

[0021] Even when the electric vehicle does not have an external charging function, it is possible to appropriately make up for a shortage of electric power, by using the solar power generation system as the electric power output unit.

[0022] The vehicle according to the first aspect of the invention may further include an engine that generates driving force for running the vehicle, a generator that is operated by the engine to generate electric power, and a solar power generation system. The solar power generation system is configured to generate electric power using solar light, and supply the generated electric power to the auxiliary load. The threshold value may be defined as a sum of a maximum value of electric power that can be generated from the auxiliary battery and electric power that can be generated from the generator, and the solar power generation system may be used as the electric power output unit.

[0023] Thus, in the vehicle having the solar power generation system and adapted to run with driving force generated by the engine, too, when it is predicted that the electric

power required by the auxiliary load becomes smaller than the electric power generated from the auxiliary battery and the generator, it is possible to appropriately make up for the shortage of electric power, by using electric power from the solar power generation system.

[0024] A second aspect of the invention is concerned with a method for
5 controlling a vehicle. The vehicle includes an auxiliary load, an auxiliary battery, at least one electric power output unit, and controller. The auxiliary battery supplies electric power to the auxiliary load. The electric power output unit is configured to supply electric power to the auxiliary load. The method includes (A) predicting a maximum
10 electric power consumption of the auxiliary load, based on a usage state of the auxiliary load by the controller, (B) determining whether the predicted maximum electric power consumption exceeds a predetermined threshold value by the controller, and (C) supplying electric power from the electric power output unit, in addition to electric power from the auxiliary battery, to the auxiliary load by the controller, when the predicted maximum electric power consumption exceeds the threshold value.

15 [0025] According to the control method as described above, the electric power from the electric power output unit can make up for a shortage of electric power, even when the electric power consumption of the auxiliary load temporarily becomes excessively large and it is predicted that the electric power supplied to the auxiliary load becomes insufficient.

20 [0026] According to the above aspects of the invention, it is possible to provide the vehicle in which electric power can be appropriately supplied to the auxiliary system, even when required electric power of the auxiliary system is temporarily increased.

BRIEF DESCRIPTION OF THE DRAWINGS

25 [0027] Features, advantages, and technical and industrial significance of exemplary embodiments of the invention will be described below with reference to the accompanying drawings, in which like numerals denote like elements, and wherein:

FIG. 1 is an overall block diagram of an electric vehicle according to one embodiment of the invention;

FIG. 2 is a view showing the detailed configuration of a charging device and a solar power generation system in FIG. 1;

FIG. 3 is a view useful for explaining the summary of auxiliary electric power control according to the embodiment of FIG. 1;

5 FIG. 4 is a functional block diagram useful for explaining auxiliary electric power control performed by an ECU;

FIG. 5 is a flowchart illustrating an auxiliary electric power control routine executed by the ECU;

10 FIG. 6 is a view useful for explaining the summary of auxiliary electric power control during execution of external charging;

FIG. 7 is a flowchart illustrating an auxiliary electric power control routine executed by the ECU during external charging;

15 FIG. 8 is an overall block diagram of an electric vehicle having no external charging function, to which the auxiliary electric power control of the above embodiment can be applied; and

FIG. 9 is an overall block diagram of a vehicle that runs using driving force generated by an engine, when the auxiliary electric power control of the above embodiment is applied to the vehicle.

20 DETAILED DESCRIPTION OF EMBODIMENTS

[0028] One embodiment of the invention will be described in detail with reference to the drawings. In the drawings, the same numerals or symbols are assigned to the same or corresponding portions or elements, which will not be repeatedly explained.

25 [0029] FIG. 1 is an overall block diagram of an electric vehicle 100 according to one embodiment of the invention. In the following description, a hybrid vehicle having an engine and rotating electric machines will be described as an example of electric vehicle. However, the electric vehicle is not limited to this type of vehicle, but the invention may also be applied to other types of electric vehicles, such as an electric automobile or fuel cell automobile capable of running with electric power supplied from a power storage

device.

[0030] Referring to FIG. 1, the vehicle 100 includes a power storage device 110, a system main relay (SMR) 115, a PCU (Power Control Unit) 120 as a drive unit, motor-generators 130, 135, power transmission gears 140, drive wheels 150, an engine 160
5 as an internal combustion engine, and an ECU (Electronic Control Unit) 300 as a controller. The PCU 120 includes a converter 121, inverters 122, 123, and capacitors C1, C2.

[0031] The power storage device 110 is an electric power storage element arranged to be rechargeable and dischargeable. The power storage device 110 may include a secondary battery, such as a lithium-ion battery, nickel-metal-hydride battery, or a
10 lead-acid storage battery, or a power storage element, such as an electric double layer capacitor, for example.

[0032] The power storage device 110 is electrically connected to the PCU 120 via power lines PL1, NL1. The power storage device 110 supplies electric power for generating driving force of the vehicle 100, to the PCU 120. Also, the power storage
15 device 110 stores electric power generated by the motor-generators 130, 135. The output voltage of the power storage device 110 is, for example, about 200V.

[0033] The power storage device 110 includes a voltage sensor and a current sensor (both of which are not shown), and the voltage VB and current IB of the power storage device 110, which are detected by these sensors, are transmitted to the ECU 300.

[0034] The SMR 115 includes relays SMR-B, SMR-P, SMR-G, and a limiting resistor R1. The relay SMR-B is connected to a positive terminal of the power storage device 110 and the power line PL1. The relay SMR-G is connected to a negative terminal of the power storage device 110 and the power line NL1. A portion of the SMR 115 in which the relay SMR-P and the limiting resistor R1 are connected in series is connected in
25 parallel with the relay SMR-G.

[0035] The relays included in the SMR 115 can be individually operated, based on a control signal SE1 from the ECU 300, and are switched between positions for allowing supply of electric power between the power storage device 110 and the PCU 120, and positions for cutting the electric power. The limiting resistor R1 is a current-limiting

resistor that is adapted to prevent large current from instantaneously flowing to the PCU 120 when electric power starts being supplied from the power storage device 110 to the PCU 120.

5 **[0036]** The converter 121 performs voltage conversion between the voltage between the power lines PL1, NL1 and the voltage between a power line PL2 and the power line NL1, based on a control signal PWC from the ECU 300.

10 **[0037]** The inverters 122, 123 are connected in parallel to the power line PL2 and the power line NL1. The inverters 122, 123 convert DC power supplied from the converter 121 to AC power, based on respective control signals PWI1, PWI2 from the ECU 300, and drive the motor-generators 130, 135, respectively.

15 **[0038]** The capacitor C1 is provided between the power line PL1 and the power line NL1, for reducing fluctuations in voltage between the power line PL1 and the power line NL1. The capacitor C2 is provided between the power line PL2 and the power line NL1, for reducing fluctuations in voltage between the power line PL2 and the power line NL1.

20 **[0039]** The motor-generators 130, 135 are AC rotating electric machines. For example, the motor-generators 130, 135 are permanent magnet type synchronous motors having rotors in which permanent magnets are embedded.

25 **[0040]** The output torque of the motor-generators 130, 135 is transmitted to the drive wheels 150 via the power transmission gears 140 including a reducer and a power split device, so as to run the vehicle 100. When the vehicle 100 operates in a regenerative braking mode, the motor-generators 130, 135 can generate electric power, using rotary force of the drive wheels 150. The electric power thus generated is converted via the PCU 120 to electric power for charging the power storage device 110.

30 **[0041]** The motor-generators 130, 135 are also coupled to the engine 160 via the power transmission gears 140. The motor-generators 130, 135 and the engine 160 are operated by the ECU 300 in a coordinated manner, so as to generate required vehicle driving force. Furthermore, the motor-generators 130, 135 are able to generate electric power by utilizing rotation of the engine 160, and the electric power thus generated can be

used for charging the power storage device 110. In this embodiment, the motor-generator 135 is used exclusively as an electric motor for driving the drive wheels 150, and the motor-generator 130 is used exclusively as a generator driven by the engine 160. The engine 160 is controlled by the ECU 300, according to a control signal DRV.

5 **[0042]** While the vehicle 100 as shown in FIG. 1 is provided with two motor generators by way of example, the number of motor-generators is not limited to two, but the vehicle of the invention may be provided with one motor-generator, or may be provided with more than two motor-generators.

10 **[0043]** The vehicle 100 further includes a DC/DC converter 170, an auxiliary load 180, and an auxiliary battery 190, as a low-voltage system (auxiliary system).

15 **[0044]** The DC/DC converter 170 is a power conversion device that is connected to the power lines PL1, NL1, and operates to lower the DC voltage supplied from the power storage device 110, based on a control signal PWD from the ECU 300. The DC/DC converter 170 then supplies the electric power to the low-voltage system, such as the auxiliary load 180 and the auxiliary battery 190, of the vehicle as a whole, via a power line PL4. The DC/DC converter 170 may be included in the PCU 120.

20 **[0045]** The auxiliary load 180 includes various devices or systems, such as lamps, wipers, heater, audio system, navigation system, power steering, power window, and an ECB. Each of the devices or systems included in the auxiliary load 180 transmits a state signal STAT indicative of whether the device is in operation or stopped, to the ECU 300.

[0046] A current sensor 195 is provided in a power line of a system to which the auxiliary load 180 is connected. The current sensor 195 detects the total current consumed by the entire auxiliary load 180, and transmits the detection value IAUX to the ECU 300.

25 **[0047]** The auxiliary battery 190 is typically formed by a lead-acid storage battery. The output voltage of the auxiliary battery 190 is lower than the output voltage of the power storage device 110, and is equal to about 12V, for example.

[0048] The vehicle 100 includes a charging device 200, a charging relay CHR 210, and an inlet 220 as a connecting portion, which constitute a system for charging the

power storage device 110 with electric power from an external power supply 500.

[0049] A charging connector 410 of a charging cable 400 is connected to the inlet 220. In operation, electric power is transmitted from the external power supply 500 to the vehicle 100 via the charging cable 400.

5 [0050] The charging cable 400 includes a plug 420 to be connected to a receptacle outlet 510 of the external power supply 500, and a cable portion 430 that connects the charging connector 410 with the plug 420, in addition to the charging connector 410. A charging circuit interrupt device (which will also be called "CCID") 440 for selectively allowing supply of electric power from the external power supply 500 and cutting the
10 power from the external power supply 500 is inserted in the cable portion 430.

[0051] The charging device 200 is connected to the inlet 220, via power lines ACL1, ACL2. The charging device 200 is also connected to the power storage device 110 through a power line PL3 and a power line NL3, via the CHR 210.

[0052] The charging device 200 is controlled according to a control signal PWE
15 from the ECU 300, so as to convert AC power supplied from the inlet 220, to charging power for charging the power storage device 110.

[0053] The charging device 200 includes a DC/DC converter 205, and supplies power-supply voltage for battery management and operation of other auxiliary load 180 while external charging is carried out. The output of the DC/DC converter 205 is
20 electrically connected to the auxiliary battery 190 via a power line PL5.

[0054] The CHR 210 includes relays CHR-B, CHR-P, CHR-G, and a limiting resistor R2. The relay CHR-B is connected to the positive terminal of the power storage device 110 and the power line PL3. The relay CHR-G is connected to the negative terminal of the power storage device 110 and the power line NL3. A portion of the CHR
25 210 in which the relay CHR-P and the limiting resistor R2 are connected in series is connected in parallel with the relay CHR-G.

[0055] The relays included in the CHR 210 can be individually operated, based on a control signal SE2 from the ECU 300, and are switched between positions for allowing supply of electric power from the charging device 200 to the power storage

device 110, and positions for cutting the electric power. The limiting resistor R2 is a current-limiting resistor adapted to prevent excessively large current from instantaneously flowing to the charging device 200, when the power storage device 110 and the charging device 200 are connected.

5 **[0056]** A solar power generation system 280 capable of generating electric power utilizing solar light is installed on the vehicle 100 according to this embodiment. The solar power generation system 280 includes a solar panel 250 and a solar unit 260.

[0057] The solar panel 250 generates electric power when receiving solar light, and provides the electric power thus generated to the solar unit 260. The solar unit 260
10 stores the electric power produced at the solar panel 250. Also, the solar unit 260 converts the voltage of the electric power produced at the solar panel 250 and/or the electric power stored therein, to a given voltage, based on a control signal PWF from the ECU 300, and provides the resulting power to the auxiliary battery 190 via the power line PL5.

15 **[0058]** The ECU 300 includes a CPU (Central Processing Unit), a storage device, and an input-output buffer, none of which is illustrated in FIG. 1. In operation, the ECU 300 receives signals from various sensors, etc., and outputs control signals to various devices and systems, so as to control the power storage device 110 and various devices and systems of the vehicle 100. These controls may be implemented not only by software,
20 but may also be implemented by exclusive hardware (such as electronic circuits).

[0059] The ECU 300 computes the state of charge SOC of the power storage device 110, based on the detection values of voltage VB and current IB from the power storage device 110.

[0060] In the embodiment of FIG. 1, one controller is provided as the ECU 300.
25 However, individual controllers, such as a controller for the PCU 120 and a controller for the power storage device 110, may be provided for respective functions or respective devices or systems to be controlled.

[0061] FIG. 2 is a view useful for describing the detailed configuration of the charging device 200 and solar power generation system 280 shown in FIG. 1.

[0062] The charging device 200 includes an AC/DC converter 202, in addition to the DC/DC converter 205. The AC/DC converter 202 converts the AC power received from the external power supply 500 via power lines ACL1, ACL2, to DC power. The AC/DC converter 202 then transmits the resulting DC power to the power storage device 110, via the power lines PL3, NL3, so that the power storage device 110 is charged with the DC power.

[0063] The DC/DC converter 205 is connected to the power lines PL3, NL3. The DC/DC converter 205 lowers the DC voltage received from the power lines PL3, NL3, and provides the resulting power to the auxiliary battery 190 via the power line PL5.

[0064] The solar unit 260 includes a solar battery 262 and a DC/DC converter 264. The solar battery 262 stores electric power generated by the solar panel 250. The DC/DC converter 264 converts the DC voltage produced at the solar panel 250 and/or the DC voltage from the solar battery 262, and provides the resulting power to the auxiliary battery 190 via the power line PL5.

[0065] The DC/DC converter 264 is also connected to the power lines PL3, NL3, and is operable to convert the DC voltage from the power lines PL3, NL3 and provides the resulting power to the auxiliary battery 190. Furthermore, the DC/DC converter 264 is operable to convert the electric power generated by the solar panel 250, and supply the resulting power to the power lines PL3, NL3.

[0066] It is to be understood that the configuration of the solar power generation system 280 as shown in FIG. 2 is a mere example, and the solar battery 262 and the DC/DC converter 264 are not necessarily provided. For example, the solar battery 262 may not be provided. If the output voltage is 12V, for example, the DC/DC converter 264 may not be provided, and the electric power generated by the solar panel 250 may be directly supplied to the power line PL5. Also, the DC/DC converter 264 may not be connected to the power lines PL3, NL3.

[0067] With the arrangement as shown in FIG. 2, during external charging, for example, the voltage of electric power received from the external power supply 500 and converted by the AC/DC converter 202 can be reduced using the DC/DC converter 205

and/or the DC/DC converter 264, and supplied to the auxiliary battery 190. During running of the vehicle 100, too, the CHR 210 is closed, so that the DC voltage from the power storage device 110 can be reduced, and supplied to the auxiliary battery 190. In this embodiment, the solar power generation system 280, and the DC/DC converter 205 included in the charging device 200, correspond to one example of “electric power output unit” according to the invention.

[0068] FIG. 3 is a view useful for explaining the summary of auxiliary electric power control according to this embodiment. In FIG. 3, the vertical axis indicates the system maximum output current that can be provided to the auxiliary load. Since the system of the auxiliary load generally has a constant voltage of, for example, DC 12V or 24V, change of the output current of the system represents or corresponds to change of electric power supplied to the auxiliary load. Therefore, in the following description, it should be noted that the term “current” can be replaced with the term “electric power”.

[0069] When the vehicle system is started to run the vehicle, electric power from the auxiliary battery 190, and electric power from the power storage device 110, whose voltage has been lowered via the DC/DC converter 170 (which will also be called “main DC/DC”), are supplied to the auxiliary load 180. Accordingly, the system maximum output current (electric power) is the sum of the maximum output current of the auxiliary battery 190 and the maximum output current of the DC/DC converter 170.

[0070] When the size of the auxiliary battery 190 is reduced, from the viewpoints of cost reduction and saving of in-vehicle space, the capacity of the auxiliary battery 190 is reduced, and the maximum output current that can be produced is reduced; therefore, electric power (current) that can be supplied to the entire auxiliary load is reduced (see the middle bar in the graph of FIG. 3).

[0071] Since the auxiliary load 180 includes devices, such as headlights and wipers, which are used only under particular situations, the system maximum output current is generally set to be smaller than the current with which the entire auxiliary load can be operated.

[0072] On the other hand, the auxiliary load 180 includes one type of devices or

systems that consume substantially constant electric power during operation, and another type of devices or systems, such as the power steering and the electronically controlled brake (ECB) system, whose electric power consumption varies according to the amount of the user operation. For the latter type of auxiliary load whose power consumption varies in this manner, large electric power may be instantaneously required, depending on the user operation, and flow of large current in a short period of time, or inrush current, may be produced.

[0073] In the condition where the auxiliary battery 190 is reduced in size, and the system maximum output current is reduced, the current required to operate the entire auxiliary load may exceed the system maximum output current, and the auxiliary load 180 may not be normally operated, or the auxiliary battery 190 may be excessively discharged to run out, which may result in a failure or deterioration.

[0074] In this embodiment, when the system is temporarily brought into the above-described condition where the current required to operate the entire auxiliary load exceeds the system maximum output current, auxiliary electric power control is implemented so that electric power from the power storage device 110, or the solar battery 262 or solar panel 250, is supplied to the system of the auxiliary load (see the right-hand bar in the graph of FIG. 3). This auxiliary electric power control is implemented under which the electric power output unit (which will be comprehensively called "sub-DC/DC") included in other devices or systems, like the solar power generation system 280 and/or the DC/DC converter 205 included in the charging device 200 as shown in FIG. 2 is operated. This makes it possible to compensate for a temporary shortage of the electric power, and thereby stabilize the operation of the auxiliary load 180 by preventing reduction of the system voltage of the auxiliary load system, while achieving the increased lifetime of the auxiliary battery 190.

[0075] FIG. 4 is a functional block diagram useful for explaining the auxiliary electric power control executed by the ECU 300 in this embodiment. Each functional block illustrated in the functional block diagram of FIG. 4 is implemented through hardware or software processing of the ECU 300.

[0076] Referring to FIG. 4, the ECU 300 includes a steady current computing unit 310, a maximum current predicting unit 320, a determining unit 330, a sub-DC/DC controller 340, and a storage unit 350.

[0077] The steady current computing unit 310 receives the state signal STAT indicative of an operating state of each auxiliary device or system from the auxiliary load 180, and computes electric current that steadily flows in the auxiliary load 180, depending on whether each auxiliary device or system is in use (the ON/OFF state). For example, the steady current computing unit 310 sums up steady current values for the auxiliary devices or systems that are currently used, using a steady current value for each auxiliary device or system stored in advance in the storage unit 350. When the current sensor 195 is provided, the steady current computing unit 310 may use the current value I_{AUX} obtained by the current sensor 195 and representing current flowing in the entire auxiliary load 180, as the steady current value, in place of or in addition to the above-described computation. The steady current computing unit 310 outputs the obtained steady current value I_{con} to the maximum current predicting unit 320.

[0078] The maximum current predicting unit 320 receives the steady current value I_{con} from the steady current computing unit 310. Also, the maximum current predicting unit 320 obtains information concerning inrush current associated with each of the auxiliary devices or systems whose current consumption can vary, from the storage unit 350. On the basis of the information, the maximum current predicting unit 320 computes the system maximum current I_{max} that would appear on the assumption that the inrush current is produced due to the conditions of the auxiliary devices or systems that are currently used. For example, the system maximum current I_{max} can be calculated as the sum of the steady current value I_{con} and the information of the inrush current received from the storage unit 350. The maximum current predicting unit 320 outputs the system maximum current I_{max} thus computed, to the determining unit 330.

[0079] The determining unit 330 receives the computed system maximum current I_{max} from the maximum current predicting unit 320. The determining unit 330 compares the received system maximum current I_{max} , with a threshold value α that represents the

sum of the maximum output current of the auxiliary battery 190 and the maximum output current of the DC/DC converter 170 stored in the storage unit 350, and determines whether current can be sufficiently supplied to the auxiliary load 180 when the inrush current is produced.

5 **[0080]** When the system maximum current I_{max} is equal to or smaller than the threshold value α , the determining unit 330 determines that current can be sufficiently supplied to the auxiliary load 180, and sets a determination flag FLG to OFF, for example. On the other hand, when the system maximum current I_{max} exceeds the threshold value α , the determining unit 330 determines that the current supplied to the auxiliary load 180
10 becomes insufficient, and set the determination flag FLG to ON. Then, the determining unit 330 outputs the determination flag FLG to the sub-DC/DC controller 340.

[0081] When the determination flag FLG is ON, namely, when the current supplied to the auxiliary load 180 becomes insufficient upon occurrence of the inrush current, the sub-DC/DC controller 340 creates control signals PWE, PWF so as to operate
15 at least one of the DC/DC converter 205 in the charging device 200 for external charging and the DC/DC converter 264 in the solar power generation system 280. Thus, relevant devices to be operated so as to generate electric power from the sub-DC/DC to the auxiliary load 180 are controlled, so as to make up for a shortage of the current required by the entire auxiliary load.

20 **[0082]** When the determination flag FLG is OFF, the auxiliary load 180 can operate with electric current received from the auxiliary battery 190 and the main DC/DC, and therefore the sub-DC/DC controller 340 stops the sub-DC/DC. When the sub-DC/DC is in the stopped state, it is kept in the stopped state.

[0083] FIG. 5 is a flowchart illustrating an auxiliary electric power control routine
25 executed by the ECU 300. The control routines illustrated in the flowcharts of FIG. 5 and FIG. 7 are implemented by calling programs stored in advance in the ECU 300, from a main routine, and executing the programs at given intervals. It is also possible to implement some steps in the flowcharts, by use of exclusive hardware (electronic circuits).

[0084] Referring to FIG. 1 and FIG. 5, the ECU 300 computes steady current

currently consumed by the auxiliary load 180, in step S100. As explained above referring to FIG. 4, the steady consumption current may be obtained by computation from the usage state of each device or system of the auxiliary load, or the detection value IAUX of the current sensor 195 may be used as the steady consumption current.

5 **[0085]** The ECU 300 predicts the maximum consumption current I_{max} of the auxiliary load 180 in step S110, in view of inrush current associated with the auxiliary load whose electric power consumption is variable, in addition to the steady consumption current obtained in step S100. Then, the ECU 300 determines in step S120 whether the predicted maximum consumption current I_{max} is larger than the threshold value α .

10 **[0086]** When the maximum consumption current I_{max} is equal to or smaller than the threshold value α (NO in step S120), the ECU 300 determines that the current supplied from the auxiliary battery 190 and the main DC/DC 170 is sufficiently large, and skips subsequent steps so that the control returns to the main routine.

15 **[0087]** On the other hand, when the maximum consumption current I_{max} exceeds the threshold value α (YES in step S120), the control proceeds to step S130, and the ECU 300 drives the sub-DC/DC so as to increase electric current that can be used by the auxiliary load system.

20 **[0088]** Although not illustrated in FIG. 5, when other devices or systems of the auxiliary load are stopped after the sub-DC/DC is once started, and the maximum consumption current I_{max} is reduced to be equal to or smaller than the threshold value α (NO in step S120), the sub-DC/DC is stopped, and the control ends.

25 **[0089]** With the control performed according to the routine as described above, when the electric power required by the auxiliary load is temporarily increased, it is possible to appropriately supply electric power to the auxiliary load, by driving the existing other power output unit (sub-DC/DC), without adding any exclusive device or system. This makes it possible to achieve reduction of the size of the auxiliary battery, reduced cost, and improvement in the energy efficiency due to reduction of the vehicle weight, which leads to increase in lifetime of the auxiliary battery.

[0090] In the above-described embodiment, the auxiliary electric power control

performed in a condition where the vehicle system is started and enables the vehicle to run, namely, where the SMR 115 is closed and the DC/DC converter 170 is driven, has been explained.

[0091] In the vehicle having the external charging function as shown in FIG. 1, the auxiliary load may be used during execution of external charging. When the external charging is conducted, the system of the drive system of the vehicle is generally placed in a stopped state, the SMR 115 is opened, and the DC/DC converter 170 is also placed in a stopped state. At this time, electric power cannot be supplied from the DC/DC converter 170 to the auxiliary load 180; therefore, the system maximum output current of the auxiliary load system is reduced as compared with that at the time when the vehicle system is started.

[0092] During execution of external charging, the charging device 200 is driven, and the DC/DC converter 205 in the charging device 200 is in operation. Accordingly, the system maximum output current during external charging is the sum of the maximum output current of the auxiliary battery 190 and the maximum output current of the DC/DC converter 205.

[0093] If the size of the auxiliary battery 190 is reduced, the system maximum output current is further reduced as shown in FIG. 6; therefore, sufficient electric power may not be supplied to the auxiliary load 180, depending on the usage state of the auxiliary load 180.

[0094] Thus, in the case where the vehicle further includes any electric power output unit, such as the solar power generation system 280 as shown in FIG. 1, other than the DC/DC converter 205 of the charging device 200, when the electric power required by the auxiliary load 180 exceeds the electric power than can be supplied from the auxiliary battery 190 and the DC/DC converter 205, it is possible, even during external charging, to make up for a shortage of the electric power by driving the other electric power output unit.

[0095] FIG. 7 is a flowchart illustrating an auxiliary electric power control routine executed by the ECU 300. In the flowchart of FIG. 7, steps S120, S130 in the flowchart

of FIG. 5 are replaced with steps S120A, S130A. In FIG. 7, the same steps as those of FIG. 5 will not be repeatedly described.

[0096] Referring to FIG. 7, the ECU 300 computes steady consumption current that is currently consumed by the auxiliary load 180 during execution of external charging (S100). Then, the maximum consumption current I_{max} is predicted in view of the inrush current in the auxiliary load that can be operated during execution of external charging (S110).

[0097] Then, the ECU 300 determines in step S120A whether the predicted maximum consumption current I_{max} is larger than a threshold value β . For example the threshold value β is set as the sum of the maximum output current of the auxiliary battery 190 and the maximum output current of the DC/DC converter 205 in the charging device 200, and is generally set to a value smaller than the threshold value α in FIG. 5.

[0098] When the maximum consumption current I_{max} is equal to or smaller than the threshold value β (NO in step S120A), the ECU 300 determines that sufficient current is supplied from the auxiliary battery 190 and the DC/DC converter 205, and skips subsequent steps so that the control returns to the main routine.

[0099] On the other hand, when the maximum consumption current I_{max} exceeds the threshold value β (YES in step S120A), the control proceeds to step S130A, and the ECU 300 drives the solar power generation system 280 so as to increase the current that can be used by the auxiliary load system.

[0100] With the control performed according to the above-described routine, it is possible to appropriately supply electric power to the auxiliary load in the vehicle, by driving the existing other electric power output unit (sub-DC/DC) when the electric power required by the auxiliary load is temporarily increased during external charging.

[0101] In the system in which the DC/DC converter 205 in the charging device 200 is not started during execution of external charging, when the electric power required by the auxiliary load in use exceeds the maximum output power of the auxiliary battery 190, at least one of the DC/DC converter 205 and the solar power generation system 280 may be driven so as to make up for a shortage of the electric power. At this time, the

charging device has already been started to permit external charging; therefore, it is preferable to use the DC/DC converter 205 of the charging device 200 at a higher priority than the solar power generation system 280, since there is no need to start an additional device or system.

5 **[0102]** While the electric vehicle 100 as described above referring to FIG. 1 has the external charging function, the auxiliary electric power control of this embodiment may be applied to an electric vehicle having no external charging function.

10 **[0103]** FIG. 8 is an overall block diagram showing the case where the above-described auxiliary electric power control is applied to an electric vehicle 100A having no external charging function. The configuration of the vehicle 100A shown in FIG. 8 is substantially identical with that of the vehicle 100 shown in FIG. 1, except that the vehicle 100A is not provided with devices (charging device, CHR, inlet, etc.) for performing external charging. In FIG. 8, the same elements as those of FIG. 1 will not be repeatedly described.

15 **[0104]** In the vehicle 100A, when the electric power consumed by the auxiliary load 180 during running of the vehicle is temporarily increased, a control routine similar to that of the flowchart of FIG. 7 as described above is executed, so that electric power is supplied from the solar power generation system 280 to the auxiliary battery 190, so as to make up for a shortage of the electric power for driving the auxiliary load 180.

20 **[0105]** Thus, when the vehicle has an electric power output unit, such as the solar power generation system 280, which is different from the power storage device 110 and the DC/DC converter 170, the auxiliary electric power control of this embodiment can be applied to the vehicle that is not provided with the external charging function.

25 **[0106]** [Application of Auxiliary Electric Power Control to Non-Electric Vehicle]
Referring to FIG. 9, the case where the auxiliary electric power control of this embodiment is applied to a vehicle 100B that runs using only driving force generated by the engine 160, rather than an electric vehicle, will be described. In FIG. 9, the same elements as those of FIG. 1 will not be repeatedly described.

[0107] Referring to FIG. 9, in the vehicle 100B, the output shaft of the engine 160

is mechanically coupled to the drive wheels 150, via a power transmission mechanism 145 including a clutch and a transmission. The vehicle 100B runs using driving force generated by the engine 160.

[0108] A generator 165 capable of generating electric power utilizing rotation of the engine is mounted on the engine 160. The electric power generated by the generator 165 is provided to the auxiliary load 180 and the auxiliary battery 190.

[0109] When a predicted value of the maximum electric power consumed by the auxiliary load 180 exceeds a threshold value determined from the sum of the maximum value of electric power that can be generated from the auxiliary battery 190 and the maximum value of electric power than can be generated from the generator 165, electric power from the solar power generation system 280 is supplied to the auxiliary load 180, so as to make up for a shortage of electric power for driving the auxiliary load 180.

[0110] Thus, the auxiliary electric power control of this embodiment can be applied to the vehicle that runs using only the driving force from the engine 160, where the vehicle has another electric power output unit, such as the solar power generation system 280.

[0111] It should be appreciated that the illustrated embodiment is exemplary in all respects and not restrictive. The scope of this invention is not defined by the above explanation but defined by the appended claims, and is intended to include all changes or modifications that fall within the range of the claims and equivalents thereof.

CLAIMS:

1. A vehicle, comprising:
 - an auxiliary load;
 - an auxiliary battery configured to supply electric power to the auxiliary load;
 - at least one electric power output unit configured to supply electric power to the auxiliary load; and
 - a controller configured to:
 - (a) predict a maximum electric power consumption of the auxiliary load based on a usage state of the auxiliary load;
 - (b) supply the electric power from the electric power output unit, in addition to the electric power from the auxiliary battery, to the auxiliary load, when the predicted maximum electric power consumption exceeds a threshold value; and
 - (c) control the electric power output unit.
2. The vehicle according to claim 1, further comprising:
 - a power storage device;
 - a drive unit configured to generate driving force for running the vehicle, using electric power from the power storage device; and
 - a first power conversion device different from the electric power output unit, the first power conversion device being configured to convert electric power from the power storage device and supply the electric power to the auxiliary load,wherein the threshold value is determined as a sum of a maximum value of electric power that can be generated from the auxiliary battery, and a maximum value of electric power that can be generated from the first power conversion device.
3. The vehicle according to claim 2, further comprising:
 - a charging device configured to convert electric power from an external power supply provided outside the vehicle, and perform external charging for supplying charging power

to the power storage device,

wherein the charging device includes a second power conversion device that is used as the electric power output unit, the second power conversion device being configured to lower a voltage of one of the converted electric power from the external power supply and the electric power from the power storage device, and supply the electric power to the auxiliary load.

4. The vehicle according to claim 3, further comprising:

a solar power generation system configured to generate electric power using solar light, and supply the generated electric power to the auxiliary load,

wherein at least one of the second power conversion device and the solar power generation system is used as the electric power output unit.

5. The vehicle according to claim 4, wherein

when the predicted maximum electric power consumption exceeds the threshold value during execution of the external charging, the controller is configured to use the electric power from the second power conversion device at a higher priority than the electric power from the solar power generation system.

6. The vehicle according to claim 4, wherein:

the controller is configured to operate in one of a running mode for running the vehicle, and a charging mode for executing the external charging;

the controller is configured to, when operating in the running mode, set a sum of a maximum value of electric power that can be generated from the auxiliary battery and a maximum value of electric power that can be generated from the first power conversion device, as the threshold value, and use at least one of the second power conversion device and the solar power generation system as the electric power output unit; and

the controller is configured to, when operating in the charging mode, set a sum of the maximum value of electric power that can be generated from the auxiliary battery and a

maximum value of electric power that can be generated from the second power conversion device as the threshold value, and use the solar power generation system as the electric power output unit.

7. The vehicle according to claim 3, wherein:

the controller is configured to operate in one of a running mode for running the vehicle, and a charging mode for executing the external charging;

the controller is configured to, when operating in the running mode, set a sum of a maximum value of electric power that can be generated from the auxiliary battery and a maximum value of electric power that can be generated from the first power conversion device, as the threshold value; and

the controller is configured to, when operating in the charging mode, set the maximum value of electric power that can be generated from the auxiliary battery as the threshold value.

8. The vehicle according to claim 2, further comprising:

a solar power generation system that is used as the electric power output unit, the solar power generation system being configured to generate electric power using solar light, and supply the generated electric power to the auxiliary load.

9. The vehicle according to claim 1, further comprising:

an engine that generates driving force for running the vehicle;

a generator that is operated by the engine to generate electric power; and

a solar power generation system configured to generate electric power using solar light, and supply the generated electric power to the auxiliary load,

wherein the threshold value is defined as a sum of a maximum value of electric power that can be generated from the auxiliary battery and electric power that can be generated from the generator, and the solar power generation system is used as the electric power output unit.

10. A method for controlling a vehicle, the vehicle including an auxiliary load, an auxiliary battery that supplies electric power to the auxiliary load, at least one electric power output unit configured to supply electric power to the auxiliary load, and a controller, the method comprising:

(A) predicting by the controller a maximum electric power consumption of the auxiliary load, based on a usage state of the auxiliary load;

(B) determining by the controller whether the predicted maximum electric power consumption exceeds a predetermined threshold value; and

(C) supplying by the controller electric power from the electric power output unit, in addition to electric power from the auxiliary battery, to the auxiliary load, when the predicted maximum electric power consumption exceeds the threshold value.

FIG. 1

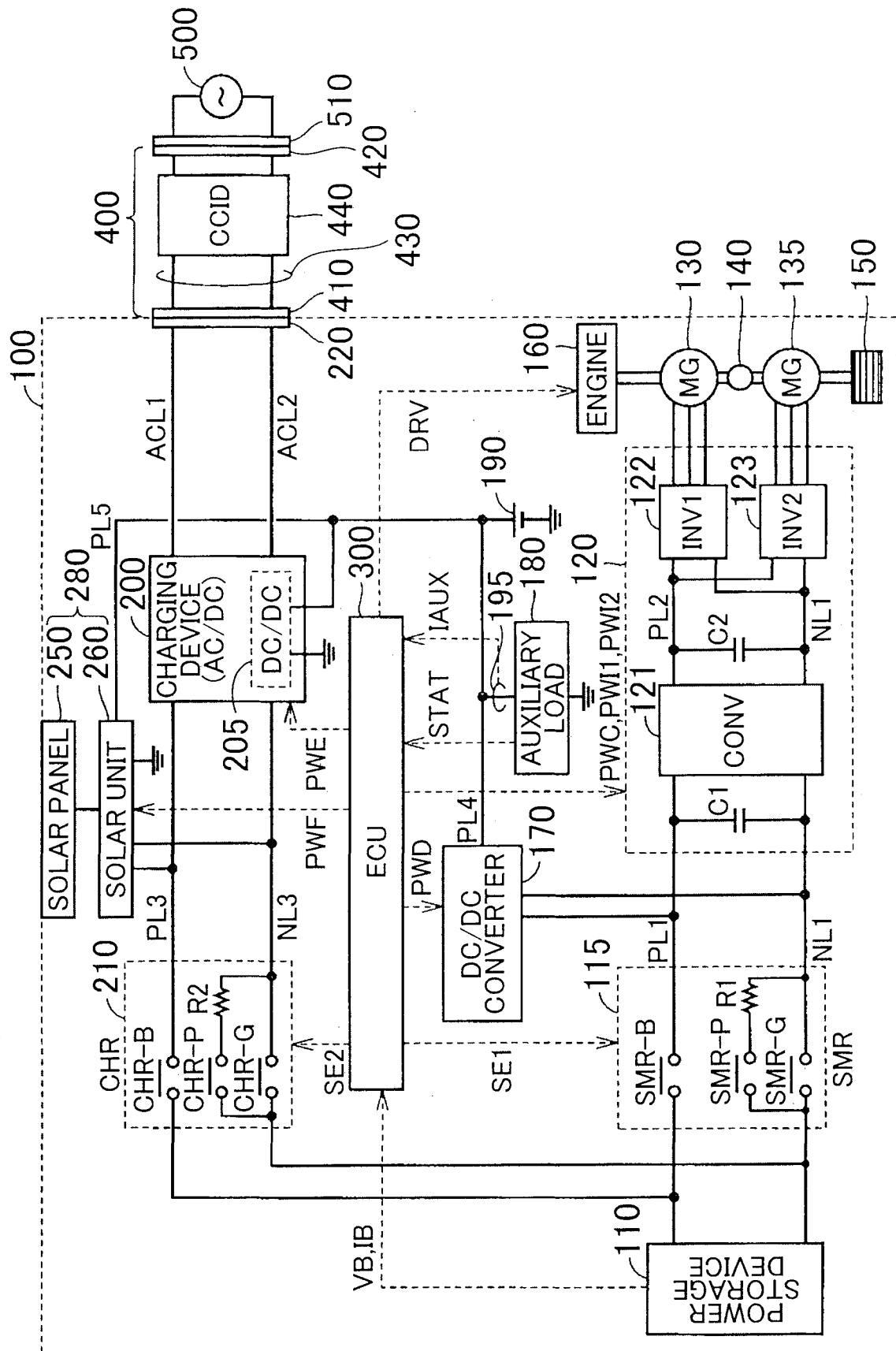


FIG. 2

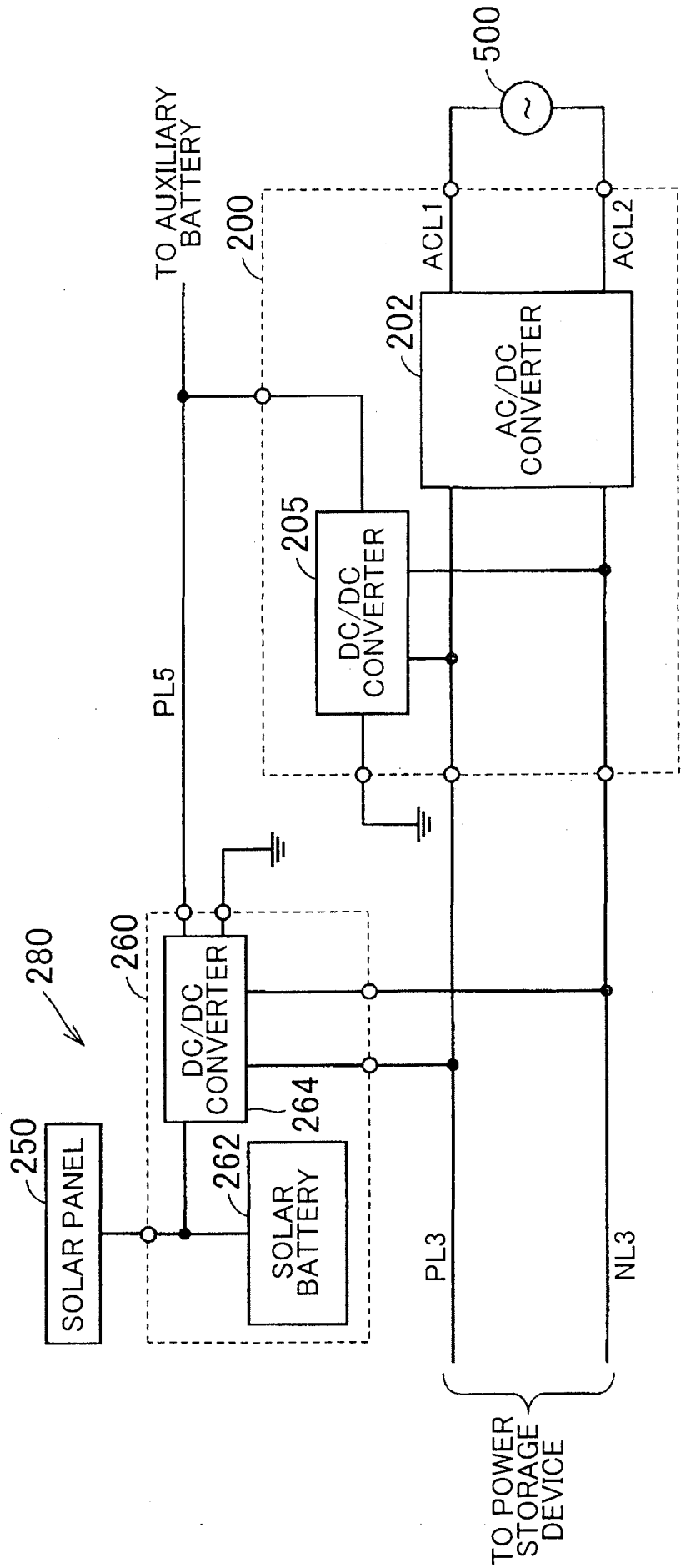


FIG. 3

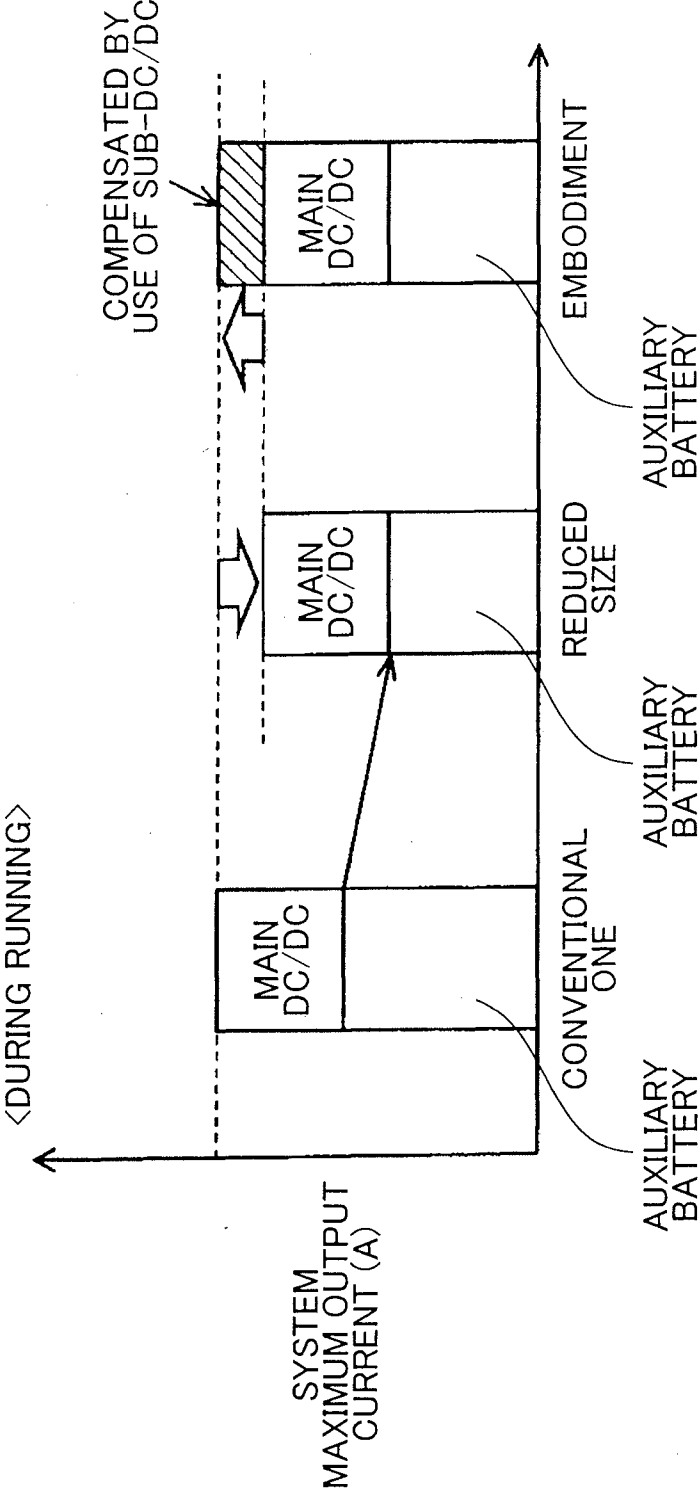


FIG. 4

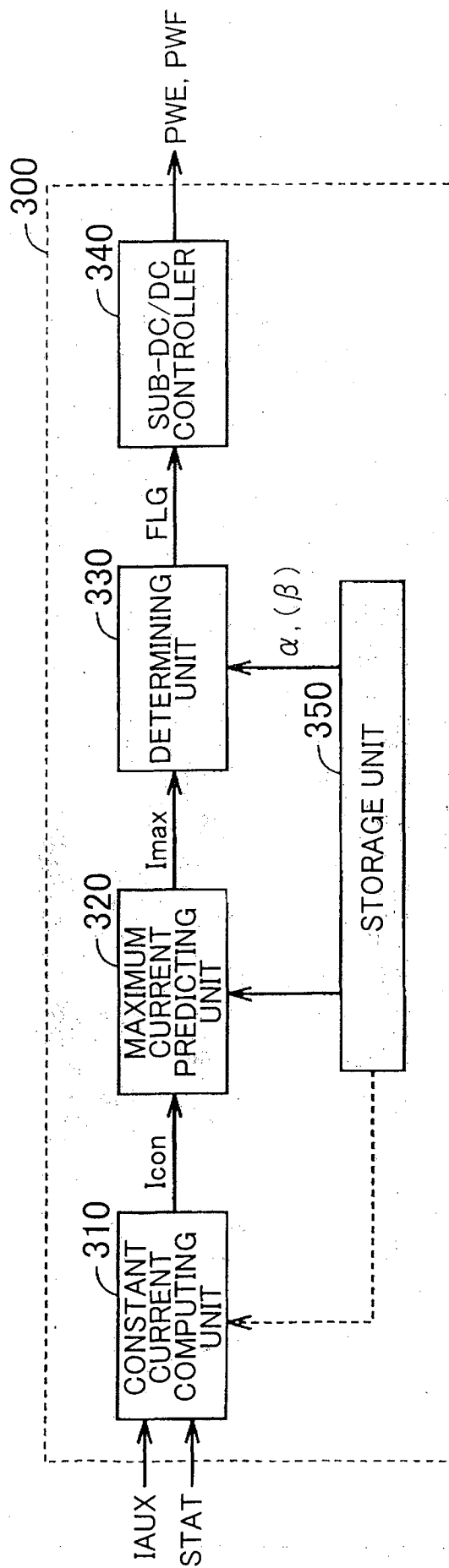


FIG. 5

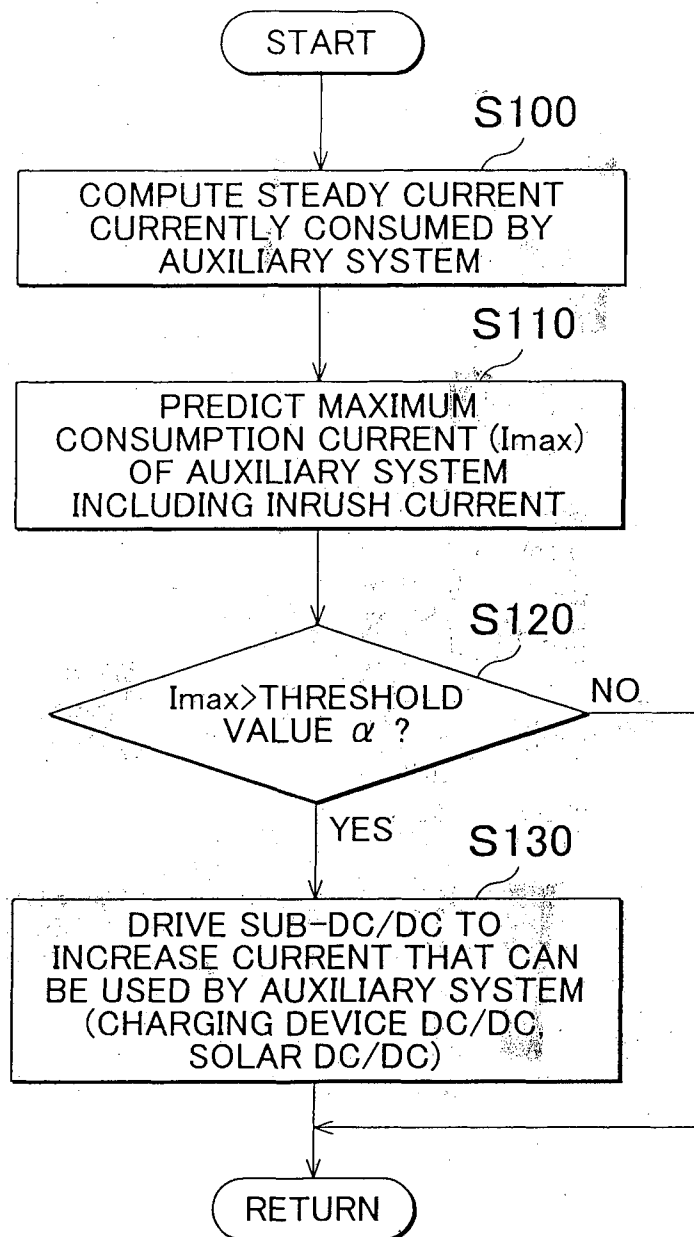
300

FIG. 6

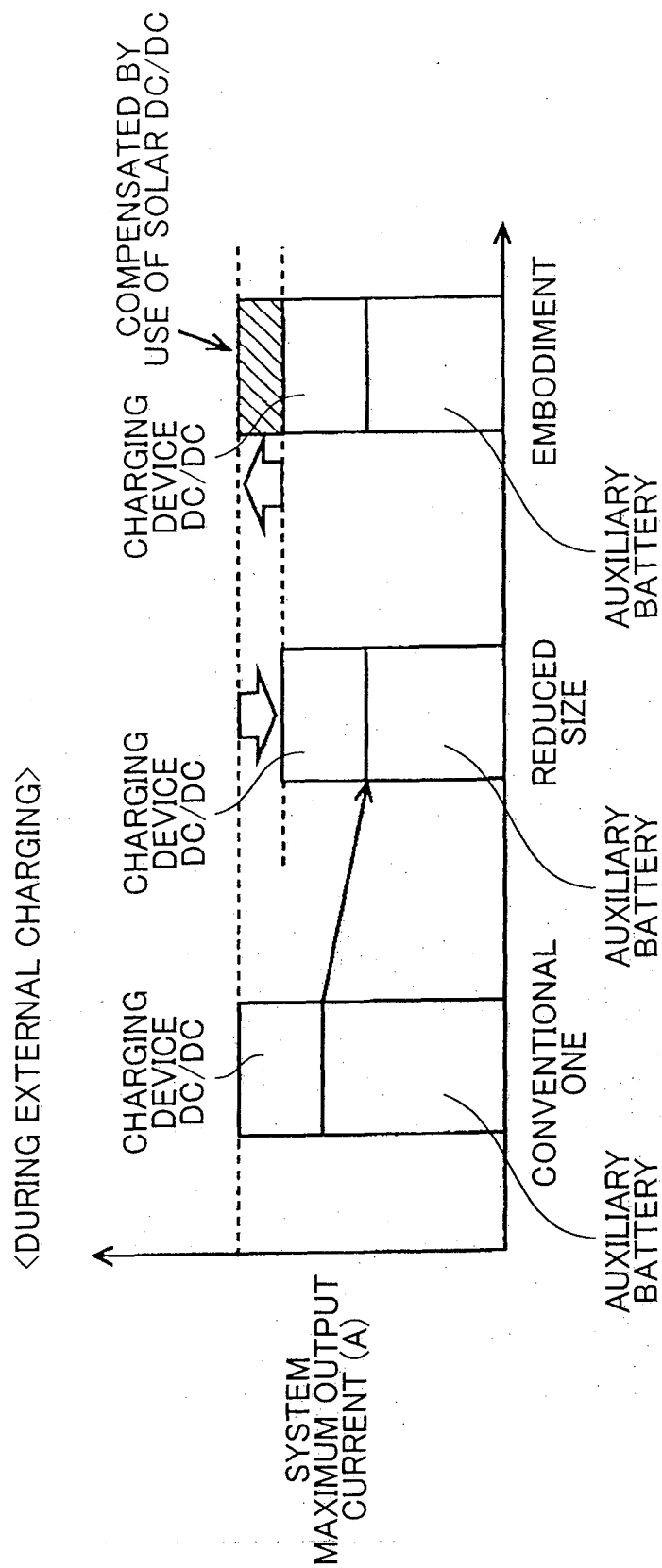


FIG. 7

300

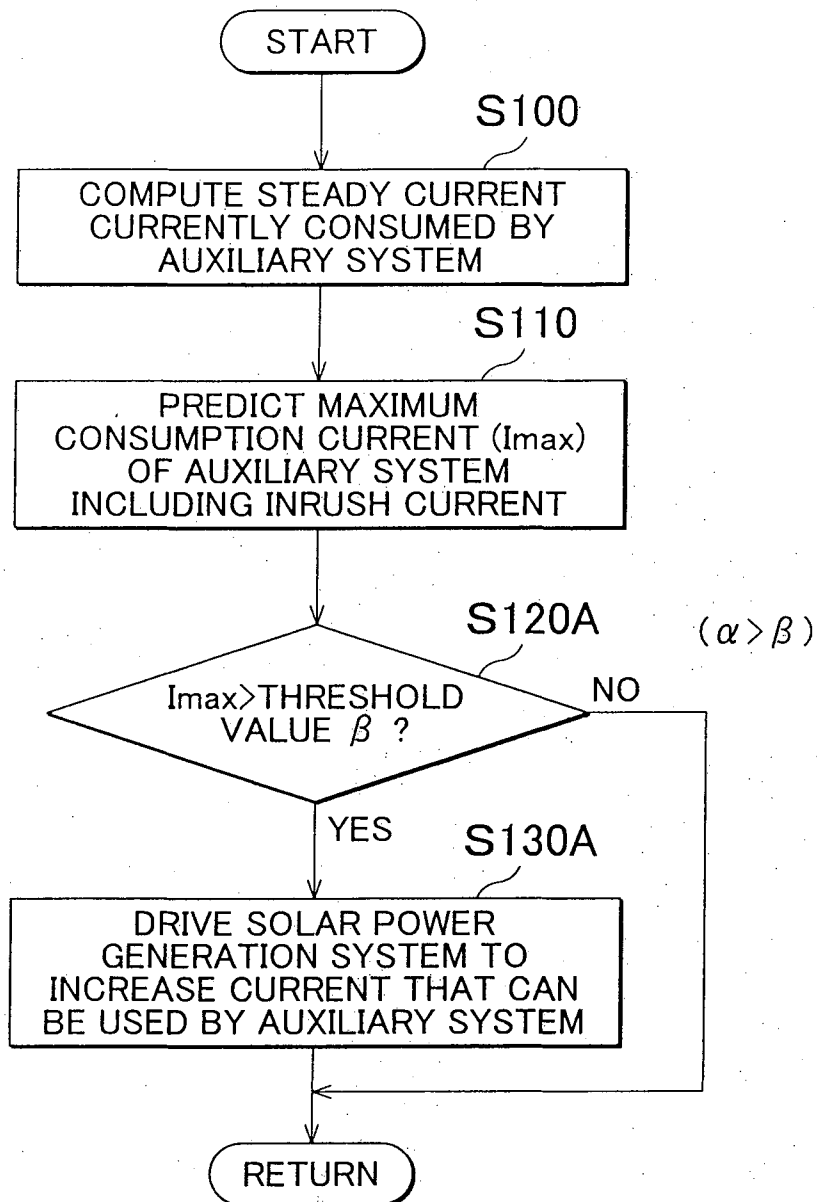


FIG. 8.

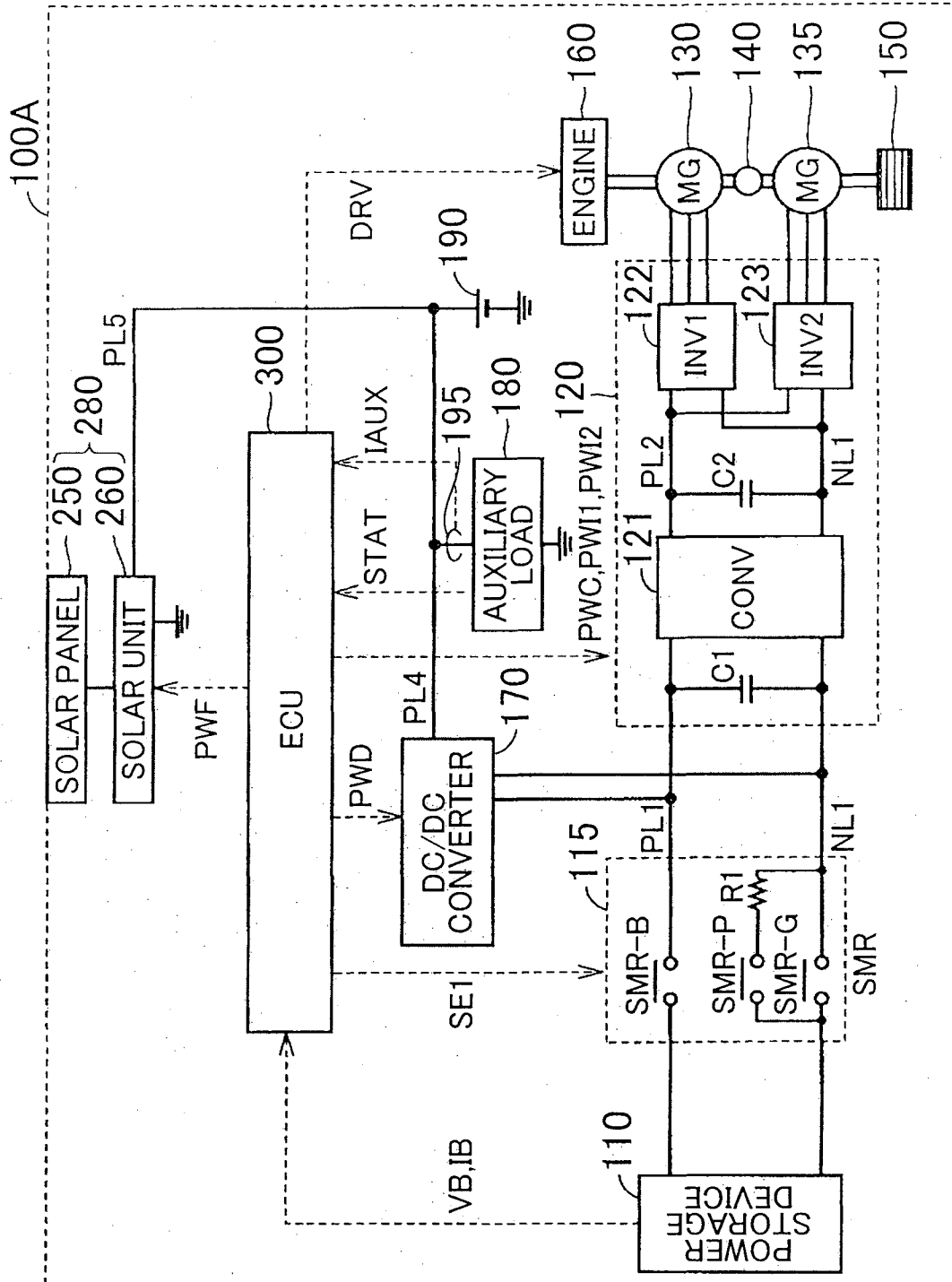


FIG. 9

