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Revolution in Renewable Energy Fuel Cell

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Abstract

A fuel cell is an electrochemical device that converts the chemical energy of a fuel and oxidant directly into electric energy. Besides being efficient and clean, fuel cells are also compatible with renewable energy sources and carriers for sustainable development and energy security. Fuel cells offer additional advantages for both mobile and stationary applications, including quiet operation without vibration and noise; they are therefore candidates for onsite applications. Whereas the 19th Century was the century of the steam engine and the 20th Century was the century of the internal combustion engine, it is likely that the 21st Century will be the century of the fuel cell. Full cells are now on the verge of being introduced commercially, revolutionizing the way we presently produce power. Fuel cells can use hydrogen as a fuel, offering the prospect of supplying the world with clean, sustainable electrical power.

Keywords

Fuel Cell, Revolution, Hydrogen, Electric Energy

I. Introduction

A fuel cell by definition is an electrical cell, which unlike storage cells can be Continuously fed with a fuel so that the electrical power output is sustained indefinitely (Connihan, 1981). They convert hydrogen, or hydrogen-containing fuels, directly into electrical energy plus heat through the electrochemical reaction of hydrogen and oxygen into water. The process is that of electrolysis in reverse.

Overall reaction:

2 H2(gas) + O_2(gas)   2 H_2O + energy

Because hydrogen and oxygen gases are electrochemically converted into water, fuel cells have many advantages over heat engines. These include: high efficiency, virtually silent operation and, if hydrogen is the fuel, there are no pollutant emissions. If the hydrogen is produced from renewable energy sources, then the electrical power produced can be truly sustainable.

The two principle reactions in the burning of any hydrocarbon fuel are the formation of water and carbon dioxide. As the hydrogen content in a fuel increases, the formation of water becomes more significant, resulting in proportionally lower emissions of carbon

II. Battery

A battery has all of its chemicals stored inside, and it converts those chemicals into electricity too.

This means that a battery eventually "goes dead" and you either throw it away or recharge it.

III. Cell

Chemicals constantly flow into the cell so it never goes dead. As long as there is a flow of chemicals into the cell, the electricity flows out of the cell. Most fuel cells in use today use hydrogen and oxygen as the chemicals.

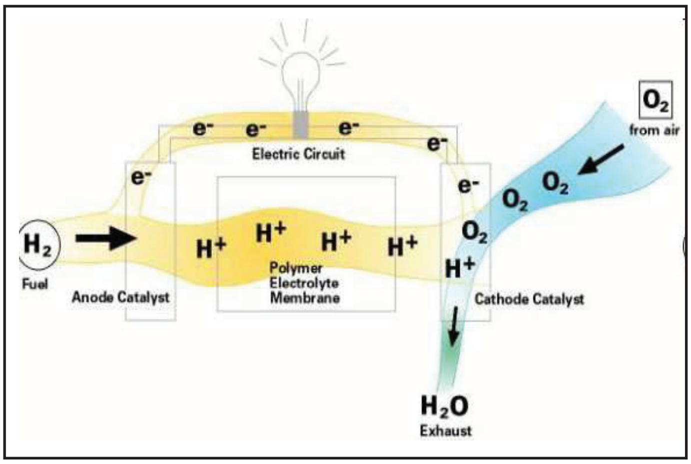

Fig. 1: Basic Principle Fuel Cell

An input fuel is catalytically reacted (electrons removed from the fuel elements) in the fuel cell to create an electric current. Fuel cells consist of an electrolyte material which is sandwiched in between two thin electrodes (porous anode and cathode). The input fuel passes over the anode (and oxygen over the cathode) where it catalytically splits into ions and electrons. The electrons go through an external circuit to serve an electric load while the ions move through the electrolyte toward the oppositely charged electrode. At the electrode, ions combine to create by-products, primarily water and CO2. Depending on the input fuel and electrolyte, different chemical reactions will occur.

IV. Chemistry of a Fuel Cell

Anodeside:

$2H_2 \Rightarrow 4H^+ + 4e^-$

Cathodeside:

$O_2 + 4H^+ + 4e^- \Rightarrow 2H_2O$

Netreaction:

$2H_2 + O^2 \Rightarrow 2H_2O$

V. Voltage And Efficiency Cell

If the fuel cell was perfect at transferring chemical energy into electrical energy, the ideal cell voltage (thermodynamic reversible cell potential) of the hydrogen fuel cell would be at 25º C, 1 atmosphere, 1.23 volts. As the fuel cell heats up to operating temperature, around 80º C the ideal cell voltage drops to about 1.18 volts. However there are many limiting factors that reduce the fuel cell voltage further. The voltage out of the cell is a good measure of electrical efficiency; the lower the voltage, the lower the electrical efficiency and the more chemical energy is released in the formation of water and transferred into heat. The primary losses that contribute to a reduction in cell voltage are:

VI. Activation Losses

Activation losses are a result of the energy required to initiate the reaction. This is a result of the catalyst. The better the catalyst the less activation energy is required. Platinum forms an excellent catalyst however there is much research underway for better materials. A limiting factor to power density available from a fuel cell is the speed at which the reactions can take place. The cathode reaction, (the reduction of oxygen) is about 100 times slower than that of the reaction at the anode, thus it is the cathode reaction that limits power density.

VII. Fuel Crossover and Internal Currents

Fuel crossover and internal currents are a result of fuel that crosses directly through the electrolyte, from the anode to the cathode without releasing electrons through the external circuit, thereby decreasing the efficiency of the fuel cell.

VIII. OHMIC Losses

Ohmic losses are a result of the combined resistances of the various components of the fuel cell. This includes the resistance of the electrode materials, the resistance of the electrolyte membrane and the resistance of the various interconnections.

IX. Concentration Losses

(Also referred to as "mass transport"). These losses result from the reduction of the concentration of hydrogen and oxygen gases at the electrode. For example, following the reaction new gases must be made immediately available at the catalyst sites. With the build up of water at the cathode, particularly at high currents, catalyst sites can become clogged, restricting oxygen access. It is therefore important to remove this excess water, hence the term mass transport.

X. Fuel Cell Stack

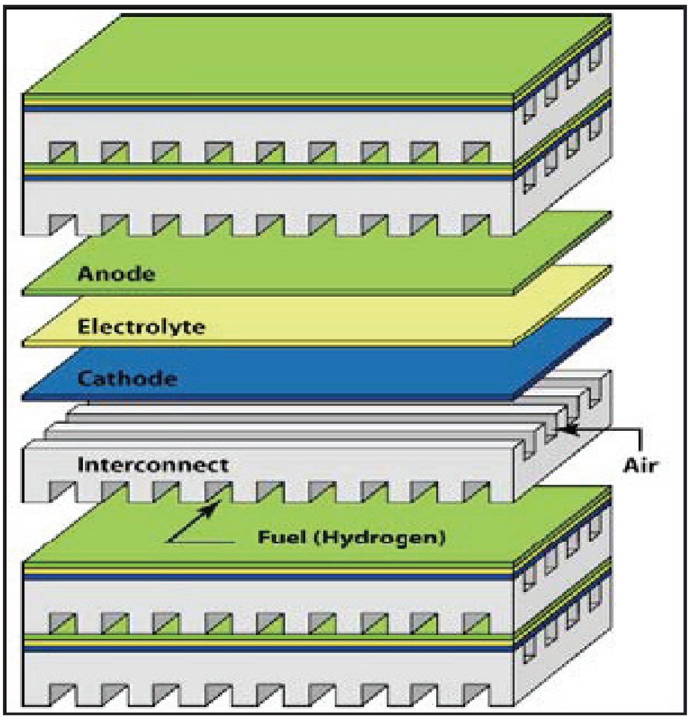

Fig. 2: Fuel Cell Stack

XI. Advantages

- We can look at the fuel cell as an efficient and simple energy converter.
- Fuel cell power sources are compact & simple noiseless do not have rotating / moving parts.
- Efficiency are 88 to 97%.
- (compared with 35 to 45% of other methods of thermal power)
- The fuel cell plants are modular and available in wide range of sizes which is 5kw to 10 mw.
- Pollution free. Emission of combustion products is negligibly small and the are no emissions of CO_2, NOx, and Sox particulates etc.
- Choice of fuels depending upon types of fuel cell.
- Do not need electrical power supply for charging.
- Low/ Medium/ high temperature options available.
- Power supply from fuel cell power plants high operational flexibilities.

XII. Applications

A. Transportation

The California Low Emission Vehicle Program, administered by the California Air Resources Board (CARB), has been a large incentive for automobile manufacturers to actively pursue fuel cell development. This program requires that beginning in 2003, ten percent of passenger cars delivered for sale in California from medium or large sized manufacturers must be Zero Emission Vehicles, called ZEVs. Automobiles powered by fuel cells meet these requirements, as the only output of a hydrogen fuel cell is pure water.

B. Distributed Power Generation

Electrical energy demands throughout the world are continuing to increase. In Canada the demand is growing at an annual rate of approximately 2.6%. In America the rate is about 2.4% (IEA., 1997), and in developing countries it is approximately 6% (Khatib., 1998). How can these energy demands be met responsibly and safely? Distributed power plants using fuel cells can provide part of the solution. Distributed or "decentralized" power plants, contrasted with centralized power plants, are plants located close to the consumer, with the capability of providing both heat and electrical power (a combination known as "cogeneration"). Heat, the by-product of electrical power generation, is transferred from the fuel cell to a heat exchanger. The exchanger transfers the heat to a water supply, providing hot water to local customers.

The overall efficiency of a cogeneration system can be in excess of 80 percent, comparatively high compared to a system producing electricity alone. An increase in efficiency naturally corresponds to a decrease in fuel consumption. Distributed power plants have many additional advantages. For example, they can provide power to a remote location without the need of transporting electricity through transmission lines from a central plant. There is also an efficiency benefit in that the cost of transporting fuel is more than offset by the elimination of the electrical losses of transmission. The ability to quickly build up a power infrastructure in developing nations is often cited. Using fuel cell power plants obviates the need for an electrical grid.

C. Grid-connect applications

Distributed power plants can provide either primary or back-up power. In primary applications they can provide base-load power, operating virtually continuously from the consumption of natural gas, reducing the demand from the electrical grid. This not only decreases the cost of displaced power, but can also result in a reduction of demand charges imposed by the utility. Should the power plant provide an excess of electricity, the excess can be fed back into the electrical grid, resulting in additional savings. In case of a power outage on the grid, a distributed power plant can continue to provide power to essential services; eliminating the need for both an uninterruptible power supply (UPS), presently handled by lead-acid battery banks, and a stand-by generator, for extended periods of power outage. An additional quality of a fuel cell power plant for UPS applications is that the average "down time" is anticipated to be low, 3.2 to 32 seconds per year versus typically nine hours for a conventional battery-bank UPS (HDR Engineering). For industries where UPS systems are critical, such as banking, minimizing down time is of up most importance.

D. Non-Grid Connect Applications

Other applications for fuel cell distributed power plants are also possible e.g. stand-alone back-up power generators. The fuel cell plant can be started in seconds, supplying power for as long as required from stored hydrogen, producing electrical power cleanly and virtually silently.

This unit provides 250 kilowatts of electricity and an equivalent amount of heat. This is enough power for a community of about 50 homes, or a small hospital or a remote school. This particular unit incorporates a fuel processor so that natural gas can be used as a fuel. The fuel processor converts the natural gas, through the process of reformation, into a hydrogen-rich gas composed primarily of hydrogen and carbon dioxide. The hydrogen is used by the fuel cell and the carbon dioxide is released into the atmosphere. Eventually as an infrastructure for hydrogen develops, these units could be powered with hydrogen directly without the need of a fuel processor. Ballard Power is presently field testing five of these units in the United States, Germany, Japan and Switzerland, with four more units planned for 2002. Testing is expected to continue until 2004 after whichcommercial introduction is planned (Ballard Power).

E. Residential Power

Fuel cell power plants are also being developed by several manufacturers to provide electricity and heat to single-family homes. Fuelled by either natural gas or propane, these plants will be able to supply base-load power or all of the electricity required by a modern-day home.

F. Characteristics of Fuel Cell:

- High energy conversion efficiency.
- Modular design.
- Very low chemical and acoustical pollution.
- Fuel flexibility.
- Cogeneration capability.
- Rapid load response.

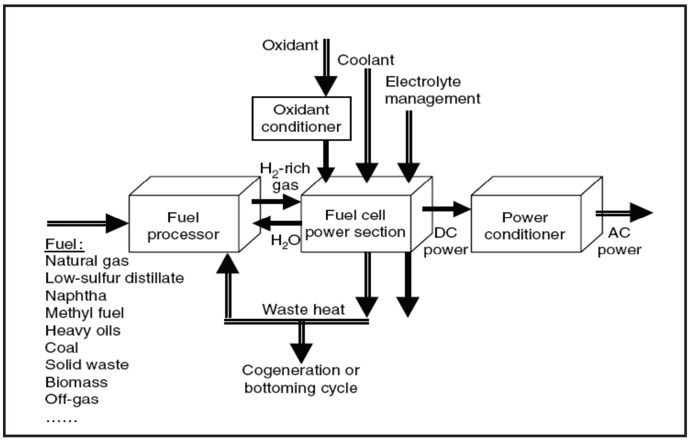

Fig. 3: Block Diagram of Fuelcell

XIII. Fuel Cell Classification

Fuel cells are often named by the nature of their electrolyte. There are presently six major fuel cell technologies at varying stages of development and commercialization:

– Alkaline fuel cells (AFC)
– Polymer-electrolyte-membrane fuel cells (PEMFC)
– Direct-methanol fuel cells (DMFC)
– Phosphoric-acid fuel cells (PAFC)
– Molten-carbonate fuel cells (MCFC)
– Solid-oxide fuel cells (SOFC)

Type	Technology Characteristics			
	Electrolyte	Operating Temperature	Efficiency (HHV)	Power Density
AFC	Potassium Hydroxide	50-200C	45-60% up to 70 with CHP	0.7-8.1kW/m2
PEM	Polymer	50-100C	35-55%	3.8-13.5.1kW/m2
DMFC	Polymer Membrane	50-200C	40-50% up to 80% with CHP	1-6kW/m2
PAFC	Phosphoric Acid	160-210C	40-50%	0.8-1.9 kW/m2
MCFC	Lithium or potassium carb0nate	800-800C	50-60% up to 80% with CHP	0.1-1.5 kW/m2
SOFC	Ceramic composed of calcium or zirconium oxides	500-1000C	50-65% up to 75% with CHP	1.5-5.0 kW/m2

Fig. 4: Characteristics of Different Types of Fuel Cells

XIV. Cost of Fuel Cell

In 2010, fuel cell industry revenues exceeded a $750 million market value worldwide, although, as of 2010, no public company in the industry had yet become profitable. There were 140,000 fuel cell stacks shipped globally in 2010, up from 11 thousand shipments in 2007.

1kW PEM Fuel Cell	$5,753.86
3kWPEMFuel Cell	$13,869.87
5kWPEMFuel Cell	$22,129.96
MES 1 kW Fuel cell	$6,350.00
MES 500 W Fuel cell	$4,150.00

Fuel cells are making an impact in every stage of the industrial process – providing reliable and green electricity to manufacturing

XV. Most Recently

- Federal Express (FedEx) Missouri facility this week to celebrate the converting of all its battery-powered forklifts to hydrogen fuel cells, 35 in all. FedEx plans to convert five propane-powered forklifts in the near future. The company also has a Bloom Energy unit at its Oakland, California hub.
- Adobe Systems installed 12 Bloom Energy Servers equalling 1.2 MW of power on the 5th floor of Adobe's West Tower in San Jose, California.
- Coca-Cola Refreshments (CCR) installed two UTC Power PureCell® Model 400 fuel cell systems to provide 35 percent of the electricity and heat at its Elmsford, New York production facility. The fuel cells will eliminate 2,635 metric tons of carbon dioxide and more than 4 metric tons of nitrogen oxide emissions and save millions of gallons of water. CCR recently signed a contract to install two more units at a bottling plant in East Hartford, Connecticut and has 40

fuel cell forklifts at a Charlotte, North Carolina production plant. BMW purchased 86 fuel cell-powered forklifts, tuggers and stackers and is installing six Linde hydrogen dispensers at its Spartanburg, South Carolina manufacturing plant. The hydrogen is a by-product of a sodium chlorate plant which is purified, compressed and liquefied by using electricity produced from renewable hydropower.

- A new Albertsons supermarket in San Diego, California, has installed a 400-kW fuel cell from UTC Power to generate nearly 90 percent of its electricity. SUPERVALU, Albertsons parent company, has a fuel cell system installed at Chestnut Hill, Massachusetts Star Market.

A. Renewable Energy Systems

Hydrogen can be produced sustainably with no emission of carbon dioxide from renewable energy systems. An example of such a system is the use of a solar panel, a wind turbine or a micro-hydro generator to convert the radiant energy of sunlight into electrical power, which drives an electrolyzer. The electrolyzer breaks apart water producing hydrogen and oxygen gases. The hydrogen is stored for use by the fuel cell and the oxygen is released into the atmosphere. Thus when the sun shines, the wind blows or the water flows, the electrolyser can produce hydrogen. A power system incorporating hydrogen from renewable sources and a fuel cell is a closed system, as none of the products or reactants, water, hydrogen and oxygen are lost to the outside environment. The water consumed by the electrolyzer is converted to gases. The gases are converted back to water. The electrical energy produced by the solar panel is transferred to chemical energy in the form of gases. The gases can be stored and transported, to be reconverted back to electricity.

These systems are truly sustainable, for as long as there is sunlight there can be electricalpower, available where and when required.

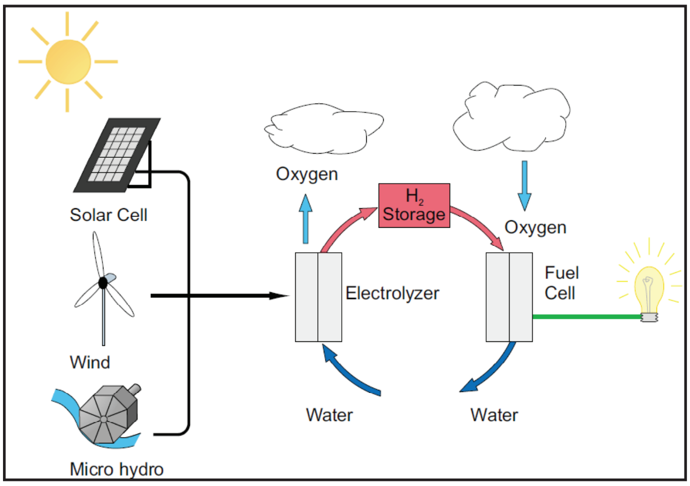

Fig. 5: Electrical Power From Renewable Energy Sources. In The Past, The Limiting Factors of

renewable energy have been the storage and transport of that energy. With the use of an electrolyzer, a method of storing and transporting hydrogen gas, and a fuel cell, electrical power from renewable energy sources can be delivered where and when required, cleanly, efficiently and sustainably.

B. Biological Methods

Research and development is taking place on the production of hydrogen from biological methods (BioHydrogen). For example, Dr. A. Melis at the University of California, Berkeley has discovered a metabolic switch in common green algae (Chlamydomonas reinhardtii) that causes the algae to oxidize water and to produce pure hydrogen gas when sulphur nutrients are depleted from the growth medium. This and other BioHydrogen mechanisms are presently in the R & D stage but may one day provide the world with an additional source of hydrogen.

BENEFITS AND OBSTACLES TO THE SUCCESS OF FUEL CELLS AND THE DEVELOPMENT OF A HYDROGEN-BASED ECONOMY:

XVI. Benefits

- Fuel cells are efficient. They convert hydrogen and oxygen directly into electricity and water, with no combustion in the process. The resulting efficiency is between 50 and 60%, about double that of an internal combustion engine.
- Fuel cells are clean. If hydrogen is the fuel, there are no pollutant emissions from a fuel cell itself, only the production of pure water. In contrast to an internal combustion engine, a fuel cell produces no emissions of sulphur dioxide, which can lead to acid rain, nor nitrogen oxides which produce smog nor dust particulates.
- Fuel cells are quiet. A fuel cell itself has no moving parts, although a fuel cell system may have pumps and fans. As a result, electrical power is produced relatively silently. Many hotels and resorts in quiet locations, for example, could replace diesel engine generators with fuel cells for both main power supply or for backup power in the event of power outages.
- Fuel cells are modular. That is, fuel cells of varying sizes can be stacked together to meet a required power demand. As mentioned earlier, fuel cell systems can provide power over a large range, from a few watts to megawatts.
- Fuel cells are environmentally safe. They produce no hazardous waste products, and their only by-product is water (or water and carbon dioxide in the case of methanol cells).
- Fuel cells may give us the opportunity to provide the world with sustainable electrical power.

A. Obstacles

At present there are many uncertainties to the success of fuel cells and the development of a hydrogen economy:

- Fuel cells must obtain mass-market acceptance to succeed. This acceptance depends largely on price, reliability, longevity of fuel cells and the accessibility and cost of fuel. Compared to the price of present day alternatives e.g. diesel-engine generators and batteries, fuel cells are comparatively expensive. In order to be competitive, fuel cells need to be mass produced less expensive materials developed.
- An infrastructure for the mass-market availability of hydrogen, or methanol fuel initially, must also develop. At present there is no infrastructure in place for either of these fuels. As it is we must rely on the activities of the oil and gas companies to introduce them. Unless motorists are able to obtain fuel conveniently and affordably, a mass market for motive applications will not develop.
- At present a large portion of the investment in fuel cells and hydrogen technology has come from auto manufacturers. However, if fuel cells prove unsuitable for automobiles, new sources of investment for fuel cells and the hydrogen industry will be needed.
- Changes in government policy could also derail fuel cell

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and hydrogen technology development. At present stringent environmental laws and regulations, such as the California Low Emission Vehicle Program have been a great encouragement to these fields. Deregulation laws in the utility industry have been a large impetus for the development of distributed stationary power generators. Should these laws change it could create adverse effects on further development.

- At present platinum is a key component to fuel cells. Platinum is a scarce natural resource; the largest supplies to the world platinum market are from South Africa, Russia and Canada. Shortages of platinum are not anticipated, however changes in government policies could affect the supply.

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