METHOD OF OPERATING A FUEL CELL APPARATUS

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] This is a divisional application of U.S. application Ser. No. 12/673,969 which is the U.S. National Stage application of PCT application PCT/JP2008/065047 filed on Aug. 22, 2008, which claims priority under 35 U.S.C. §119 to Japanese Patent Application No. 2007-222980 filed on Aug. 29, 2007, and the contents of each of these applications are incorporated herein by reference in their entirety.

FIELD OF THE INVENTION

[0002] The present invention relates to fuel cell apparatuses, and particularly to a method of operating a fuel cell apparatus.

BACKGROUND

[0003] Fuel cell apparatuses and their operation methods have recently been proposed for next-generation energy. Fuel cells can generate electric power, using a fuel gas (hydrogen-containing gas) and an oxygen-containing gas (normally air), and the fuel cell apparatus comprises the fuel cell and auxiliary devices operating the fuel cell within an enclosure. For example, a fuel cell apparatus has been proposed which comprises within a housing case a cell stack comprising a plurality of fuel cells electrically connected in series, a reforming portion comprising a reforming catalyst, disposed over the cell stack, and a vaporizing portion generating steam to be supplied to the reforming portion (for example, Japanese Unexamined Patent Application Publication No. 2007-59377).

[0004] In the start-up operation of such a fuel cell apparatus, it is necessary to increase the temperature of the reforming portion, which reforms a reforming target gas (raw fuel) and supplies the reformed fuel gas (hydrogen-containing gas) to the fuel cell, to a predetermined value. It is also necessary to increase the temperature of the fuel cells (cell stack) to a predetermined value. After the fuel cells (cell stack) reach the predetermined temperature, the start-up operation is terminated and the fuel cell is brought into a power-generating state.

[0005] It is known that the start-up operation of the reforming portion performs partial oxidation reforming (pox), autothermal reforming (ATR) and steam reforming (SR) in that order for producing hydrogen used for fuel cell power generation from a reforming target gas (raw fuel) such as natural gas (for example, Japanese Unexamined Patent Application Publication No. 2004-319420).

[0006] More specifically, for example, it has been proposed that: when the temperature of the reforming portion is low, the reforming reaction is performed by partial oxidation reforming; the reforming reaction is switched from the partial oxidation reforming to autothermal reforming according to the temperature of the reforming portion increased by the partial oxidation reforming; and when the temperature of the reforming portion (vaporizing portion) is further increased, the reforming reaction is switched from the autothermal reforming to steam reforming. Accordingly, the temperature of the fuel gas generated in the reforming portion is increased as the temperature of the reforming portion is increased. In addition, it has been proposed for the type of fuel cell apparatus disclosed in the above-cited Patent Document that the temperature of the reforming portion be increased by heat generated by burning unreacted gas (reforming target gas) and the fuel gas in one end side (reforming portion side) of the fuel cells.

[0007] The fuel gas and unreacted gas (reforming target gas) warmed in the reforming portion in the start-up operation is supplied to the fuel cell (cells), and the fuel cell is thus warmed by the warmed fuel gas. Also, the fuel cell (cells) is heated by combustion reaction of the fuel gas and unreacted gas (reforming target gas) supplied to the fuel cell (cells) with an oxygen-containing gas. The temperature of the fuel cell is thus increased. When the reforming portion and the fuel cell (cells) come to predetermined temperatures, the start-up operation of the fuel cell apparatus is completed and the fuel cell (cells) starts power generation.

[0008] Accompanying the operation of the fuel cell apparatus, it may be suspended in some cases, for example, for maintenance or with an event of failure. The period of operational suspension of the fuel cell apparatus may be over several minutes to several hours (or, in some cases, several days). After maintenance or repairing the failure, the fuel cell apparatus is restarted to operate.

[0009] Unfortunately, if the temperature of the reforming portion of a fuel cell apparatus controlled to perform reforming reaction in the order of partial oxidation reforming, autothermal reforming and steam reforming is a predetermined value or more when the fuel cell restarts, the reforming target gas (raw fuel) supplied to the reforming portion may be rapidly increased. Accordingly, carbon, a constituent of the reforming target gas, may be easily precipitated, and, consequently the fuel cells may deteriorate. In addition, ignition for burning the fuel gas and unreacted gas (reforming target gas) in one end side of the fuel cells may become difficult.

[0010] Also, if partial oxidation reforming is performed in the reforming portion having a predetermined temperature or more at the starting time of the fuel cell apparatus, the reforming portion may easily come to high temperature. Such a condition may easily cause the reforming catalyst to deteriorate and its lifetime to decrease.

SUMMARY OF THE INVENTION

[0011] Accordingly, an object of the present invention is to provide a method of operating a fuel cell apparatus in which the reforming reaction in the reforming portion can be controlled (changed) at the starting time of the apparatus according to the temperatures of the reforming portion and the vaporizing portion at the starting time of the apparatus so that the fuel cell apparatus can efficiently start while the reforming catalyst can be less likely to deteriorate.

[0012] A fuel cell apparatus of the present invention comprises a cell stack, a reforming portion, a vaporizing portion, a reforming target gas supply portion, an oxygen-containing gas supply portion, a water supply portion, and a controller. The cell stack comprises a plurality of fuel cells electrically connected in series in a housing case. The reforming portion is disposed over the cell stack and is to be exposed to a gas produced by burning a fuel gas from the fuel cells. The reforming portion comprises a reforming catalyst. The reforming catalyst can perform partial oxidation reforming, autothermal reforming and steam reforming as a reforming reaction. The vaporizing portion generates steam to be supplied to the reforming portion. The reforming target gas supply portion supplies a reforming target gas to the reforming portion. The oxygen-containing gas supply portion supplies