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FUEL CELL SYSTEM

Field of Invention

The present invention relates generally to a fuel cell. More specifically, the present invention relates to a modified fuel cell system capable of circulating gaseous fuel for thereby enhancing electricity or power generating efficiency thereof.

Background

A fuel cell is an electrochemical device that enables generation of electricity or power through oxidation of a fuel, which is also known as a reactant. Typically, the fuel introduced into the fuel cell gets oxidized at an anode within the fuel cell. Oxidation of the fuel produces protons and electrons. The electrons are generally harvested for production of electricity or power by an external circuit. The protons travel to a cathode and are utilized thereat for reduction of an oxidant. Reaction products, for example water, are produced by the reduction reaction at the cathode. The reaction products, together with unreacted or excess fuel, are typically removed from the fuel cell.

An exemplary fuel cell utilizes hydrogen gas as fuel, and is generally referred to as a hydrogen fuel cell. Hydrogen gas introduced into the hydrogen fuel cell is oxidized at the anode for production of electrons and protons. As previously mentioned, the electrons are generally harvested by the external circuit for generating electricity or power. The protons travel to the cathode for reducing oxygen gas, which is supplied thereto. The reduction reaction at the cathode produces water as the reaction product. The water produced, together with unreacted or excess hydrogen gas, is removed as a mixture from the fuel cell.

Government and private or commercial interest in fuel cells as a source of alternative energy has significantly increased recently, especially in the wake of surging prices of more conventional fuels such as oil and gas. High volatility in oil prices has also contributed to the heightened urgency for diversifying energy resources and has consequently led to an increased focus on fuel cells.

Fuel cells are generally considered to be energy efficient and of low pollutant emissions. Heightened global awareness of environmental issues such as global warming and

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climate change has also catalyzed a drive for use of fuel cells for the generation of clean and sustainable energy. As such, fuel cells are increasingly considered by governments to be a highly viable and attractive option for enhancing national energy security and as an economic opportunity.

The fuel cell is theoretically capable of continuous generation of energy as long as there exists a continuous supply or introduction of fuel into, and removal of reaction products from, the fuel cell. Unlike closed energy generation systems such as batteries, fuel cells generally require continuous supply of fuel for their operation.

Generally, increasing the electricity or power generating capacity of fuel cells causes a decrease in efficiency thereof. The efficiency of hydrogen fuel cells is also typically adversely affected by incomplete oxidation of the hydrogen gas introduced into the fuel cell. The decrease in efficiency of hydrogen fuel cells is further caused by a need for humidifying the hydrogen gas and for pressurization of the hydrogen gas.

Another main disadvantage or drawback to the use of fuel cells is a relatively high cost involved. Most fuel cell systems are generally not considered to be cost-effective in comparison with existing fuel sources such as oil and gas. Generally, the electricity or power generated by fuel cells has not been considered capable of reliably and independently supporting large-scale energy consumers, such as relatively large office buildings or factories.

It will therefore be appreciated by a person skilled in the art that improvements to fuel cells or fuel cell systems is required for facilitating sustainable large-scale take-up of fuel cells for the generation of electricity or power. More specifically, such improvements to fuel cells or fuel cell systems should enhance the efficiency of electricity or power generation as well as increase the cost-effectiveness of the use thereof. Increasing reliance on alternative sources of energy, such as fuel cells, will significantly enhance national energy security in a climate of rising and volatile oil prices.

Summary

In accordance with a first aspect of the present invention, there is disclosed a system comprising a fuel cell end plate for receiving gaseous fuel, the fuel cell end plate

mediating introduction of received gaseous fuel into a fuel cell. The gaseous fuel introduced into the fuel cell is one of utilized for producing water therewithin and unutilized for removal therefrom, the gaseous fuel being removed from the fuel cell in a mixture with the water produced. The system further comprises a separator for receiving the mixture being removed from the fuel cell, the mixture separating into the gaseous fuel and water within the separator. The system also comprises a control system operable for determining volume of water accumulating within the separator and controlling discharge of water from the separator based on determined volume of water accumulating within the separator. The discharge of water from the separator is initiated in response to the volume of the water accumulating within the separator reaching a predetermined reference magnitude.

In accordance with a second aspect of the present invention, there is disclosed a method comprising separating gaseous fuel and water from a mixture within a separator and accumulating the water within the separator. The method further comprises determining volume of water accumulating within the separator by a control system and controlling discharge of water from the separator based on the determined volume of water accumulating therein. The discharge of water from the separator is initiated in response to the volume of the water accumulating within the separator reaching a predetermined reference magnitude.

Brief Description of the Drawings

FIG. 1 shows a schematic overview of an exemplary fuel cell system as provided by the present invention;

FIG. 2 shows a partial front elevation of a fuel cell end plate of the exemplary fuel cell system of FIG.1;

FIG. 3 shows a partial isometric view of the fuel cell end plate of FIG. 2;

FIG. 4 shows a cross-sectional view of a separator used with the exemplary fuel cell system of FIG. 1;

FIG. 5 shows a partial isometric view of the separator of FIG. 4;

FIG. 6 shows a system flow diagram of the exemplary fuel cell system of FIG. 1;

FIG. 7 is a process flow diagram of an exemplary method for circulating gaseous fuel performable by the exemplary fuel cell system of FIG. 1; and

FIG. 8 is a process flow diagram of an exemplary cycle of operation of the separator of FIG. 4.

Detailed Description

A fuel cell is an electrochemical device for facilitating generation of electricity or power. Fuel cells are increasingly important as an alternative source of energy, especially in light of surging oil prices and heightened global awareness of environmental issues such as global warming. Efficiency of fuel cells is generally adversely affected by incomplete fuel utilization, more specifically fuel oxidation, within the fuel cells. A need for humidifying of gaseous fuel such as hydrogen gas also decreases the efficiency of the fuel cell. It will be appreciated by a person skilled in the art that enhancing the efficiency of fuel cells will be important for promoting and sustaining large-scale utilization of fuel cells as a viable and attractive source of alternative energy.

For purposes of brevity and clarity, the description of the present invention is limited hereinafter to applications relating to a fuel cell system utilizing hydrogen gas as fuel. The fuel cell system enables recirculation of gaseous fuel for enhancing electricity or power generating efficiency thereof. A method for circulation of gaseous fuel is also provided by the present invention. This however does not preclude various embodiments of the present invention from other applications where fundamental principles prevalent among the various embodiments of the invention such as operational, functional or performance characteristics are required.

An exemplary system 20 for circulating gaseous fuel is provided according to an exemplary embodiment of the present invention. A schematic overview of the exemplary system 20 is shown in FIG. 1. Preferably, the gaseous fuel is hydrogen gas. It is known in the art of fuel cell science that hydrogen gas is replaceable with other forms of gaseous fuel.

The system 20 comprises a number of different components or elements. Preferably, the components include, but are not limited to, an inlet 22, a fuel cell end plate 24, an outlet 26, a separator 28 and a recirculation duct 30.

The inlet 22 is couplable or connectable to the fuel cell end plate 24. The fuel cell end plate 24 is a key component of a fuel cell 32 or fuel cell system. Hydrogen gas is introduced into the fuel cell end plate 24 via the inlet 22 that is coupled thereto. The fuel cell end plate 24 mediates consequent introduction or entry of hydrogen gas into the fuel cell 32. Preferably, the hydrogen gas is supplied from a hydrogen tank 34 or a hydrogen container to which the inlet 22 is coupled or connected. The inlet 22 therefore intercouples or interconnects the hydrogen tank 34 and the fuel cell end plate 24. Preferably, a shut-off valve 36 or regulation mechanism is coupled to the inlet 22 for controlling or regulating the introduction of hydrogen gas into the fuel cell end plate 24, and consequently into the fuel cell 32.

The fuel cell 32 comprises electrodes, more specifically an anode and a cathode. Hydrogen gas introduced into the fuel cell 32 via the inlet 22 and the fuel cell end plate 24 is oxidized at the anode. Oxidation of hydrogen gas at the anode produces electrons and protons. The electrons produced are generally harvested by an external circuit for generating electricity or power. The protons produced typically travel to the cathode. At the cathode, protons are utilized for reducing an oxidant that is supplied thereto. The oxidant supplied to the cathode is preferably oxygen gas. The oxygen gas reacts or combines with the protons. More specifically the oxygen gas is reduced by the protons to produce water as a reaction product. The water being produced at the cathode accumulates over time. The accumulation of water at the cathode causes flow or transfer of water from the cathode to the anode.

Generally, the hydrogen gas introduced into the fuel cell 32 is not fully utilized or oxidized at the anode. The unutilized hydrogen gas is hereinafter referred to as excess hydrogen gas. The excess hydrogen gas typically dissolves or mixes with the water, which is transferred from the cathode to the anode, to form a mixture (the mixture also known as a liquid-gas mixture). In other words, the excess hydrogen gas and the water produced in the fuel cell 32 are removed therefrom as the mixture or liquid-gas mixture.

Preferably, the mixture is removed from the fuel cell 32 via the outlet 26, which is coupled or connected to the fuel cell end plate 24.

It will be apparent that the fuel cell end plate 24 is preferably designed and structured for coupling or connecting with the inlet 22 and the outlet 26. The fuel cell end plate 24 preferably comprises a number of openings or fittings to which the inlet 22 and the outlet 26 can be securely coupled or connected to. Preferably, the fuel cell end plate 24 comprises a first opening 38 for coupling to the inlet, and a second opening 40 for coupling to the outlet. Further preferably, the first opening 38 and the second opening 40 are specifically shaped and dimensioned for facilitating secure and substantially airtight coupling with the inlet 22 and the outlet 26 respectively.

Preferably, the outlet 26 intercouples or interconnects the fuel cell end plate 24 to the separator 28. More specifically, the outlet 26 facilitates fluid communication between the fuel cell end plate 24 and the separator 28. Preferably, the mixture formed within the fuel cell 32 is removed from the fuel cell 32 via the outlet 26. Further preferably, the mixture is transferred from the fuel cell 32 to the separator 28 via the outlet 26.

The outlet 26 is preferably connected to a first valve 42. The first valve 42 preferably controls or regulates the removal of the mixture from the fuel cell 32. Further preferably, the first valve 42 controls or regulates transfer of the mixture from the fuel cell 32 to the separator 28. The first valve 42 is preferably operable between an open state and a closed state for respectively opening and closing the outlet 26 to thereby facilitate and impede removal and transfer of the mixture from the fuel cell 32 to the separator 28 respectively.

Preferably, the outlet 26 for transferring the mixture from the fuel cell 32 into the separator terminates within the separator at a terminal end 44. The mixture transferred from the fuel cell 32 into the separator 28 is separated within the separator 28 into the hydrogen gas and the water. Therefore, increased transfer of mixture from the fuel cell 32 into the separator 28 facilitates accumulation of water within the separator 28. Increasing transfer of mixture from the fuel cell 32 into the separator 28 therefore increases volume of water (also known as accumulated water) within the separator 28. Hydrogen gas

separated from the mixture also accumulates within the separator 28 and can be referred to as accumulated hydrogen gas or accumulated gas.

The volume of water accumulating within the separator 28 is reflected by a level of the water within the separator 28. The separator 28 is preferably in signal communication with a control system (not shown). The control system preferably determines volume of water stored within the separator 28. In other words, the control system preferably detects the level of water within the separator 28. Further preferably, the control system controls discharge of at least one of water and hydrogen gas from the separator 28. The control system preferably controls the discharge of at least one of water and hydrogen gas from the separator 28 based on or with reference to the volume of water within the separator 28.

The control system preferably comprises a float switch 46. The float switch 46 is preferably located within, or is coupled to, the separator 28. Preferably, the separator 28 establishes and maintains signal communication with the control system via the float switch 46. The float switch 46 preferably senses or detects the level of water within the separator 28. Correspondingly, the float switch 46 senses or detects the volume of water within the separator 28. Alternatively, the separator 28 comprises a capacitive sensor for sensing or detecting the volume of water within the separator 28. Further alternatively, the separator 28 comprises sensors utilizing alternative elements or properties, such as light, for sensing or detecting the volume of water within the separator 28. The sensors are preferably in signal communication with the control system. Alternatively, the sensors may be components of the control system.

The float switch 46 is coupled to a water removal duct 48, also known as a drainage duct. The water removal duct 48 facilitates removal of water from the separator 28. The water removal duct 48 is preferably positioned at a side of the separator 28. Further preferably, the water removal duct 48 is positioned at the side of the separator 28 at a predetermined distance from the base of the separator 28. Alternatively, the position of the water removal duct 48 can be varied as required.

Preferably, the water removal duct 48 is positioned at a level higher than the terminal end 44 of outlet 26 during normal operation or use of the system 20. Accordingly, the level of

water within the separator 28 is maintained above the terminal end 44 of the outlet 26, such that the terminal end 44 of the outlet 26 remains constantly submerged in the water accumulating within the separator 28.

The constant submergence of the terminal end 44 of the outlet 26 in the water within the separator 28 ensures that the excess hydrogen gas of the mixture transferred from the fuel cell 32 to the separator 28 passes through the water within the separator 28 before being separated from the mixture. The passage of excess hydrogen gas through the water within the separator 28 facilitates humidification of, or moisture retention in, the excess hydrogen gas when it is separated from the mixture.

As mentioned above, the float switch 46 is coupled to the water removal duct 48. More specifically, the float switch 46 is coupled or in signal communication with a drainage valve 50 that is integrated with or coupled to the water removal duct 48. Preferably, the operation of the float switch 46 controls the removal or discharge of water from the separator 28. In other words, the control system preferably controls the removal of water from the separator 28. More specifically, the operation of the float switch 46 controls activation and inactivation of the drainage valve 50 to thereby respectively open and close the water removal duct 48. Correspondingly, the activation and inactivation of the drainage valve 50 respectively facilitates and impedes removal of water from the separator 28.

The operation of the float switch 46 for controlling the removal of water from the separator 28 preferably depends on the level of water accumulating within the separator 28 as detected by the float switch 46. For example, the float switch 46 preferably causes the activation of the drainage valve 50 upon detection of a first predetermined volume or level of water accumulated within the separator 28. In addition, the float switch 46 preferably causes the inactivation of the drainage valve 50 water upon detection of a second predetermined volume or level of water accumulated within the separator 28. Preferably, the first predetermined volume or level of water is higher than the second predetermined volume of level of water.

The fuel cell end plate 24 and the separator 28 are preferably interconfigured for circulating or conveying the excess hydrogen gas from the separator 28 into the inlet 22.

For example, the system 20 comprises the recirculation duct 30 for interconnecting or intercoupling the separator 28 to the inlet 22. More specifically, the recirculation duct 30 provides a channel for facilitating fluid communication between the separator 28 and the inlet 22. The channel preferably facilitates transfer or circulation of the excess hydrogen gas from the separator 28 into the inlet 22. The excess hydrogen gas transferred or circulated into the inlet 22 is preferably reintroduced into the fuel cell end plate 24 for consequent reintroduction into the fuel cell 32.

As previously described, the excess hydrogen gas being reintroduced into the fuel cell 32 is preferably humidified or contains a level of moisture. The moisture contained within the excess hydrogen gas being reintroduced into the fuel cell 32 facilitates enhancement of the electricity generation efficiency of the fuel cell 32. More specifically, the moisture contained within the excess hydrogen gas being reintroduced into the fuel cell 32 facilitates prevention of unwanted drying of the anode, especially at point of entry of the excess hydrogen gas thereinto.

The reintroduction of excess hydrogen gas into the fuel cell 32 provides another opportunity for the oxidization of hydrogen gas at the anode of the fuel cell 32. It will be appreciated by a person skilled in the art that the ability for circulating excess hydrogen gas initially removed from the fuel cell 32 for reintroduction thereinto helps to prevent wastage of the excess hydrogen gas. Therefore, the system 20 provided by the present invention facilitates enhancement of electricity or power generating efficiency of the fuel cell 32 used therewith.

A pump 52 is preferably coupled or connected to the recirculation duct 30. Preferably, operation of the pump 52 causes or effects the transfer or circulation of the excess hydrogen gas from the separator 28 to the inlet 22. In addition, the operation of the pump 52 preferably facilitates creation and maintenance of a vacuum above the level of water accumulating within the separator 28.

Preferably, the vacuum created by the operation of the pump 52 facilitates removal of water, which is mixed with the excess hydrogen gas, from the fuel cell 32. Preferably, the removal of water from the fuel cell 32 enhances the electricity or power generation efficiency of the fuel cell 32. In addition, the vacuum created by the operation of the

pump 52 preferably helps to pressurize the excess hydrogen gas being circulated into the inlet 22 for reintroduction into the fuel cell end plate 24, and consequently into the fuel cell 32. The ability of the system 20 to pressurize the excess hydrogen gas thereby facilitates enhancement of the electricity or power generating efficiency of the fuel cell 32 used with the system 20.

Preferably, the control system further comprises a controller 54. Preferably, the controller 54 is programmable for controlling operative communication of the control system. Preferably, the controller 54 is in signal communication with the float switch 46 for controlling the operation of the float switch 46. The controller 54 is preferably in signal communication with each of the first valve 42, the float switch 46 and the pump 52. Alternatively, the controller 54 is in signal communication with at least one of the first valve 42, the float switch 46 and the pump 52. The controller 54 preferably controls or regulates the operation of the first valve 42, the float switch 46 and the pump 52. Further preferably, the controller 54 controls the operation of each of the first valve 42, the float switch 46 and the pump 52 with reference to each another.

As previously mentioned, the float switch 46 detects the level of water accumulating within the separator 28. The level of water detected is preferably communicated to the controller 54. The controller 54 is preferably capable of at least one of storage, processing and further communicating received information. Preferably, the controller 54 controls the operation of the first valve 42 and the pump 52 with reference to the received information, more specifically the received level of water within the separator 28 as detected by the float switch 46. Therefore, the controller 54 preferably enables an integration of, or correlation between, the operation of each of the first valve 42, the float switch 46 and the pump 52.

The integration of the operation of each of the first valve 42, the float switch 46 and the pump 52 preferably increases the hydrogen circulation efficiency of the system 20. In addition, the integration of the operation of each of the first valve 42, the float switch 46 and the pump 52 preferably facilitates enhancement of the electricity or power generation efficiency and cost-effectiveness of the fuel cell 32.

In summary, the system 20 enables circulation of excess hydrogen gas for facilitating a more complete or efficient utilization or oxidation of supplied hydrogen gas. It will be appreciated by a person skilled in the art that increasing the efficiency of hydrogen gas (gaseous fuel) utilization enhances the electricity or power generating efficiency of the fuel cell 32. Enhancement of the electricity or power generating efficiency of the fuel cell 32 thereby increases cost-effectiveness of the fuel cells 32 used with the system 20 and hence helps to promote and sustain the use of fuel cells 32 as a viable and attractive alternative source of energy.

An exemplary method 100 for circulating a gaseous fuel is also provided by the present invention. A process flow diagram of the method 100 is shown in FIG. 7. Preferably, the exemplary method 100 is performed by the system 20. The gaseous fuel is preferably hydrogen gas. As previously mentioned, it is known in the art of fuel cell science that hydrogen gas can be replaced with other types of gaseous fuels.

In a step 110, hydrogen gas is supplied or provided. Preferably, the hydrogen gas is supplied in a tank 46 or a container. The hydrogen gas is then introduced into the fuel cell 32 in a step 120. Preferably, the hydrogen gas is introduced into the fuel cell 32 via the inlet 22 and the fuel cell end plate 24. As previously mentioned, inlet 22 intercouples the hydrogen tank 34 and the fuel cell end plate 24. The fuel cell end plate 24 that is coupled to the inlet 22 is preferably an end plate of the fuel cell 32. Alternatively, the fuel cell end plate 24 is a bipolar plate of the fuel cell 32.

As previously described, the hydrogen gas is oxidized at the anode of the fuel cell 32 for production of electrons and protons. The electrons are harvested by the external circuit for generating electricity or power. The protons are transferred to the cathode for reducing the oxidant, more specifically oxygen gas, supplied thereto. Reduction of oxygen gas at the cathode results in production of water as the reaction product in a step 130.

The hydrogen gas introduced into the fuel cell in the step 120 is typically not totally utilized or oxidized. The unutilized hydrogen gas is referred to as excess hydrogen. In a step 140, the excess hydrogen gas dissolves in or is mixed with the water produced to form the mixture of water and excess hydrogen gas.

The mixture is removed from the fuel cell 32 and transferred to the separator 28 in a step 150. Preferably, the mixture is removed from the fuel cell 32 via the fuel cell end plate 24. The mixture is transferred from the fuel cell end plate 24 into and the separator 28 via the outlet 26. The operation of the first valve 42, which is coupled to the outlet 26, controls or regulates the removal and transfer of the mixture from the fuel cell 32 to the separator 28. More specifically, the first valve 42 is operable between an open state and a closed state for respectively opening and closing the outlet 26 to thereby respectively facilitate and impede the step 150.

As previously mentioned, the fuel cell end plate 24 is preferably specifically designed and constructed for facilitating secure and airtight coupling with the inlet 22 and the outlet 26. The secure and airtight coupling of the inlet 22 and the outlet 26 with the fuel cell end plate 24 helps prevent unwanted leakage of hydrogen gas from the system 20, especially during the method 100. The prevention of leakage of hydrogen gas from the system 20 thereby helps to increase electricity or power generation efficiency and cost-effectiveness of the fuel cell 32 used with the system 20.

Entry of the mixture into the separator 28 stimulates a cycle or process of operation 200 of the separator 28 in a step 160. A process flow diagram of the cycle of operation 200 of the separator 28 is shown in FIG. 8.

As previously described, the mixture entering the separator 28 comprises excess hydrogen gas and water. In a step 210 of the cycle of operation 200, the mixture entering the separator 28 is separated into the excess hydrogen gas and water. Preferably, water is retained at the base of the separator 28 while the excess hydrogen gas moves to a space above the level of the water within the separator 28. Separation of the mixture into the excess hydrogen gas and water thereby facilitates accumulation of water (also known as accumulated water) within the separator 28 in a step 220. Increasing volume of water accumulating within the separator 28 is reflected by corresponding increase in level of water within the separator 28. Excess hydrogen gas separated from the mixture also accumulates within the separator 28 and can be referred to as accumulated gas.

As previously described, the control system, and more specifically the float switch 46 or sensor, senses or detects the volume or level of water accumulating within the separator 28. The float switch 46 is preferably coupled or in signal communication with the drainage valve 50 for controlling the opening and closing of the water removal duct 48. Preferably, the drainage valve 50 is at the inactivated state during start of normal operation of the system 20. Accordingly, the water removal duct 48 is closed for facilitating water accumulation within the separator 28 (i.e. for impeding water drainage or removal from the separator 28).

In a step 230, the float switch 46 is actuated to an "on" (also known as an "active") state. Preferably, the step 230 occurs when the float switch 46 detects the first predetermined level of water within the separator 28. The first predetermined level of water can be adjusted as required.

When the float switch 46 is actuated to the "on" state, the first valve 42 is operated to be at the closed state for closing the outlet 26 and preventing transfer of the mixture from the fuel cell 32 to the separator 28. In addition, the operation of the pump 52 is stopped to thereby prevent the transfer or recirculation of excess hydrogen from the separator 28 to the inlet 22.

The step 230 of actuating the float switch 46 to the "on" state also results in the activation of the drainage valve 50 to thereby open the water removal duct 48. The opening of the water removal duct 48 causes removal or draining of water from the separator 28 in a step 240. The removal of water from the separator 28 thereby causes a consequent decrease in the volume, and hence level, of water within the separator 28.

The decrease in the level or volume of water within the separator 28 causes actuation of the float switch 46 from the "on" to an "off" (also known as an "inactive") state in a step 250. Preferably, the step 250 occurs when the volume of water within the separator 28 has decreased such that the level of the water within the separator 28 is at or below the second predetermined value. Preferably, the second predetermined value can be adjusted as required.

Actuation of the float switch 46 to the "off" state returns the drainage valve 50 to the inactivated state and thereby closes the water removal duct 48. The closing of the water removal duct 48 prevents the removal or draining of water from the separator 28. In other words, the closing of the water removal duct 48 facilitates accumulation of water within the separator 28.

When the float switch 46 is at the "off" state, the first valve 42 is operated to be at the open state for opening the outlet 26 to thereby facilitate transfer of the mixture from the fuel cell 32 to the separator 28. Alternatively, the first valve 42 is operated for intermittently being at the open state when the float switch 46 is at the "off" state. The intermittent opening of the first valve 42 enables intermittent transfer of the mixture from the fuel cell 32 to the separator 28. Such an intermittent transfer of the mixture from the fuel cell 32 to the separator 28 preferably facilitates humidifying of the excess hydrogen gas.

In addition, when the float switch 46 is at the "off" state, the operation of the pump 52 resumes. The operation of the pump 52 helps to produce and maintain a vacuum above the level of water within the separator 28. Preferably, the operation of the pump 52 is continuous. Alternatively, the operation of the pump 52 is intermittent and corresponds with the intermittent opening of the first valve 42. The creation and maintenance of the vacuum facilitates the transfer of the mixture from the fuel cell 32 to the separator 28 in the step 150.

The controller 54, which is preferably in signal communication with the float switch 46, the first valve 42, the drainage valve 50, and the pump 44, preferably controls the cycle of operation 200 of the separator 28. The controller 54 is preferably programmable for effecting automatic control of the cycle of operation 200 of the separator 28. Further preferably, the controller 54 is programmable for controlling or coordinating actuation of the float switch 46 with a sequencing of the operation of the first valve 42, the drainage valve 50 and the pump 52.

The operation of the pump 52 causes transfer or recirculation of excess hydrogen from the separator 28 to the inlet 22 in a step 170 of the method 100. Preferably, the excess

hydrogen is transferred or circulated from the separator 28 to the inlet 22 via the channel provided by the recirculation duct 30.

The excess hydrogen gas being transferred or circulated from the separator 28 to the inlet 22 is consequently reintroduced into the fuel cell end plate 24, and consequently into the fuel cell 32 in a step 180. The reintroduction of excess hydrogen gas into the fuel cell end plate 24 and the fuel cell 32 provides another opportunity for the excess hydrogen gas to undergo oxidation at the anode to thereby produce electrons for the generation of electricity.

It will therefore be appreciated by a person skilled in the art that the continuous circulation of excess hydrogen gas with the system 20 enhances electricity or power generating efficiency of the fuel cell 32 used with the system 20. It will also be appreciated by a person skilled in the art that the exemplary method 100 for circulating gaseous fuel, more specifically hydrogen gas, provided by the present invention also helps facilitate enhanced electricity or power generating efficiency of the fuel cell 32 utilizing the method 100.

Preferably, latent air present within the system 20 is first purged or removed from the system 20 before commencement of the method 100 and the cycle of operation 200 of the separator 28. The removal of latent air from the system 20 is preferably effected by a constant introduction of hydrogen gas into the system 20 while maintaining non-operation of the pump 52. The non-operation of the pump 52 prevents recirculation of excess hydrogen gas from the separator 28 into the fuel cell 32. However, the drainage valve 50 is activated to open the water removal duct 48. Therefore, the excess hydrogen in the separator 28, together with the latent air present within the system 20, is removed from the system 20 via the water removal duct 48. Extent of removal of latent air from the system 20 can be varied as required. The removal of latent air from the system 20 before commencement of the method 100 and the cycle of operation 200 of the separator 28 helps to prevent entry of latent air, which may comprise a mixture of different gases and impurities, into the fuel cell 32.

As previously described, the system 20 provided by the exemplary embodiment of the present invention comprises different components. However, it will be appreciated by a

person skilled in the art that the separator 28 may be integrated with the fuel cell end plate 24. Preferably, the separator 28 is specifically shaped and dimensioned for physical or functional integration with the fuel cell end plate 24. Further preferably, the separator 28 and the fuel cell end plate 24 are inter-configured for secure coupling with each other.

Preferably, the separator 28 is attached or fitted with a surface or an edge of the fuel cell end plate 24. The surface is preferably a base 56 of the fuel cell end plate 24. Preferably, the separator 28 is shaped and dimensioned for enabling secure attachment to the base 56 of the fuel cell end plate 24. The separator 28 may alternatively be welded to the base 56 of the fuel cell end plate 24 or attached to the fuel cell end plate 24 via adhesives or fasteners.

The integration of the separator 28 with the fuel cell end plate 24 preferably facilitates reduction in cost of manufacture of the system 20. In addition, the integration of the separator 28 with the fuel cell end plate 24 preferably spatially compacts the system 20 to thereby increase ease of at most one of manufacturing, transport and storage. Preferably, this will help to increase cost-effectiveness of the fuel cells 32 used with the system 20. Improving cost-effectiveness of the fuels cells 32 thereby helps to promote and sustain increased use of fuel cells or fuel cell systems as a viable and attractive source of alternative energy.

Installation or use of the fuel cell end plates 24 integrated with the separators 28 with fuel cells or fuel cell systems enables the method 100 to be performed by the fuel cells. Therefore, the integration of separators 28 with fuel cell end plates 24, the fuel cell end plates 24 for subsequent use with the fuel cells or fuel cell systems helps to enhance fuel utilization efficiency of the fuel cell or fuel cell system. Consequently, the electricity or power generating efficiency, and hence cost-effectiveness, of the fuel cells or fuel cell systems are preferably increased.

In the foregoing manner, an exemplary system and method for circulating gaseous fuel, more specifically hydrogen gas, are described according to exemplary embodiments of the present invention. Although only exemplary embodiments of the present invention are disclosed, it will be apparent to a person skilled in the art in view of this disclosure

that numerous changes and/or modifications can be made without departing from the scope and spirit of the present invention.

Claims

1. A fuel cell system comprising:

a fuel cell end plate for receiving gaseous fuel and for mediating introduction of the gaseous fuel into a fuel cell, one portion of the gaseous fuel introduced into the fuel being utilized for production of water thereby and another portion of the gaseous fuel being mixed with at least a portion of the water to obtain a mixture therefrom, the mixture being dischargeable from the fuel cell;

a separator for receiving the mixture discharged from the fuel cell and for separating the mixture into separated gas and separated water, the separator further for containing accumulated water comprising the separated water and accumulated gas comprising the separated gas; and

a control system in operative communication with the separator for determining volume of the accumulated water stored within the separator and for controlling discharge of at least one of the accumulated water and the accumulated gas from the separator,

wherein subsequent discharge of at least a portion of the accumulated water is initiatable by the control system upon the control system determining the volume of the accumulated water within the separator reaching a reference magnitude.

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

a pump operable for facilitating discharge of the accumulated gas from the separator.

3. The fuel cell system as in claim 2, the fuel cell end plate comprising:

an inlet coupled thereto for fluid communication with a gaseous fuel source, the inlet further in fluid communication with the pump for receiving the accumulated gas discharged from the separator.

4. The fuel cell system as in claim 2, wherein the pump is in signal communication with the control system, the operation of the pump being dependent on the volume of the accumulated water within the separator as determined by the control system.

5. The fuel cell system as in claim 4, wherein the operation of the pump is temporarily stopped by the control system upon the control system determining volume of the accumulated water reaching the reference magnitude.

6. The fuel cell system as in claim 2, further comprising:

a drainage duct wherethrough the accumulated water within the separator displaces for discharge therefrom; and

a drainage valve couplable to the drainage duct,

wherein the drainage valve is operable for one of enabling and impeding discharge of the accumulated water from the separator.

7. The fuel cell system as in claim 6, wherein the control system is in operative communication with the drainage valve to thereby control the operation of the drainage valve.

8. The fuel cell system as in claim 6, the control system comprising:

one of a float switch and a sensor for detecting level of accumulated water within the separator, the one of the float switch and the sensor for further determining volume of the accumulated water within the separator based on detected level of accumulated water within the separator,

wherein the control system controls discharge of the accumulated water within the separator based on the volume of the accumulated water stored within the separator as determined by the one of the float switch and the sensor.

9. The fuel cell system as in claim 8, wherein the control system controls the operation of the drainage valve for opening and closing the drainage duct in response to the volume of accumulated water reaching a first and a second reference magnitude respectively as determined by the one of the float switch and the sensor, the first reference magnitude being larger than the second reference magnitude.

10. The fuel cell system as in claim 9, the control system further comprising:

a controller programmable for controlling the operative communication of the control system.

11. The fuel cell system as in claim 10, wherein the controller determines the volume of accumulated water stored within the separator, the controller being further programmable for at least one of storing, processing and communicating the received volume of accumulated water stored within the separator.

12. The fuel cell system as in claim 10, wherein the controller is programmable for controlling opening and closing of the drainage valve in response to the volume of the accumulated water with the separator reaching the first and the second reference magnitude respectively.

13. The fuel cell system as in claim 12, further comprising:

a valve interposing the fuel cell end plate and the separator, the valve being operable between a closed state and an open state for respectively facilitating and impeding fluid communication between the fuel cell end plate and the separator.

14. The fuel cell system as in claim 13, wherein the control system is further in operative communication with the valve for controlling the operation of the valve based on the volume of the accumulated water stored within the separator as determined by the one of the float switch and the sensor.

15. The fuel cell system as in any of the preceding claims, wherein the gaseous fuel is hydrogen gas.

16. A method comprising:

separating a mixture into separated gas and separated water within a separator, the mixture being received by the separator from a fuel cell, the separator further for containing accumulated water comprising the separated water and accumulated gas comprising the separated gas;

determining volume of the accumulated water within the separator by a control system; and

controlling discharge of at least one of the accumulated water and the accumulated gas from the separator,

wherein discharge of the at least one of the accumulated water and the accumulated gas from the separator is controlled by the control system, the discharge of the accumulated water from the separator being initiatable by the control system upon the control system determining the volume of the accumulated water within the separator reaching a predetermined reference magnitude.

17. The method as in claim 16, further comprising:

communicating gaseous fuel into a fuel cell end plate, the fuel cell end plate mediating introduction of the gaseous fuel into the fuel cell, one portion of the gaseous fuel introduced into the fuel cell being utilized for production of water thereby and another portion of the gaseous fuel being mixed with at least a portion of the water to obtain the mixture; and

discharging the mixture from the fuel cell,

wherein the mixture discharged from the fuel cell is consequently received by the separator.

18. The method as in claim 16, further comprising:

communicating discharged accumulated gas into an inlet, the inlet being couplable to the fuel cell end plate for facilitating introduction of the discharged accumulated gas thereinto.

19. The method as in claim 18, further comprising:

providing a pump, the pump operable for facilitating discharge of the accumulated gas from the separator, the pump being in fluid communication with the inlet for further facilitating communication of the discharged accumulated gas thereinto.

20. The method as in claim 19, wherein the pump is in signal communication with the control system, the operation of the pump being dependent on the volume of the accumulated water within the separator as determined by the control system.

21. The method as in claim 19, wherein the operation of the pump is temporarily stopped by the control system upon the control system determining volume of the accumulated water reaching the reference magnitude.

22. The method as in claim 19, further comprising:

connecting a drainage duct to the separator wherethrough the accumulated water within the separator displaces for discharge from the separator; and

coupling a drainage valve to the drainage duct,

wherein the drainage valve is operable for one of enabling and impeding discharge of the accumulated water from the separator.

23. The method as in claim 22, wherein the control system is in operative communication with the drainage valve to thereby control the operation of the drainage valve.

24. The method as in claim 23, the control system comprising:

one of a float switch and a sensor for detecting level of accumulated water within the separator, the one of the float switch and the sensor for further determining volume of the accumulated water within the separator based on detected level of accumulated water within the separator,

wherein the control system controls discharge of the accumulated water within the separator based on the volume of the accumulated water stored within the separator as determined by the one of the float switch and the sensor.

25. The method as in claim 24, wherein the control system controls the operation of the drainage valve for opening and closing the drainage duct in response to the volume of accumulated water reaching a first and a second reference magnitude respectively as determined by the one of the float switch and the sensor, the first reference magnitude being larger than the second reference magnitude.

26. The method as in claim 25, the control system further comprising:

a controller programmable for controlling the operative communication of the control system.

27. The method as in claim 26, further comprising:

determining the volume of accumulated water within the separator by the controller, the controller being further programmable for at least one of storing, processing and communicating the determined volume of accumulated water within the separator.

28. The method as in claim 26, wherein the controller is further programmable for controlling opening and closing of the drainage valve in response to the volume of the accumulated water with the separator reaching the first and the second reference magnitude respectively.

29. The method as in claim 26, further comprising:

interposing a valve between the fuel cell end plate and the separator, the valve being operable between a closed state and an open state for respectively facilitating and impeding fluid communication between the fuel cell end plate and the separator.

30. The method as in claim 29, wherein the control system is further in operative communication with valve for controlling the operation of the valve based on the volume of the accumulated water stored within the separator as determined by the one of the float switch and the sensor.

31. The fuel cell system as in any of the preceding claims, wherein the gaseous fuel is hydrogen gas.