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Fuel Cell Technology for Distributed Generation

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ABSTRACT

Fuel cell technology plays an important role now days due to its high efficiency, more reliability and noise less operation. The fuel cell technology is one of the alternative technique for generation of electricity. This paper contains the working principle and operation of fuel cell, development and application status of fuel cell technologies, characteristics and requirements of major fuel cell technologies, applications and advantages, and also comparisions between different fuel cells such as PEMFC, PAFC, MCFC, SOFC are discussed.

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I. INRODUCTION

In 1839, the first fuel cell was conceived by sir William Robert groove, a welsh judge, inventor and physicist .he mixed hydrogen and oxygen in the presence of an electrolyte and produced electricity and water.

A fuel cell is a device that generates electricity by means of a chemical reaction .each and every fuel cell has two electrodes called the anode and cathode. The reactions the electricity takes place at electrodes. And a also each and every fuel cell has an electrolyte which carries electrically charged particles from one electrode to another and also a catalyst which purpose is to speed up the reactions at the electrodes.

Hydrogen is the basic fuel, but fuel cells also require oxygen .the main purpose of fuel cell is it generates electricity with a very less pollution -much of the hydrogen and oxygen used in generating electricity combine to form an harmless byproduct called water.

II. WORKING PRICIPLE AND OPERATION OF FUEL CELL

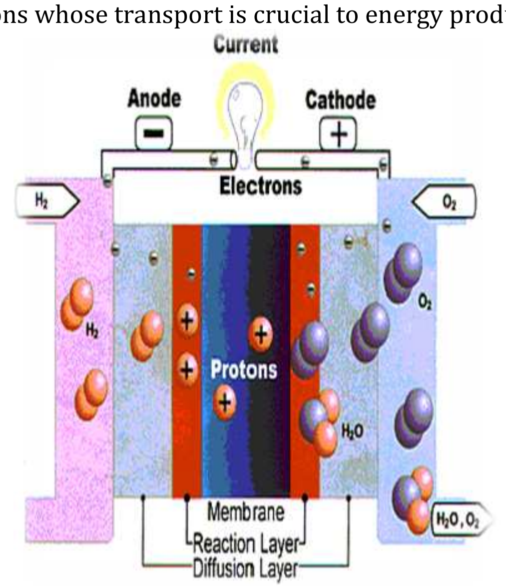
The fuel cell is an electrochemical devise, which converts chemical energy of the fuel to electricity by combining gaseous hydrogen with air in the absence of combustion. The basic principles of operation of the fuel cell is similar to that of the electrolyze in that the fuel cell is constructed with two electrodes with a conducted electrolyte between them.

For a better explanation of the fuel cell operation, take a closer look at the **Proton Exchange Membrane (PEM)** fuel cell (click on the picture for animation)

The heart of the cell is the proton conducting solid **PEM.** It is surrounded by two layers, a diffusion and a reaction layer. Under constant supply of hydrogen and oxygen the hydrogen diffuses through the anode and the diffusion layer up to the platinum catalyst, the reaction layer. The reason for the diffusion current is the tendency of hydrogen oxygen reaction.

Two main electrochemical reactions occur in the fuel cell. One at the anode (anodic reaction) and one at the cathode.

At the anode, the reaction releases hydrogen ions and electrons whose transport is crucial to energy production.



H_2®$2H^+ + 2e^-$

The hydrogen ion on its way to the cathode passes through the polymer membrane while the only possible way for the electrons is through an outer circuit. The hydrogen ions together with the electrons of the outer electric circuit and the oxygen which has diffused through the porous cathode reacts to water.

$2H^+ + \frac{1}{2} O_2 + 2e^-$ ®H_2O

The water resulting from this reaction is extracted from the system by the excess air flow. The reaction is:

$H + \frac{1}{2} O_2$ ®H_2O

III. DEVELOPMENT AND APPLICATION STATUS OF FUELCELL TECHNOLOGIES.

Over the last five years growth in shipments of fuel cells has accelerated rapidly as various applications have become commercial. Portable fuel cells saw the most rapid rate of growth over the period since 2009 as increasing numbers of fuel cell educational kits were sold to consumers. This genuine commercial market generated much-needed revenue for several key players and has allowed those companies to invest in research into larger stationery and transport applications. The portable sector has also been boosted by shipments of APU products for the leisure market, in particular camping and boating. Shipments in the portable sector were also augmented by the launch of Toshiba's Dynario fuel cell battery charger in 2009. On a limited production run of 3,000, demand for the Dynario far outstripped supply. Stationary fuel cell adoption has increased rapidly as the rollout of the Japanese Ene-Farm project took place and fuel cells for uninterruptible power supplies (UPS) were adopted in North America. The fuel cell industry has faced and continues to face challenges as it comes through a period of recession and completes the transition from R&D to commercialization. On the whole, it has survived extremely difficult circumstances. Although many fuel cell companies are still far from being profitable, the opportunities for growth in the future are very promising. The success of certain application segments in recent years means that there has been a move to consolidate particular technologies into a standard reference design for a particular type of fuel cell. This has led to fuel cells increasingly being developed as scalable energy solutions capable of serving several different market segments, be they APU or to power devices such as unmanned aerial vehicles (UAV). The Base Structure of Fuel Cells A fuel cell is an electrochemical device which converts the chemical energy of a fuel and an oxidant directly into electrical energy. The basic physical structure of a single cell consists of an electrolyte layer in contact with a porous anode and cathode on either side. In a typical fuel cell, gaseous fuels are fed continuously to the anode (negative electrode) and an oxidant (i.e., oxygen from air) is fed continuously to the cathode (positive electrode) compartment; the electrochemical reactions take place at the electrodes to produce an electric current (Fig. 1). In the case of a fuel cell with an acid electrolyte the electrochemical reactions are

anodic reaction: H2 → 2H+ + 2e

cathodic reaction: 1/2O2 + 2H+ + 2e- → H2O H=-286 kJ mol-1)Δ

overall reaction: H2 + 1/2O2 → H2O + heat (exothermic reaction),

A fuel cell, although having components and characteristics similar to those of a typical battery, differs in several respects. The battery is an energy storage device and the available energy is determined by the chemical reactant stored within the battery itself. The battery will cease to produce electrical energy when the chemical reactants are consumed (i.e., battery discharged). In a secondary battery (fuel cell), the reactants are continuously supplied from an external source.

A fuel cell is an electrochemical that converts the chemical energy of a fuel and an oxidizing agent into electricity through a pair of redox reactions. The structure of a simplified fuel cell is shown in Fig. 1 [3]. A positive electrode (anode), a negative electrode (cathode), and an electrolyte are essential for the reaction to take place. In addition, the material of electrolyte is generally used to identify the type of fuel cells.

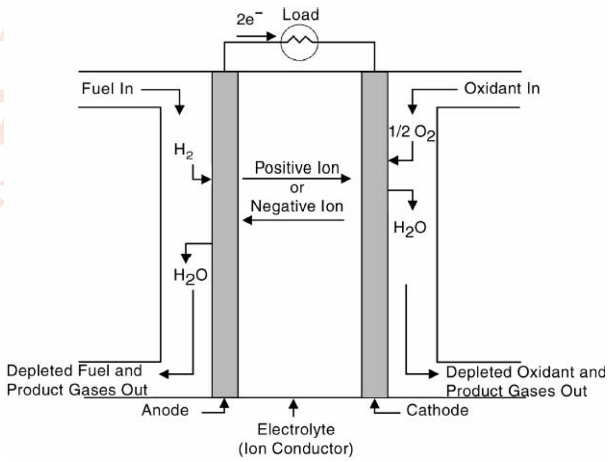


Fig.1. Fuel cell operation diagram

CHARACTERISTICS AND REQUIREMENTS OF MAJOR FUEL CELL TYPES

Ideally, the theoretical maximum voltage produced by a single cell as shown in Table I would be realized at all operating currents. In reality, the cell achieves its highest output voltage only at open circuit conditions and voltage drops off with increasing current drawn, similar as any voltage source with internal resistance. In fuel cell terminology.

The polarization curve characterizes the cell voltage as a function of the current. The current, in turn, depends on the size of the external electrical load that the fuel cell powers. The polarization curve also shows the electrochemical efficiency of the fuel cell at any operating current since the efficiency is often defined as the ratio of the actual cell voltage over the theoretical maximum voltage.

Polarization is caused by chemical and physical factors associated with various elements in the fuel cell, such as temperature, pressure, gas composition, and fuel properties and reactant utilization. These factors limit the reaction processes

Parameters	Fuel Cell Type			
	PEMFC	PAFC	MCFC	SOFC
Electrolyte	Solid organic polymer	Liquid phosphoric acid	Liquid solution of lithium, sodium and/or potassium carbonate	Yittria stabilized zirconia
Operating temp.(˚C)	50-100	150-200	600-700	600-1000
Operating Press. (psig)	15-30	~15	15-150	~15
Fuel	Pure H_2 (toleratesCO_2)	Pure H2 (toleratesCO_2, approx. 1% CO)	H2, CO, CH_4, other hydrocarbons (tolerates CO_2)	H2, CO, CH_4, other hydrocarbons (tolerates CO_2)
Oxidant	O_2 in air	O_2 in air	O_2 in air	O_2 in air
Efficiency	25.58%	>40	45-47	Z
Cell voltage (VDC)	1.1	1.1	0.7-1.0	0.8-1.0
Install Cost (US$/KW)	1,400	2,100	2,600	3,000

ADVANTAGES DISADVANTAGES OF FUEL CELLS

S.NO	ADVANTAGES	DISADVANTAGES
1	High Efficiency- when utilizing co-generation, fuel cells can attain over 80% energy efficiency	Expensive to manufacture due the high cost of catalysts (platinum)
2	Good reliability- quality of power provided does not degrade over time	Lack of infrastructure to support the distribution of hydrogen
3	Noise- offers a much more silent and smoother alternative to conventional energy production.	A lot of the currently available fuel cell technology is in the prototype stage and not yet validated.
4	Environmentally beneficial- greatly reduces CO2 and harmful pollutant emissions	Hydrogen is expensive to produce and not widely available
5	Size reduction- fuel cells are significantly lighter and more compact	corrosive
6	Biodegradable	Toxic

APPLICATIONS: -

Automobiles

Most automobile manufacturers have been developing fuel cell vehicles for at least a couple of decades. Automotive manufacturers are interested in fuel cell technology because it is a "next-generation" technology that could have fuel reproduced from local sources and low or zero emissions. Fuel cell vehicles usually use compressed hydrogen as the fuel type, although several manufacturers have also demonstrated a fuel cell vehicle with methanol. Automotive fuel cells can have one or more of the following:

- A fuel cell can be used for start-up only or to provide all of the power to a vehicle.
- A fuel cell supplies a constant amount of power, so for vehicle acceleration and other power increased power needs, additional devices are connected to the fuel cell.
- A fuel cell can be used as the secondary power source.

The operating temperature of an automotive fuel cell is between 60 to 80ºC due to the utilization of the polymer membrane, which limits the temperature to below 100ºC.

Buses

Buses have successfully demonstrated the use of fuel cells for transportation purposes into the commercial vehicle market. The difference between buses and automobiles are the power requirements, space availability, operating regimen, and refueling sites. Buses require more power than automobiles and get more wear due to constant stops and starts. Large quantities of hydrogen can also be stored on-board buses easily because of the available area of a bus.

Fuel cell buses have an advantage over diesel buses because they have zero emissions. This is critical in heavily populated and polluted cities. Many bus manufacturers began demonstrating their first fuel cell buses in the early 1990s. Like the fuel cell automobiles, the fuel type most often used is compressed hydrogen, although methanol and zinc have been demonstrated. Fuel cell buses have been running in British Columbia, California, Amsterdam, Barcelona, Hamburg, London, Luxembourg, Madrid, Porto, Reykjavik, Stockholm, and Stuttgart.

Utility Vehicles

Utility vehicles have been a successful early adapter of fuel cell technology because the competing technology for these vehicles is often lead-acid batteries which require maintenance and charging. Demonstrations of fuel cell utility vehicles show that they offer lower operating cost, reduced maintenance, lower downtime, and extended range. Fuel cell–powered utility vehicles can also be operated indoors because there are no emissions. Utility vehicles that can be powered by fuel cells are forklifts, golf carts, lawn maintenance vehicles, airport movers, wheelchairs, unmanned vehicles, boats, small planes, submarines, small military vehicles. The first fuel cell utility vehicles were demonstrated in the early 2000s. Like the fuel cell automobiles, the fuel type most often used is compressed hydrogen, although methanol, metal hydrides, and sodium borohydride have also been demonstrated. The most common type of fuel cell used is the Proton Exchange Membrane Fuel Cell (PEMFC), but **Direct Methanol Fuel Cells (DMFC)** and Alkaline Fuel Cells (AFC) have also been used.

Scooters and Bicycles

In countries with large populations, scooters, and bicycles are popular forms of transportation. Fuel cells have been positively demonstrated for these applications with compressed hydrogen and methanol. Hydrogen storage is still an issue for these vehicles; therefore, metal hydrides and electrolyzes have been researched during the last decade.

Many manufacturers demonstrated their first fuel cell scooters and bicycles in the early 2000s, which is later than many of the fuel cell automobile and bus demonstrations. Like the fuel cell automobiles, the fuel type most often used is compressed hydrogen, although methanol, metal hydrides, and zinc have also been demonstrated. The most common type of fuel cell used is the PEMFC, but DMFCs and Zinc-Air Fuel Cells (ZAFC) have also been used.

Stationary Power Applications

Fuel cells for stationary applications have been used commercially for over twenty years. The main difference in these fuel cell systems is the choice of a fuel cell and fuel and the heating and cooling of the stacks. Stationary fuel cells can be used as a primary power source. It is often used to power houses that are not connected to the grid or to provide supplemental power.

In hybrid power systems, fuel cells can be connected to photovoltaics, batteries, capacitors, or wind turbines, providing primary or secondary power. Fuel cells can also be used as a backup or energy power generator providing power when the grid is down. A standalone system may require another source of energy for peak periods. These can be batteries and super capacitors, or a combination of both.

Many manufacturers began demonstrating their stationary power stations in the 1990s. Unlike other fuel cell applications, the fuel type most often used is natural gas. Other common fuel types are propane, compressed hydrogen, bio-gas, methanol, oil-based fuels, town gas, synthesis gas, digestor gas, and land fill gas. The most common stationary fuel cell type is the Proton Exchange Membrane Fuel Cell (PEMFC), but Solid Oxide Fuel Cells (SOFC), Molten Carbonate Fuel Cells (MCFC), Alkaline Fuel Cells (AFC), and **Phosphoric Acid Fuel Cells (PAFC)** have also been used. The United States, Germany, and Japan have the greatest number of stationary fuel cell power stations.

CONCLUSION: -

Fuel cell is a promising and competent power generation technique. It is anticipated that the future power market will be a combination of centralized power generation and DG with small to medium scales. Fuel cell technologies will play an important role in the future development of distributed generation.

All fuel cell types currently still suffer from high capital costs. If fuel cells can realize their target cost reduction and continue to demonstrate their anticipated wide range applicability, they will become a successful candidate for different applications, such as stationary, space, portable and transportation applications including locomotive and marine.

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