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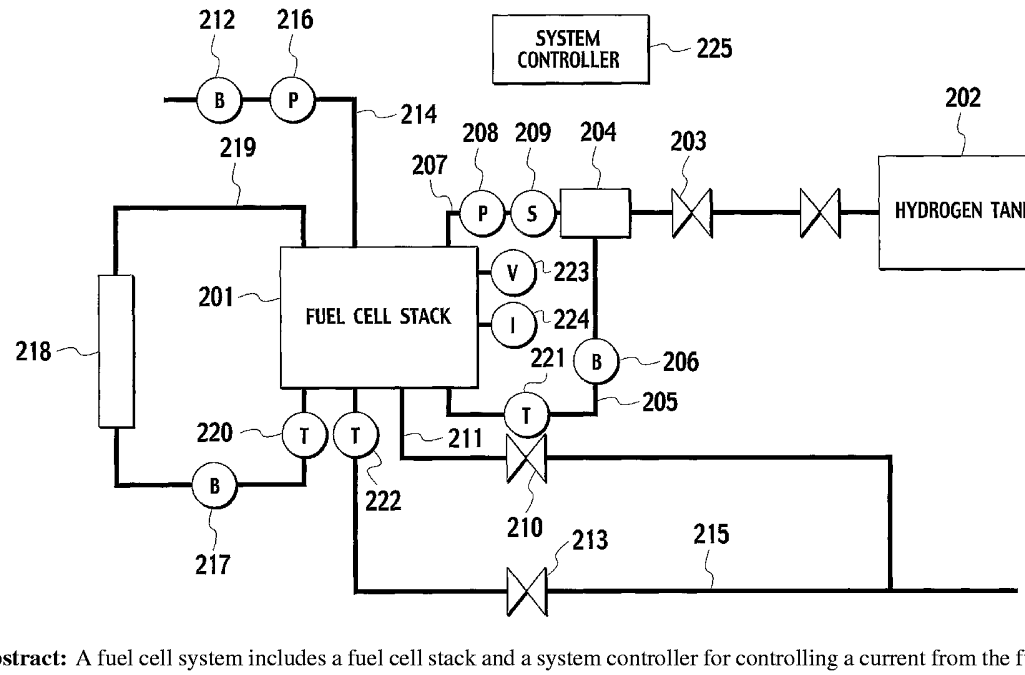
(54) Title: FUEL CELL SYSTEM



(57) Abstract: A fuel cell system includes a fuel cell stack and a system controller for controlling a current from the fuel cell stack. When the idle stop state of a fuel cell system is cancelled and thereafter the fuel cell system moves to an idle state, the system controller controls the current such that the fuel cell stack has a voltage less than or equal to a certain voltage which promotes deterioration of the fuel cell stack.

WO 2006/117969 A1

DESCRIPTION

FUEL CELL SYSTEM

TECHNICAL FIELD

The present invention relates to a fuel cell system installed as a power source for driving a fuel cell vehicle, where the fuel cell system has a control which is improved in moving from an idle stop state to an idle state.

BACKGROUND ART

Conventional technologies known for allowing a fuel cell system on a fuel cell vehicle to move from an idle stop state to an idle state include the following:

Japanese Patent Unexamined Publication No. 2001-359204 discloses a device for controlling idle of fuel cell vehicle, in which, with an idle stop mode is started according to a traveling state of a fuel cell vehicle, an auxiliary unit and the like (such as an air compressor) for driving the fuel cell is stopped and output of the fuel cell body is also stopped, followed by stopping of certain loads such as an auxiliary unit and the like excluding various controllers, thus improving fuel economy.

In addition, Japanese Patent Unexamined Publication No. 2004-014159 discloses a power supply device, in which, with a low load, a fuel cell system is detached from a circuit and a power is supplied to the fuel cell system from a capacitor, to thereby implement a low-load operation of the fuel cell system, thus preventing decreased energy efficiency of an entire power system.

As described above, with the fuel cell system having an idle stopping function for stopping power generation of the fuel cell stack in a small load area requiring a small driving force, continuing the idle state for a long time results in repetitions of the idle states and the idle stop states, due to restriction on capacity of a battery which is installed on the vehicle together with the fuel cell system and which supplies an initial power to the fuel cell system's auxiliary unit and the like.

Specifically, as shown in Fig. 1-(b), when the fuel cell system enters an idle stop state with the battery at an idle stop allowable SOC (state of charge) level, the battery's SOC starts decreasing. Then, when the battery's SOC is decreased to an idle stop unallowable SOC level, the idle stop state will be canceled to thereafter start the power generation in the idle state, to thereby increase the battery's SOC with the thus generated power.

In the above operation, the fuel cell stack moves from a low-voltage state of the idle stop state to a high-voltage state of the idle state, as shown in Fig. 1-(a). The above change in voltage of the fuel stack moving below and beyond a certain voltage {referred to as "a deterioration prompting potential" shown in Fig. 1-(a)} inconveniently promotes deterioration of the fuel cell stack.

DISCLOSURE OF INVENTION

It is therefore an object of the present invention to provide a fuel cell system which prevents deterioration of a fuel cell stack by suppressing a voltage of the fuel cell stack when the fuel cell system moves from an idle stop state to an idle state.

According to a first aspect of the present invention, there is provided a fuel cell system for generating a power by an electrochemical reaction between a fuel gas and an oxidizing gas, the fuel cell system comprising: 1) a fuel cell stack for receiving the fuel gas and the oxidizing gas, the fuel cell system implementing the following operations: i) when the power is required, supplying to the fuel cell stack the fuel gas and the oxidizing gas each having a quantity and a pressure which correspond to a current from the fuel cell stack, to thereby generate the power of the fuel cell stack, and ii) when the power is not required, stopping the supplying of the fuel gas and the oxidizing gas to the fuel cell stack, to thereby stop the generating of the power of the fuel cell stack, leading to an idle stop state of the fuel cell system; and 2) a controller for controlling the current from the fuel cell stack such that the fuel cell stack has a voltage less than or equal to a certain voltage, the controlling being implemented when the idle stop state is cancelled and thereafter the fuel cell system moves to an idle state.

According to a second aspect of the present invention, there is provided a method for generating a power by an electrochemical reaction between a fuel gas and an oxidizing gas, the method comprising: 1) when the power is required, supplying to a fuel cell stack the fuel gas and the oxidizing gas each having a quantity and a pressure which correspond to a current from the fuel cell stack, to thereby generate the power of the fuel cell stack; 2) when the power is not required, stopping the supplying of the fuel gas and the oxidizing gas to the fuel cell stack, to thereby stop the generating of the power of the fuel cell stack, leading to an idle stop state of the fuel cell system; and 3) controlling the current from the fuel cell stack such that the fuel cell stack has a voltage less than or equal to a certain voltage, the controlling being implemented when the idle stop state is cancelled and thereafter the fuel cell system moves to an idle state.

According to a third aspect of the present invention, there is provided a fuel cell system for generating a power by an electrochemical reaction between a fuel gas and an oxidizing gas, the fuel cell system comprising: 1) means for receiving the fuel gas and the oxidizing gas, the fuel cell system implementing the following operations: i) when the power is required, supplying to the receiving means the fuel gas and the oxidizing gas each having a quantity and a pressure which correspond to a current from the receiving means, to thereby generate the power of the receiving means, and ii) when the power is not required, stopping the supplying of the fuel gas and the oxidizing gas to the receiving means, to thereby stop the generating of the power of the receiving means, leading to an idle stop state of the fuel cell system; and 2) means for controlling the current from the receiving means such that the receiving means has a voltage less than or equal to a certain voltage, the controlling being implemented when the idle stop state is cancelled and thereafter the fuel cell system moves to an idle state.

Other and further features, advantages and benefits of the present invention will become apparent from the following description in conjunction with the following drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 shows diagrams of an idle stop state and an idle state after the idle stop state being cancelled, according to a related art, in which;

Fig. 1-(a) shows a change of a voltage of a fuel cell stack, and

Fig. 1-(b) shows a change of an SOC (state of charge) of a secondary battery.

Fig. 2 shows a structure of a fuel cell vehicle provided with a fuel cell system, according to an embodiment of the present invention.

Fig. 3 shows a structure of the fuel cell system, according to the embodiment of the present invention.

Fig. 4 shows a flow chart of operations, according to the embodiment of the present invention.

Fig. 5 shows a flow chart of operations for the fuel cell system to move to the idle stop state, according to the embodiment of the present invention.

Fig. 6 shows a flow chart of operations for the fuel cell system to be canceled from the idle stop state, according to the embodiment of the present invention.

Fig. 7 shows diagrams of an idle stop state and an idle state after the idle stop state being cancelled, according to the embodiment of the present invention, in which

Fig. 7-(a) shows a change of a voltage of a fuel cell stack, and

Fig. 7-(b) shows a change of a current from the fuel cell stack.

Fig. 8 shows voltage-current characteristics of the fuel cell stack corresponding to a temperature of the fuel cell stack, according to the embodiment of the present invention.

Fig. 9 shows voltage-current characteristics of the fuel cell stack corresponding to a stoichiometric ratio of a cathode of the fuel cell stack, according to the embodiment of the present invention.

Fig. 10 shows diagrams of the idle stop state and the idle state after the idle stop state being cancelled, according to the embodiment of the present invention, in which;

Fig. 10-(a) shows the change of the voltage of the fuel cell stack,

Fig. 10-(b) shows the change of the current from the fuel cell stack, and

Fig. 10-(c) shows a change of rotary speed of an air compressor.

BEST MODE FOR CARRYING OUT THE INVENTION

Hereinafter described referring the drawings is the best mode for carrying out the invention. For convenience sake, the term "state of charge" is denoted by "SOC."

Fig. 2 shows a basic structure of a fuel cell vehicle on which a fuel cell system 102 is installed, according to an embodiment of the present invention. Fig. 3 shows a structure of the fuel cell system 102, according to the embodiment of the present invention.

In Fig. 2, the fuel cell vehicle includes a vehicular body 101 on which the fuel cell system 102 is installed as a driving power source. Moreover, the fuel cell vehicle is provided with an inverter 103, a driving motor 104, a driving wheel 105, a vehicle speed sensor 106, a secondary battery 107, a relay 108 and a controller 109. Moreover, the fuel cell vehicle is provided with a shift position sensor 111 (for sensing a position of a vehicular shift), a brake sensor 112 (for sensing whether or not a braking is implemented), and an accelerator opening sensor 113 (for sensing an opening of an accelerator).

In the fuel cell system 102, a hydrogen pressure adjusting valve 203 (refer to an after-described Fig. 3), an air pressure adjusting valve 213 (refer to the after-described Fig. 3), an air compressor 212 (refer to the after-described Fig. 3) and the like control a pressure, a flowrate and the like of i) hydrogen of a fuel gas and ii) air of an oxidizing gas which are supplied to a fuel cell stack 201 (refer to the after-described Fig. 3), so as to generate i) a power consumed by the driving motor 104 and ii) a power necessary for charging the secondary battery 107.

Converting a direct current power (generated by the fuel cell system 102) to an alternating current power, the inverter 103 controls the driving motor 104 such that the thus converted alternating current power serves as an output torque which is instructed from the controller 109 for driving the driving motor 104.

The driving wheel 105 is mechanically connected to the driving motor 104. With a drive torque transmitted from the driving motor 104 to the driving wheel 105, the driving wheel 105 brings about a driving force, thereby driving the vehicle. The vehicle speed sensor 106 senses a rotary speed of the driving wheel 105.

In a state where no power is supplied from the fuel cell system 102, specifically, in such a state as an idle stop and the like of the vehicle, the secondary battery 107 supplies a power to auxiliary units such as the hydrogen pressure adjusting valve 203, the air pressure adjusting valve 213 and the air compressor 212 which are necessary for generating the driving motor 104 and the fuel cell system 102. The secondary battery 107 is provided with i) a voltage sensor 114 for sensing a voltage of the secondary battery 107 and ii) a current sensor 115 for sensing a current of the secondary battery 107. Based on the thus sensed voltage and current, a charging quantity of the secondary battery 107 can be estimated.

Based on an instruction from the controller 109, a relay 108 connects the fuel cell system 102 with a load or cuts the fuel cell system 102 from the load.

The controller 109 functions as a control center for controlling an operation of the fuel cell system 102. The controller 109 is realized, for example, by a microcomputer and the like provided with resources such as CPU, memory, input/output device and the like which are necessary for a computer controlling various operations based on a program. The controller 109 reads in a signal from each of the above sensors of the fuel cell vehicle, then sends instructions to each of the structural elements of the fuel cell vehicle based on the thus read various signals and on a pre-retained control logic (program). Then, the controller 109 administratively controls all operations necessary for operating and stopping the fuel cell vehicle, including operations of the fuel cell system 102 in a process of moving to the idle stop state of the fuel cell vehicle, to be described afterward.

Hereinafter described referring to Fig. 3 is the fuel cell system 102.

In Fig. 3, the fuel cell system 102 includes: i) the fuel cell stack 201 for power generation, ii) a hydrogen supply system for supplying to the fuel cell stack 201 hydrogen (or hydrogen rich gas) as a fuel gas, and iii) an air supply system for supplying to the fuel cell stack 201 an air including oxygen as an oxidizing gas.

The fuel cell stack 201 has a multilayer structure of generator cells in which a hydrogen electrode (to which hydrogen is supplied) and an air electrode {to which oxygen (air) is supplied} are overlapped with an electrolyte-electrode catalyst complex sandwiched therebetween, and includes a generating portion for converting chemical energy to electrical energy through electrochemical reaction between the hydrogen and the oxygen.

To the hydrogen electrode of the fuel cell stack 201, the hydrogen is supplied, to thereby dissociate hydrogen ion from electron. Then, the hydrogen ion passes through the electrolyte while the electron passes through an outer circuit, to thereby generate a power, thereafter, the hydrogen and the electron respectively move to the air electrode. In the air electrode, the oxygen (in the thus supplied air), the hydrogen ion and the electron react, to thereby bring about water, to be exhausted outward.

In view of higher energy concentration, lower cost, lighter weight and the like, the fuel cell stack 201 uses, for example, a solid high molecular electrolyte. The solid high molecular electrolyte is made of ion (proton)-conductive high molecule film such as fluorine resin ion exchange film and the like, serving as an ion-conductive electrolyte by hydrous saturation.

To the hydrogen electrode of the fuel cell stack 201 via a hydrogen electrode passage, the hydrogen supply system leads the hydrogen supplied from a hydrogen supplier. Specifically, the hydrogen supply system has i) a hydrogen tank 202 which is a hydrogen supplier for storing the hydrogen at a high pressure, 2) the hydrogen pressure adjusting valve 203 for adjusting the pressure of the hydrogen supplied to the fuel cell stack 201 such that the hydrogen necessary for the power generation by the fuel cell stack 201 can be supplied to the fuel cell stack 201, 3) a hydrogen circulating pump 206 for circulating a hydrogen-off gas (which is exhausted from the fuel cell stack 201) through a hydrogen circulating pipe 205, to thereby return the hydrogen-off gas to an inlet side of the fuel cell stack 201 via an ejector 204, and 4) a hydrogen supply pipe 207 serving as the hydrogen electrode passage.

Moreover, in the vicinity of an inlet of the hydrogen electrode of the fuel cell stack 201, there are provided i) a hydrogen pressure sensor 208 for sensing pressure of the hydrogen supplied to the fuel cell stack 201, and ii) a hydrogen concentration sensor 209 for sensing the hydrogen concentration.

The hydrogen gas supplied from the hydrogen tank 202 (hydrogen supply source) is sent to the hydrogen supply pipe 207 via the hydrogen pressure adjusting valve 203, to thereafter be supplied to the hydrogen electrode of the fuel cell stack 201. In this case, the pressure of the thus supplied hydrogen gas is adjusted by the hydrogen pressure adjusting valve 203 in such a manner as to be controlled based on the hydrogen pressure sensed by a hydrogen pressure sensor 208, and such that pressures in the hydrogen electrode and hydrogen electrode passage of the fuel cell stack 201 can be varied according to the load.

In the fuel cell stack 201, all the thus supplied hydrogen gases are not completely consumed. Specifically, the hydrogen-off gas exhausted from the fuel cell stack 201 without being consumed is circulated by means of the hydrogen circulating pump 206 via the hydrogen circulating pipe 205, and then is mixed with a fresh hydrogen gas supplied by the ejector 204, to be thereafter supplied to the hydrogen electrode of the fuel cell stack 201. With this, stoichiometric ratio (supply flowrate/consumption flowrate) of the hydrogen can be kept more than or equal to 1, thus stabilizing a cell voltage.

On an outlet side of the fuel cell stack 201 of the hydrogen supply system, there is provided a purge valve 210 and a purge pipe 211. The purge valve 210 is ordinarily closed, however, is opened with a decrease in cell voltage sensed which decrease is attributable to the fuel cell stack 201's failures such as water clogging, stored inactive gas and the like. Circulating the hydrogen gas may store impurity, nitrogen and the like in the hydrogen circulating pipe 205, thereby decreasing a partial pressure of the hydrogen, leading to a possible decrease in generation efficiency of the fuel cell stack 201. Therefore, providing the outlet side of the fuel cell stack 201 with the purge valve 210 and the purge pipe 211, and when necessary, opening the purge valve 210 for purging can remove the impurity, the nitrogen and the like from the hydrogen circulating pipe 205.

To the air electrode of the fuel cell stack 201 through the air electrode passage, the air supply system of the fuel cell stack 201 leads the air from an air supplier. Specifically, the air supply system includes i) the air compressor 212 as the air supplier, ii) the air pressure adjusting valve 213, and iii) an air pressure supply pipe 214 serving as an air electrode passage.

The air compressor 212 sends the air to the air electrode of the fuel cell stack 201. For example, an air compressed by driving a motor is supplied to the air electrode of the fuel cell stack 201 via the air pressure supply pipe 214.

The air pressure adjusting valve 213 adjusts the air supplied by the air compressor 212 to the fuel cell stack 201, and is disposed on an exhaust pipe 215 outside the air electrode of the fuel cell stack 201.

In the vicinity of an inlet of the air electrode of the fuel cell stack 201, there is provided an air pressure sensor 216. In this case, the pressure of the air supplied by the air compressor 212 is adjusted by the air pressure adjusting valve 213 in such a manner as to be controlled based on the air pressure sensed by the air pressure sensor 216, and such that the pressures in the air electrode and air electrode passage of the fuel cell stack 201 can be varied according to the load.

The oxygen and other components of the air which are not consumed by the fuel cell stack 201 are exhausted from the fuel cell stack 201 via the air pressure adjusting valve 213 and the exhaust pipe 215.

The fuel cell stack 201 using the above solid high molecular electrolyte film has a proper operating temperature about 80° C (relatively low), and needs cooling when overheated. Therefor, a cooling mechanism for maintaining the fuel cell stack 201 at a proper temperature is provided for the fuel cell stack 201. The cooling mechanism ordinarily cools the fuel cell stack 201 by circulating cooling water in the fuel cell stack 201.

Specifically, the cooling mechanism includes: i) a cooling water pump 217 as a cooling water supplier, ii) a radiator 218 for properly cooling the cooling water, and iii) a cooling water pipe 219 serving as a passage of the cooling water. Moreover, in the vicinity of a cooling water's inlet of the fuel cell stack 201, there is provided a cooling water temperature sensor 220 for sensing a temperature of the cooling water supplied to the fuel cell stack 201. Based on the cooling water temperature sensed by the cooling water temperature sensor 220, the cooling water pump 217 is controllably driven, adjusting the flowrate of the cooling water in such a manner that the temperature of the cooling water distributed in the cooling water pipe 219 is kept at about 80° C.

At least any one of the following can be regarded as the temperature of the fuel cell stack 201:

I) a temperature of the hydrogen-off gas exhausted from the hydrogen electrode of the fuel cell stack 201,

II) a temperature of the air-off gas exhausted from the air electrode,

III) the cooling water's temperature sensed by the cooling water temperature sensor 220, and

iv) an outer temperature.

For the item I) above, in the vicinity of an outlet of the hydrogen electrode, there is provided a temperature sensor 221 for sensing the temperature of the hydrogen-off gas exhausted from the fuel cell stack 201.

For the item II) above, in the vicinity of an outlet of the air electrode, there is provided a temperature sensor 222 for sensing the temperature of the air-off gas exhausted from the fuel cell stack 201.

For the item III) above, in the vicinity of the fuel cell stack 201, a temperature sensor (not shown) for sensing the outer temperature is to be provided.

Moreover, the fuel cell system 102 is provided with a voltage sensor 223, a current sensor 224, and a system controller 225. The voltage sensor 223 senses a stack voltage generated by the fuel cell stack 201. The current sensor 224 senses a current I_{201} from the fuel cell stack 201.

The system controller 225 functions as a control center for controlling the operation of the fuel cell system 102. The system controller 225 is realized, for example, by a microcomputer and the like provided with resources such as CPU, memory, input/output device and the like which are necessary for a computer controlling various operations based on a program. Specially, the system controller 225 is realized, for example, as part of a function of the controller 109 in Fig. 2. The system controller 225 reads in the signal from each of the above sensors of the fuel cell system 102, then sends instructions to each of the structural elements of the fuel cell system 102 based on the thus read various signals and on the pre-retained control logic (program). Then, the system controller 225 administratively controls all operations necessary for operating and stopping the fuel cell system 102, including operations of the fuel cell system 102 in the process of moving between the idle state and the idle stop state, to be described afterward.

(Controlling operation)

Hereinafter described referring to a flow chart in Fig. 4 is a controlling operation between the idle state and the idle stop state of the fuel cell system 102. The controlling operation is implemented by the system controller 225. Herein, controlling operation in Fig. 4 is to be repeatedly implemented at a preset period.

(S301) In Fig. 4, for implementing the controlling operation of the idle stop of the fuel cell system 102, a routine determines whether or not the fuel cell system 102 is in the idle stop state.

(S302) When No at S301, the routine determines whether or not an allowable condition (for example, the SOC of the secondary battery 107) is established for moving the fuel cell system 102 to the preset idle stop state.

(S303) When Yes at S302, the routine implements a treatment for moving the fuel cell system 102 to the idle stop state.

(S304) The fuel cell system 102 enters the idle stop state.

For moving the fuel cell system 102 to the idle stop state, the routine implements operations shown by a flow chart in Fig. 5.

(S41) In Fig. 5, at first, the routine closes the hydrogen pressure adjusting valve 203, to thereby stop supplying the hydrogen.

(S42) Then, the routine determines whether or not the hydrogen pressure of the fuel cell stack 201 is less than or equal to a certain pressure, for example, a certain negative pressure lower than an atmospheric pressure.

(S43) When Yes at S42, the routine closes the purge valve 210 and stops driving the hydrogen circulating pump 206.

(S44) Then, the routine stops driving the air compressor 212 and closes the air pressure adjusting valve 213, to thereby stop supplying the air.

(S45) Then, the routine stops driving the cooling water pump 217.

Thereby, the routine stops generating the fuel cell stack 201, to thereafter move the fuel cell system 102 to the idle stop state.

In sum, the routine moving the fuel cell system 102 to the idle stop state stops the operation of the auxiliary units such as the hydrogen circulating pump 206 and the air compressor 212, thereby improving fuel economy, improving noise-vibration performance and decreasing power consumption.

(S305) Back to Fig. 4, when No at S302, the routine continues generating the fuel cell stack 201 instead of allowing the fuel cell system 102 to enter the idle stop state.

(S306) On the other hand, when Yes at S301, the routine determines whether or not the idle stop state is to be canceled (determination 1). The determination 1 determines whether or not the vehicle requires the fuel cell system 102 for a driving force.

(S307) When Yes at S306, the routine cancels the idle stop state and then starts generating the fuel cell stack 201, to thereby implement an ordinary generation control.

Fig. 6 shows a flow chart of operations for restarting the fuel cell system 102 from the idle stop state.

(S51) In Fig. 6, at first, the routine opens the hydrogen pressure adjusting valve 203, to thereby start supplying the hydrogen.

(S52) Then, the routine drives the cooling water pump 217.

(S53) Then, the routine drives the air compressor 212.

(S54) Then, the routine opens the air pressure adjusting valve 213, to thereby start supplying the air.

(S55) Then, the routine starts the generation, to thereby take out the power from the fuel cell stack 201. In addition, after restarting the generation, the routine opens the purge valve 210 to thereby aggressively exhaust impurities such as the nitrogen and the like.

Then, the routine returns to an ordinary purge control.

(S308) Back to Fig. 4 again, when No at S306, the routine determines whether or not the idle stop state is to be canceled (determination 2). The determine 2 determines whether or not the idle stop is to be canceled regardless of the vehicle's requirement for the driving force. For example, the routine determines whether or not the SOC of the secondary battery 207 is decreased to such an extent as to become lower than an idle stop state cancellation level which is preset through an experiment, study and the like.

(S309) When Yes at S308, the routine cancels the idle stop state to thereafter move the fuel cell system 102 to the idle state, thus controlling the generation in the idle state.

(S310) On the other hand, when No at S308, the routine continues the idle stop state.

For moving the fuel cell system 102 from the idle stop state to the idle state, a power generation quantity is to be controlled in the following manner:

With the fuel cell system 102 moved to the idle state and then starting the generation, the fuel cell stack 201 has a voltage less than or equal to a certain voltage (Vdp), specifically, less than or equal to a deterioration-promoting potential Vdp (for example, about 0.7 V) which promotes deterioration of the fuel cell stack 201.

In the above controlling of the power generation quantity, as shown in Fig. 7-(a), for the generation in the idle state after the idle stop state being canceled, the current I_{201} from the fuel cell stack 201 is so set as to allow the fuel cell stack 201 to have the voltage less than or equal to the deterioration-promoting potential Vdp, contrary to the ordinary idle state showing the voltage more than the deterioration-promoting potential Vdp. In other words, the current I_{201} taken out from the fuel cell stack 201 in the idle state after the idle stop state being canceled is, as shown in Fig. 7-(b), larger in quantity than the current I_{201} in the generation in the ordinary idle state in which the fuel cell stack 201 has the voltage more than the deterioration-promoting potential Vdp.

Specifically, the current I_{201} from the fuel cell stack 201 is set based on a voltage-current characteristic of the fuel cell stack 201 in Fig. 8. The voltage-current characteristic in Fig. 8 is set in advance through an experiment and the like according to the temperature of the fuel cell stack 201, and is memorized in the system controller 225. Therefore, the current I_{201} from the fuel cell stack 201 can be variably set according to the temperature of the fuel cell stack 201. As is seen in Fig. 8, the higher the temperature of the fuel cell stack 201 is, the more the current I_{201} is. Moreover, the taken-out current I_{201} causing the voltage of the fuel cell stack 201 to be less than or equal to the deterioration-promoting potential Vdp is feedbacked and is set according to the voltage of the fuel cell stack 201 based on the voltage-current characteristic in Fig. 8.

Moreover, in the idle state after the idle stop state being cancelled, an air quantity (oxidizing gas quantity) supplied to the fuel cell stack 201 is so rendered as not to increase according to the power generation quantity, that is, the taken-out current I_{201}. In other words, as shown in Fig. 10-(c), the above air quantity is like the one in the ordinary idle state, namely, the air quantity in the idle state other than the idle state after the idle stop being cancelled.

As shown in Fig. 10-(c), in the idle state after the idle stop state being cancelled, the rotary speed of the air compressor 212 is set as low as that in the ordinary idle state. In other words, the air stoichiometric ratio (supply flowrate/consumption flowrate) of the cathode is decreased within such an extent that a difference between the air pressure in the cathode and the hydrogen pressure in the anode is allowable, to thereby generate the power with decreased generation efficiency.

For generating the power with the cathode's stoichiometric ratio decreased, the current I_{201} from the fuel cell stack 201 is set based on a voltage-current characteristic of the fuel cell stack 201 shown in Fig. 9. The voltage-current characteristic in Fig. 9 is set in advance through an experiment and the like according to increase or decrease in the stoichiometric ratio of the cathode of the fuel cell stack 201, and is memorized in the system controller 225. Therefore, the current I_{201} from the fuel cell stack 201 can be variably set according to the stoichiometric ratio of the cathode. As is seen in Fig. 9, the less the stoichiometric ratio of the cathode is, the less the above current I_{201} is.

In sum, decreasing the stoichiometric ratio of the cathode can decrease the rotary speed of the air compressor 212 in the idle state, thereby preventing repetitions of calm states (the idle stop state) and noisy states (the idle state) of the air compressor 212, to thereby suppress deterioration of the noise-vibration performance. Moreover, decreasing the generation efficiency decreases the power generated in the idle state, thereby suppressing increase in the SOC of the secondary battery 107 when the secondary battery 107 is charged with the power through the above generation, to thereby increase the power generation quantity, that is, the taken-out current I_{201}.

Moreover, in the idle state after the idle stop being cancelled, an allowable SOC (in other words, upper limit of SOC) of the secondary battery 107 is to be set, for example, about 5% to 10% more than the one in the ordinary idle state. With this, the charge quantity to the secondary battery 107 is increased, thereby increasing the taken-out current I_{201}, leading to an increase in the power generation quantity. Moreover, in the idle state after the idle stop being cancelled, another idle stop state is highly probable thereafter. Therefore, when the SOC of the secondary battery 107 is high in the idle state, and then the fuel cell system 102 moves to the idle stop state in the above high-SOC idle state, the idle stop state can be maintained for a long time. Moreover, even when the idle stop state is cancelled with the SOC of the secondary battery 107 being high, the secondary battery 107 can be charged.

The embodiment of the present invention can be summarized below:

The operation according the embodiment is implemented in a state where the vehicle does not require the driving force. When the fuel cell system 102 moves from the idle stop state to the idle state to start the generation, increasing the current I_{201} (from the fuel cell stack 201) to more than the current I_{201} in the ordinary idle within such an extent as to keep the voltage of the fuel cell stack 201 less than or equal to the deterioration-promoting potential Vdp can prevent the deterioration of the fuel cell stack 201 from being promoted when the fuel cell system 102 moves to the idle state.

Moreover, increasing the taken-out current I_{201} to thereby increase the power generation quantity, and charging the secondary battery 107 with the thus generated power can rapidly increase the SOC of the secondary battery 107, thus preventing in a short time the charge quantity of the secondary battery 107 from being low immediately after the idle stop is cancelled.
With this, the fuel cell system 102 can be more often moved to the idle stop state.

The entire contents of Japanese Patent Application No. 2005-128274 with its filing date of April 26, 2005 in Japan are incorporated herein by reference.

Although the present invention has been described above by reference to a certain embodiment, the present invention is not limited to the embodiment described above. Modifications and variations of the embodiment described above will occur to those skilled in the art, in light of the above teachings.

INDUSTRIAL APPLICABILITY

Under the present invention, when the fuel cell system moves from the idle stop state to the idle state, setting the current I_{201} from the fuel cell stack in such a manner as to keep the voltage of the fuel cell stack less than or equal to the certain voltage, that is the deterioration-promoting potential, can eliminate the fuel cell stack's potential change between the idle stop state and the idle state, thereby preventing the deterioration of the fuel cell stack from being promoted both in the fuel cell system's periods of i) moving to the idle state and ii) in the idle state.

The scope of the present invention is defined with reference to the following claims.

CLAIMS

1. A fuel cell system for generating a power by an electrochemical reaction between a fuel gas and an oxidizing gas, the fuel cell system comprising:

1) a fuel cell stack for receiving the fuel gas and the oxidizing gas, the fuel cell system implementing the following operations:

i) when the power is required, supplying to the fuel cell stack the fuel gas and the oxidizing gas each having a quantity and a pressure which correspond to a current from the fuel cell stack, to thereby generate the power of the fuel cell stack, and

ii) when the power is not required, stopping the supplying of the fuel gas and the oxidizing gas to the fuel cell stack, to thereby stop the generating of the power of the fuel cell stack, leading to an idle stop state of the fuel cell system; and

2) a controller for controlling the current from the fuel cell stack such that the fuel cell stack has a voltage less than or equal to a certain voltage, the controlling being implemented when the idle stop state is cancelled and thereafter the fuel cell system moves to an idle state.

2. The fuel cell system as claimed in claim 1, wherein the current from the fuel cell stack is so set as to be varied according to a temperature of the fuel cell stack.

3. The fuel cell system as claimed in claim 2, wherein the higher the temperature of the fuel cell stack is, the more the current from the fuel cell stack is.

4. The fuel cell system as claimed in claim 1, wherein current from the fuel cell stack is feedbacked and set according to the voltage of the fuel cell stack.

5. The fuel cell system as claimed in claim 1, wherein the quantity of the oxidizing gas supplied to the fuel cell stack in the idle state after the idle stop state is:

free from being according to the current from the fuel cell stack, and

decreased within such an extent that a difference between the pressure of the oxidizing gas and the pressure of the fuel gas is allowable.

6. The fuel cell system as claimed in claim 1, wherein the current from the fuel cell stack is so set as to be varied according to a stoichiometric ratio of the oxidizing gas in a cathode of the fuel cell stack.

7. The fuel cell system as claimed in claim 6, wherein the less the stoichiometric ratio of the oxidizing gas in the cathode is, the less the current from the fuel cell stack is.

8. The fuel cell system as claimed in claim 1, further comprising:

a secondary battery charged with the power generated by the fuel cell system,

wherein a first upper limit of the power charged in the secondary battery through the power generation in the idle state after the idle stop state is so controlled as to be more than a second upper limit of the power charged in the secondary battery in a state other than the idle state after the idle stop state.

9. The fuel cell system as claimed in claim 8, wherein

the first upper limit is about 5% to 10% more than the second upper limit, and

the state defining the second upper limit is an ordinary state.

10. The fuel cell system as claimed in claim 1, wherein the certain voltage is about 0.7 V which promotes a deterioration of the fuel cell stack.

11. A method for generating a power by an electrochemical reaction between a fuel gas and an oxidizing gas, the method comprising:

1) when the power is required, supplying to a fuel cell stack the fuel gas and the oxidizing gas each having a quantity and a pressure which correspond to a current from the fuel cell stack, to thereby generate the power of the fuel cell stack;

2) when the power is not required, stopping the supplying of the fuel gas and the oxidizing gas to the fuel cell stack, to thereby stop the generating of the power of the fuel cell stack, leading to an idle stop state of the fuel cell system; and

3) controlling the current from the fuel cell stack such that the fuel cell stack has a voltage less than or equal to a certain voltage, the controlling being implemented when the idle stop state is cancelled and thereafter the fuel cell system moves to an idle state.

12. A fuel cell system for generating a power by an electrochemical reaction between a fuel gas and an oxidizing gas, the fuel cell system comprising:

1) means for receiving the fuel gas and the oxidizing gas, the fuel cell system implementing the following operations:

i) when the power is required, supplying to the receiving means the fuel gas and the oxidizing gas each having a quantity and a pressure which correspond to a current from the receiving means, to thereby generate the power of the receiving means, and

ii) when the power is not required, stopping the supplying of the fuel gas and the oxidizing gas to the receiving means, to thereby stop the generating of the power of the receiving means, leading to an idle stop state of the fuel cell system; and

2) means for controlling the current from the receiving means such that the receiving means has a voltage less than or equal to a certain voltage, the

controlling being implemented when the idle stop state is cancelled and thereafter the fuel cell system moves to an idle state.

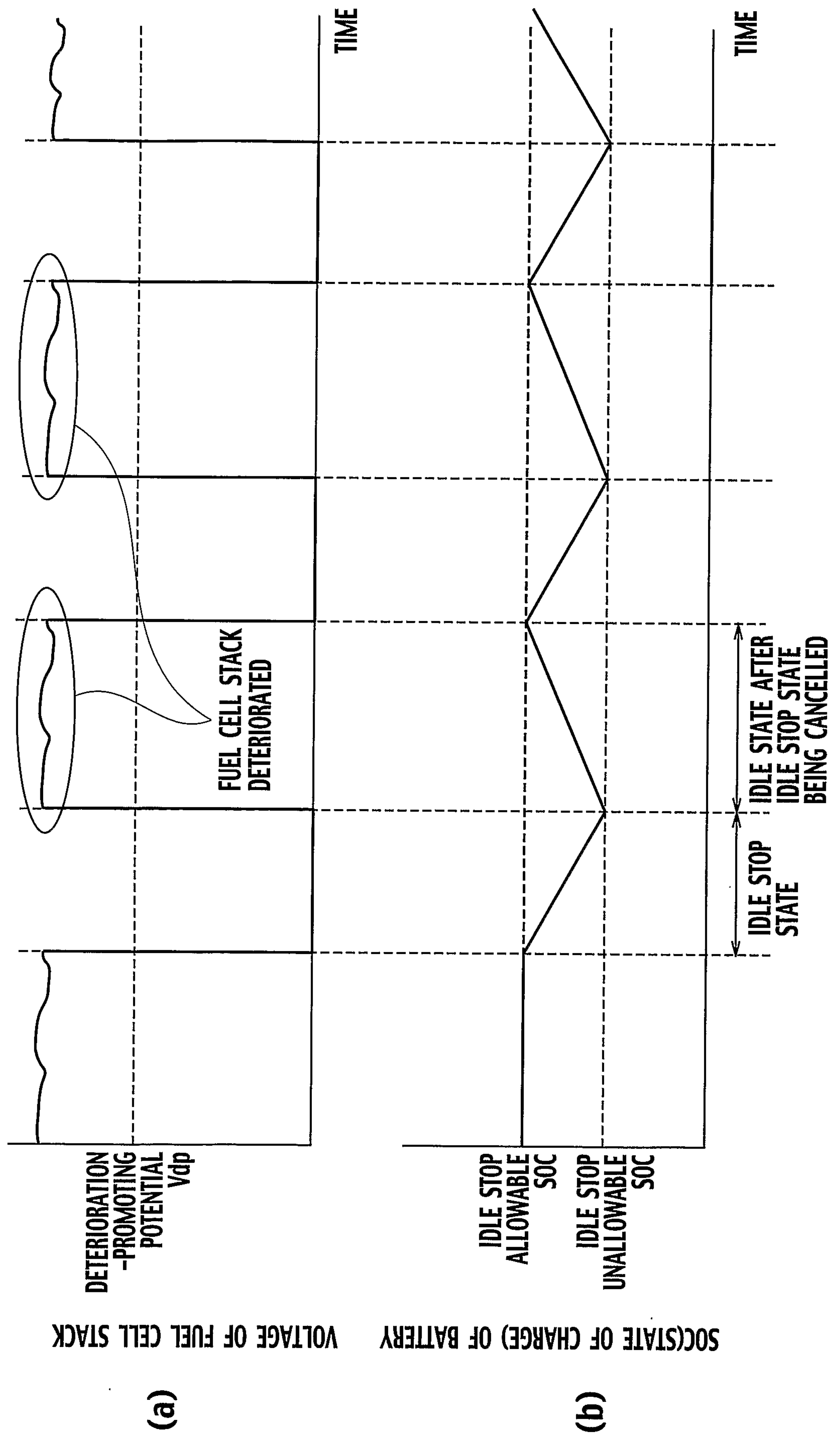


FIG. 1
RELATED ART

FIG. 2

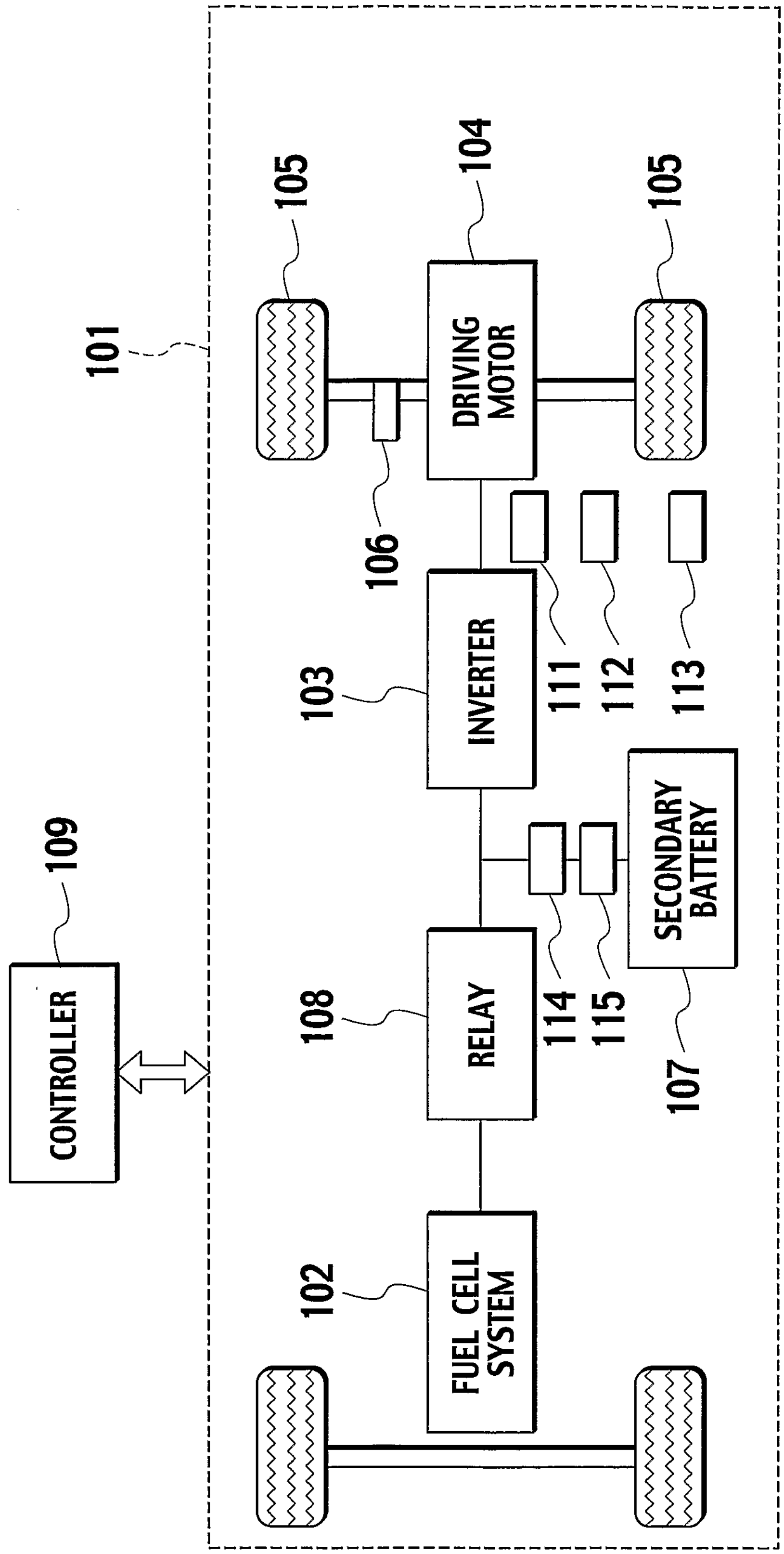

101
105
104
105
DRIVING MOTOR
106
111
112
113
INVERTER
103
SECONDARY BATTERY
109
CONTROLLER
108
RELAY
114
115
107
102
FUEL CELL SYSTEM

FIG. 3

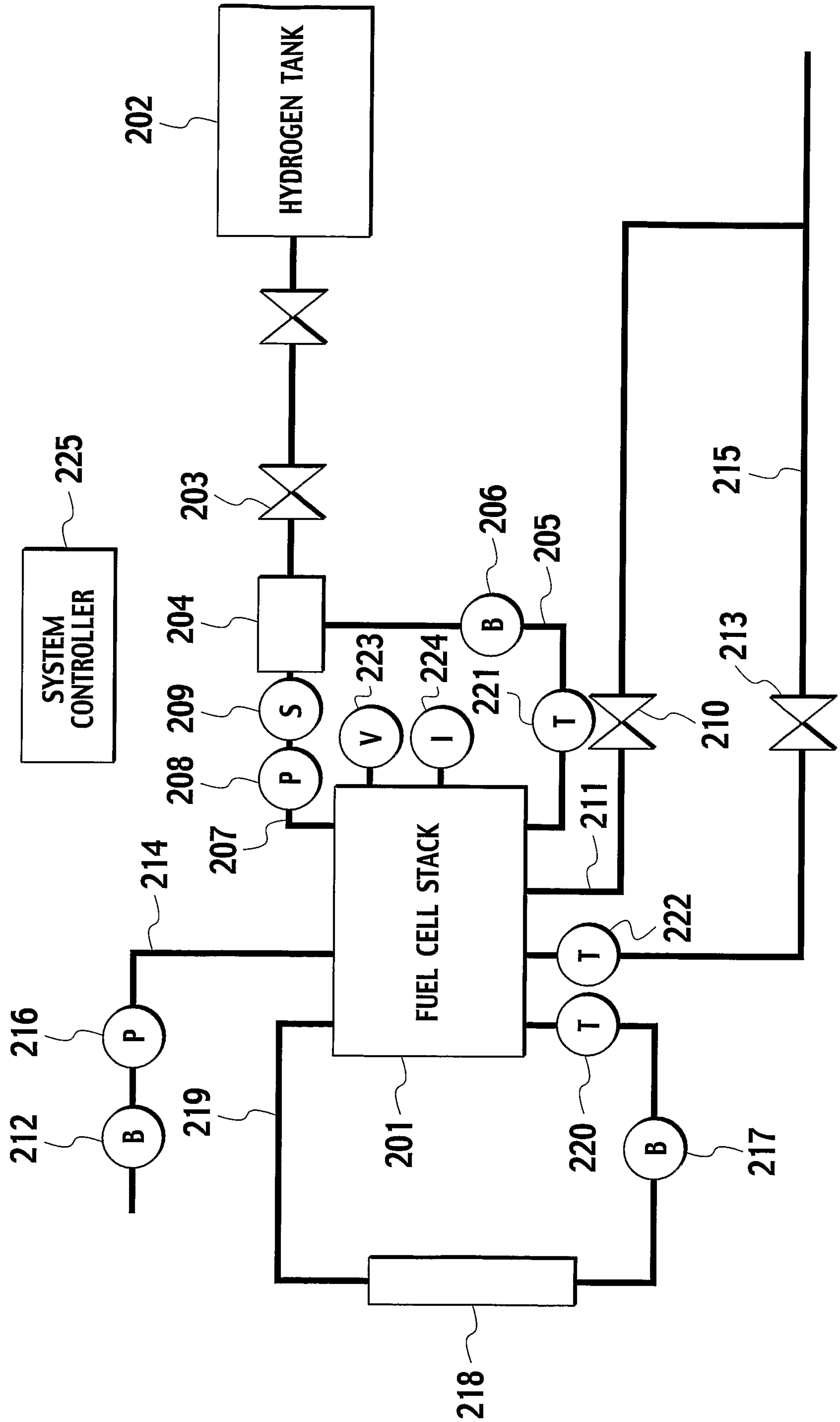

HYDROGEN TANK
202
SYSTEM CONTROLLER
225
FUEL CELL STACK
201
203
204
205
206
207
208
209
210
211
212
213
214
215
216
217
218
219
220
221
222
223
224
P
S
V
I
T
B

FIG. 4

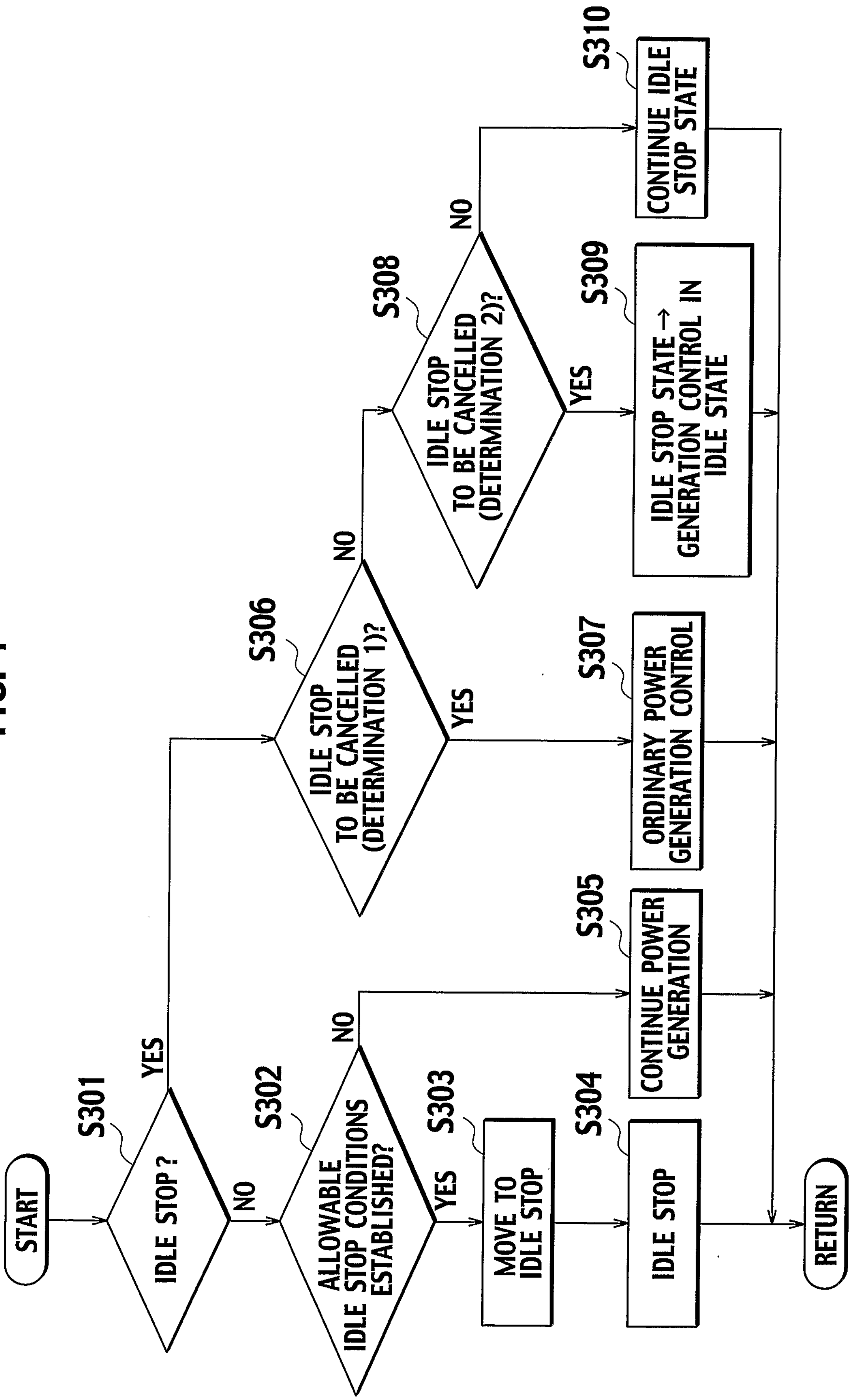

START
S301
IDLE STOP ?
YES
NO
S302
ALLOWABLE IDLE STOP CONDITIONS ESTABLISHED?
YES
NO
S303
MOVE TO IDLE STOP
S304
IDLE STOP
S305
CONTINUE POWER GENERATION
S306
IDLE STOP TO BE CANCELLED (DETERMINATION 1)?
YES
NO
S307
ORDINARY POWER GENERATION CONTROL
S308
IDLE STOP TO BE CANCELLED (DETERMINATION 2)?
YES
NO
S309
IDLE STOP STATE → GENERATION CONTROL IN IDLE STATE
S310
CONTINUE IDLE STOP STATE
RETURN

FIG. 5

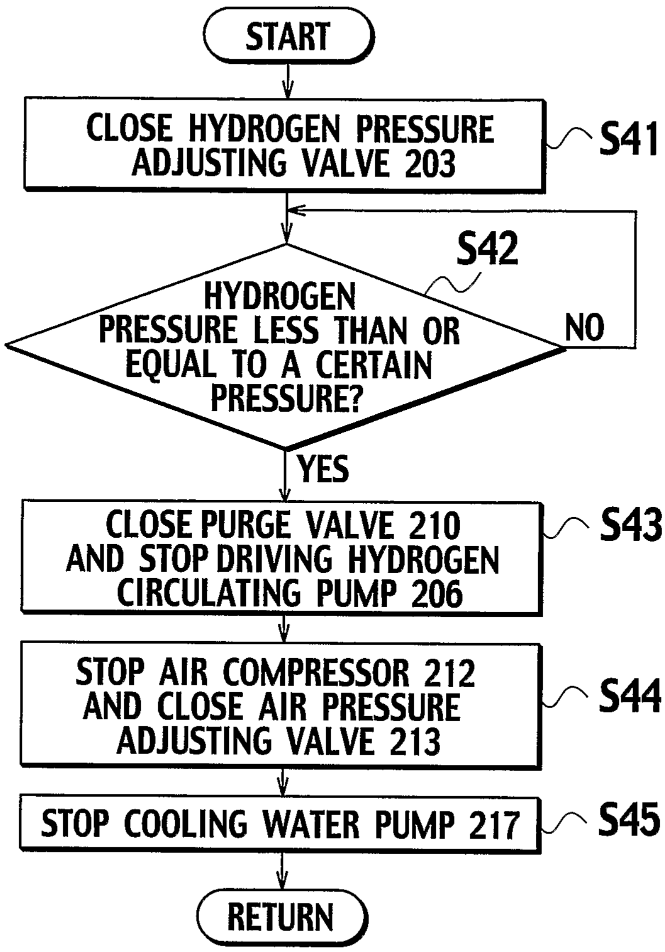

START
CLOSE HYDROGEN PRESSURE ADJUSTING VALVE 203
S41
S42
HYDROGEN PRESSURE LESS THAN OR EQUAL TO A CERTAIN PRESSURE?
NO
YES
CLOSE PURGE VALVE 210 AND STOP DRIVING HYDROGEN CIRCULATING PUMP 206
S43
STOP AIR COMPRESSOR 212 AND CLOSE AIR PRESSURE ADJUSTING VALVE 213
S44
STOP COOLING WATER PUMP 217
S45
RETURN

FIG. 6

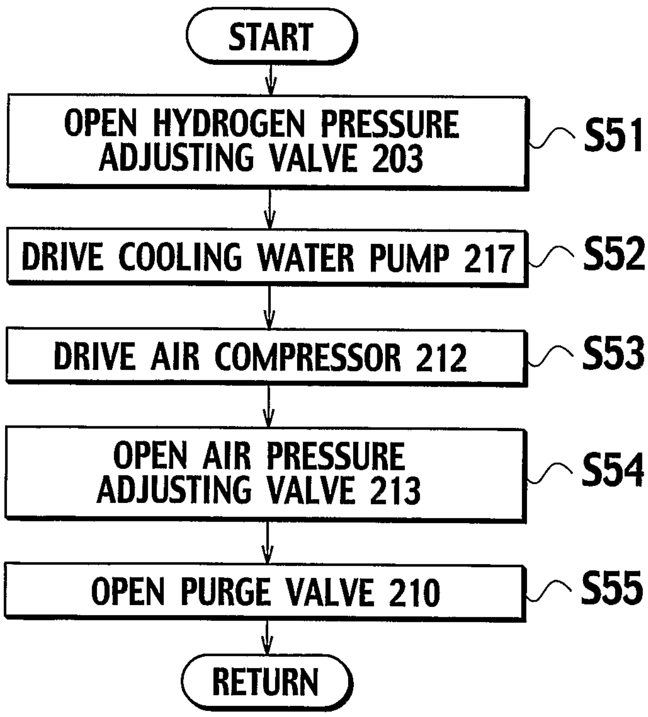
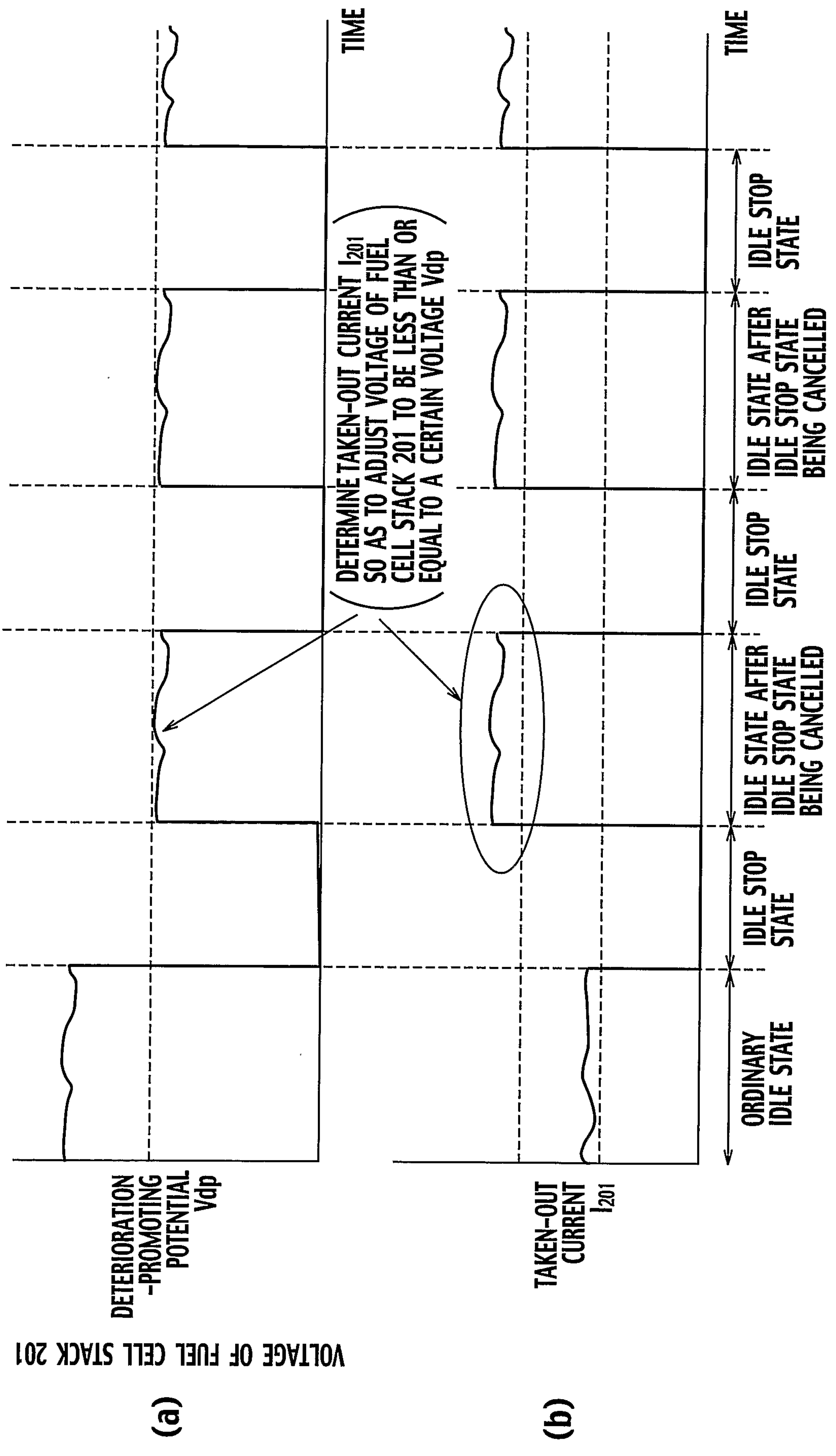

START
OPEN HYDROGEN PRESSURE ADJUSTING VALVE 203
S51
DRIVE COOLING WATER PUMP 217
S52
DRIVE AIR COMPRESSOR 212
S53
OPEN AIR PRESSURE ADJUSTING VALVE 213
S54
OPEN PURGE VALVE 210
S55
RETURN

FIG. 7



(a)
VOLTAGE OF FUEL CELL STACK 201
DETERIORATION -PROMOTING POTENTIAL Vdp
TIME
DETERMINE TAKEN-OUT CURRENT I201 SO AS TO ADJUST VOLTAGE OF FUEL CELL STACK 201 TO BE LESS THAN OR EQUAL TO A CERTAIN VOLTAGE Vdp
(b)
TAKEN-OUT CURRENT I201
TIME
ORDINARY IDLE STATE
IDLE STOP STATE
IDLE STATE AFTER IDLE STOP STATE BEING CANCELLED
IDLE STOP STATE
IDLE STATE AFTER IDLE STOP STATE BEING CANCELLED
IDLE STOP STATE

FIG. 8

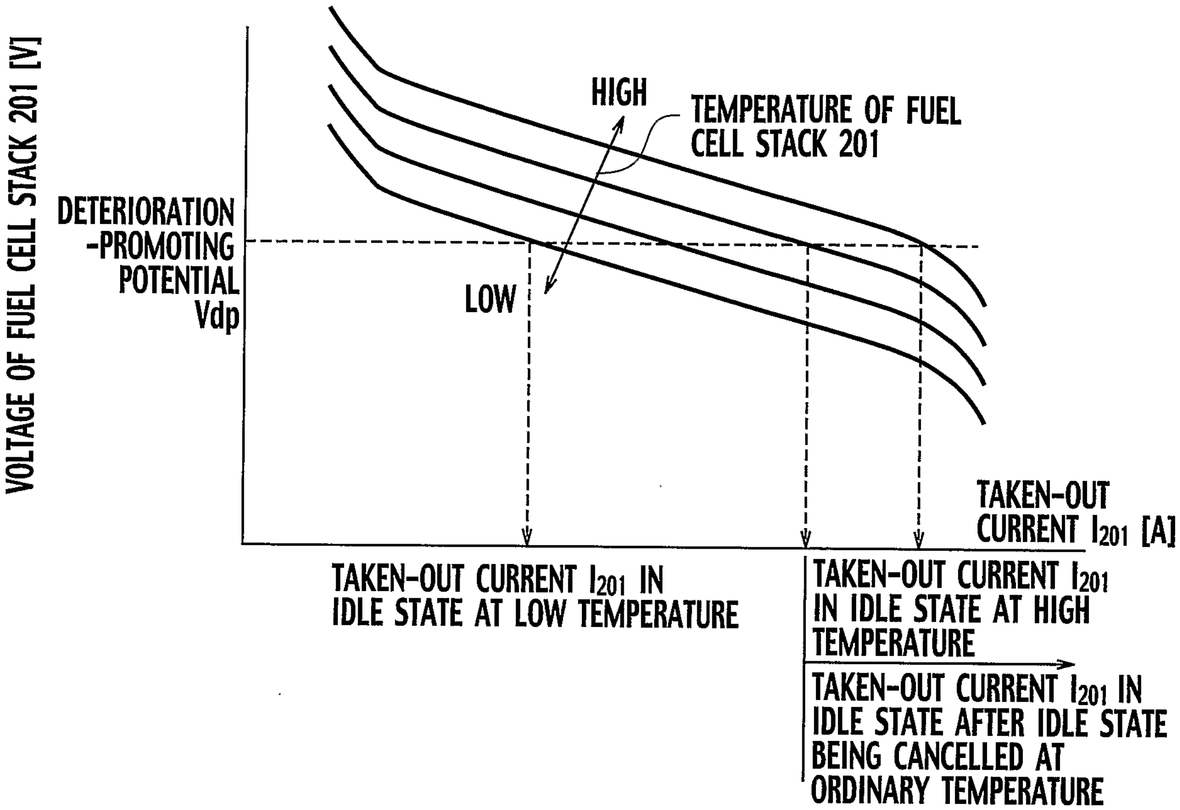

VOLTAGE OF FUEL CELL STACK 201 [V]
HIGH
TEMPERATURE OF FUEL CELL STACK 201
DETERIORATION -PROMOTING POTENTIAL Vdp
LOW
TAKEN-OUT CURRENT I201 [A]
TAKEN-OUT CURRENT I201 IN IDLE STATE AT LOW TEMPERATURE
TAKEN-OUT CURRENT I201 IN IDLE STATE AT HIGH TEMPERATURE
TAKEN-OUT CURRENT I201 IN IDLE STATE AFTER IDLE STATE BEING CANCELLED AT ORDINARY TEMPERATURE

FIG. 9

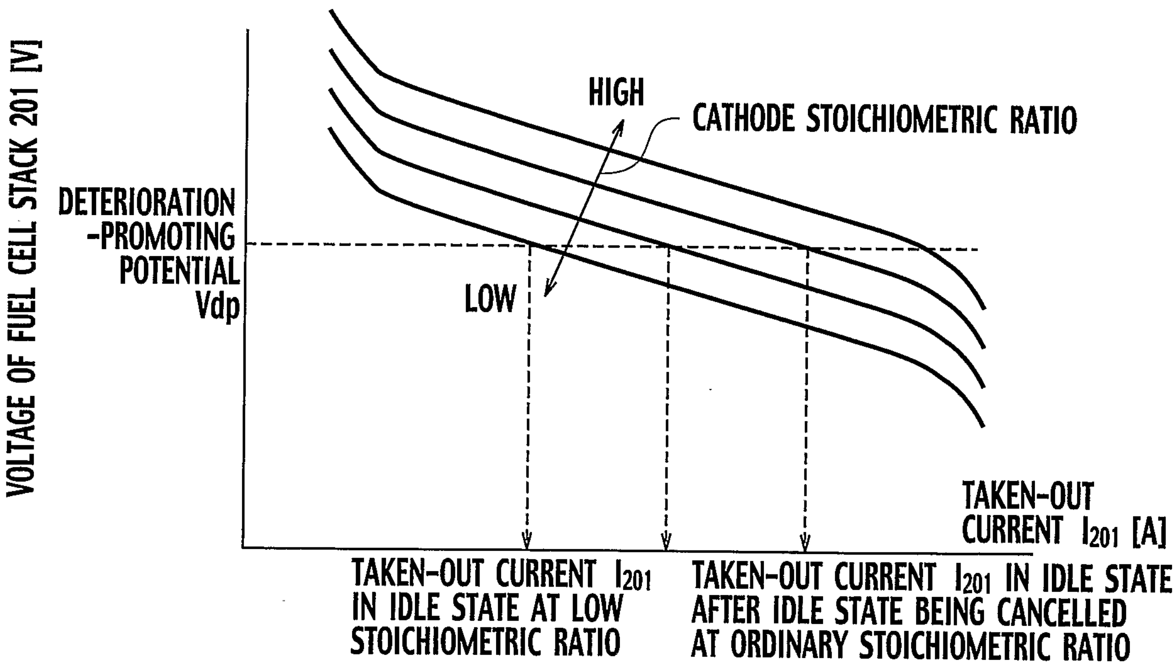
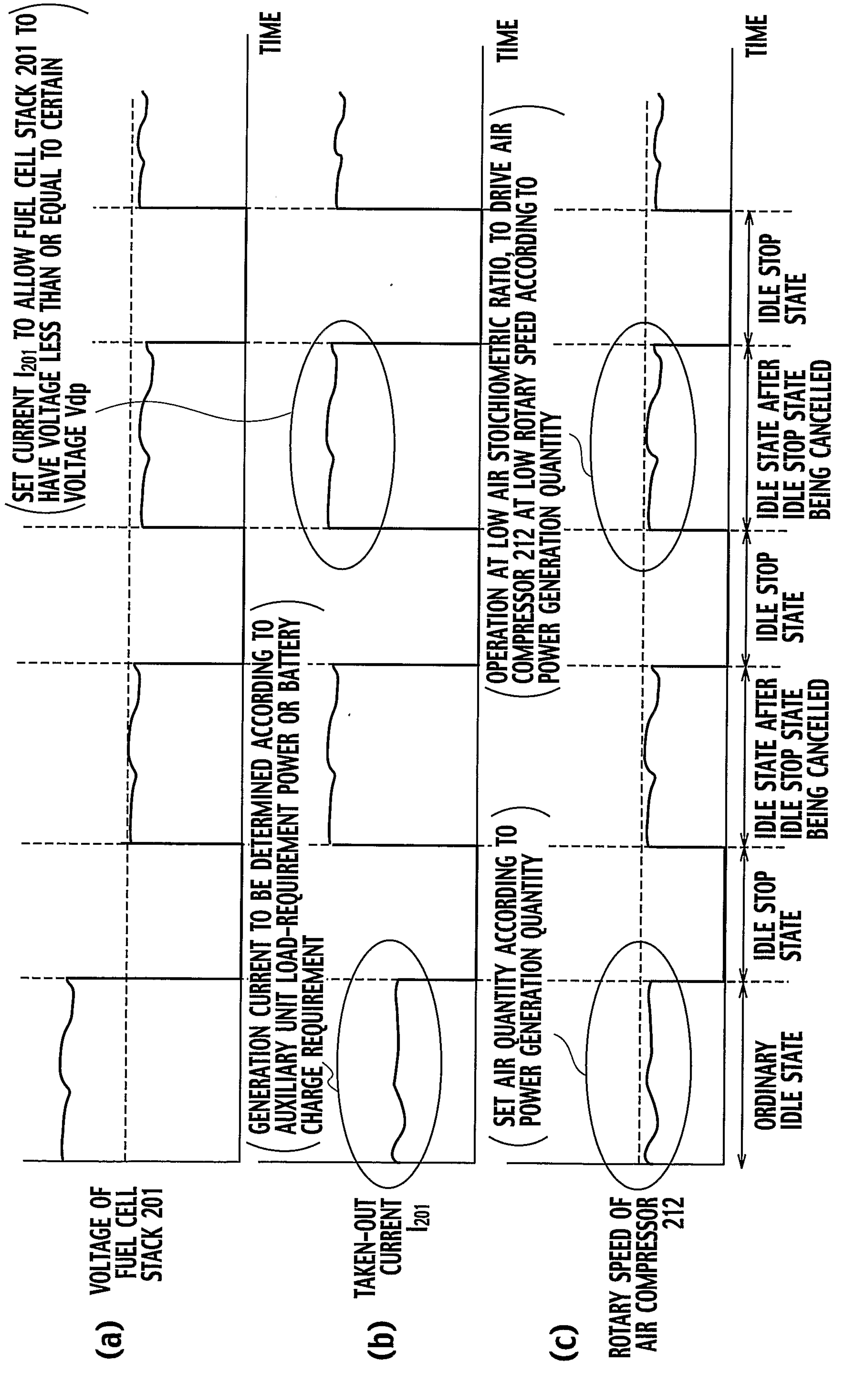

VOLTAGE OF FUEL CELL STACK 201 [V]
HIGH
CATHODE STOICHIOMETRIC RATIO
DETERIORATION -PROMOTING POTENTIAL Vdp
LOW
TAKEN-OUT CURRENT I201 [A]
TAKEN-OUT CURRENT I201 IN IDLE STATE AT LOW STOICHIOMETRIC RATIO
TAKEN-OUT CURRENT I201 IN IDLE STATE AFTER IDLE STATE BEING CANCELLED AT ORDINARY STOICHIOMETRIC RATIO

FIG. 10


(a) VOLTAGE OF FUEL CELL STACK 201
(b) TAKEN-OUT CURRENT I_{201}
(c) ROTARY SPEED OF AIR COMPRESSOR 212
TIME
TIME
TIME
(SET CURRENT I_{201} TO ALLOW FUEL CELL STACK 201 TO HAVE VOLTAGE LESS THAN OR EQUAL TO CERTAIN VOLTAGE Vdp)
(GENERATION CURRENT TO BE DETERMINED ACCORDING TO AUXILIARY UNIT LOAD-REQUIREMENT POWER OR BATTERY CHARGE REQUIREMENT)
(OPERATION AT LOW AIR STOICHIOMETRIC RATIO, TO DRIVE AIR COMPRESSOR 212 AT LOW ROTARY SPEED ACCORDING TO POWER GENERATION QUANTITY)
(SET AIR QUANTITY ACCORDING TO POWER GENERATION QUANTITY)
ORDINARY IDLE STATE
IDLE STOP STATE
IDLE STATE AFTER IDLE STOP STATE BEING CANCELLED
IDLE STOP STATE
IDLE STATE AFTER IDLE STOP STATE BEING CANCELLED
IDLE STOP STATE

INTERNATIONAL SEARCH REPORT

International application No
PCT/JP2006/307290

A. CLASSIFICATION OF SUBJECT MATTER
INV. H01M8/04
ADD. B60L11/18

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
H01M

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, PAJ, WPI Data, COMPENDEX, INSPEC

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 2004/202901 A1 (LOGAN VICTOR W ET AL) 14 October 2004 (2004-10-14) paragraph [0039] - paragraph [0042]	
A	PATENT ABSTRACTS OF JAPAN vol. 2003, no. 12, 5 December 2003 (2003-12-05) & JP 2004 014159 A (TOYOTA MOTOR CORP; EQUOS RESEARCH CO LTD), 15 January 2004 (2004-01-15) cited in the application abstract	
A	US 2004/137291 A1 (SMEDLEY STUART I ET AL) 15 July 2004 (2004-07-15) claims 49,50	

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents :

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
3 August 2006	10/08/2006

Name and mailing address of the ISA/	Authorized officer
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1

INTERNATIONAL SEARCH REPORT

nformation on patent family members

In tional application No
PCT/JP2006/307290

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2004202901 A1	14-10-2004	DE 102004017848 A1	11-11-2004
JP 2004014159 A	15-01-2004	NONE	
US 2004137291 A1	15-07-2004	NONE	