Proton Exchange Membrane Fuel Cells (PEM) Alternative Fuel Resource

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Abstract— One of the major sources of power is the engines. These are presently used for transport and for other applications. The fuels to these engines are nothing but the products obtained from fractional distillation of petroleum. Incomplete combustion produces carbon monoxide which depletes the ozone layer. These are the problems our environment faces today. Since there are more kinds of fuel cells, this paper has been narrowed down to PEM fuel cell which uses only hydrogen as a fuel to produce power. Hydrogen is available in plenty. The bye product is nothing other than water. So there is no hazard to environment. Same water can be used to produce hydrogen by passing current into water. It does not create any noise pollution as like a generator. These are some points to be highlighted in PEM fuel cells.

Key words: Proton Exchange Membrane Fuel Cells (PEM), Fuel Resource

I. INTRODUCTION

Energy is the most important thing for the present society. Our work, leisure and economic and social welfare depend on this sufficient and uninterrupted supply of energy. The oil we obtain from fossil fuels is ultimately limited and there is a growing increase in demand. More over the hazardous emissions are there in this present fuel. These have a negative impact on the global climate change. The European "World Energy technology and climate policy outlook" (WETO), predicts an average growth of energy requirement is1.8% per annum. Currently the CO_2 emissions by developing nation are 20% of major industrial nations. But by 2030, this will account to more than half of world's CO_2 emission. A coherent energy strategy is required due to the depletion of fossil fuel resource and also due to the hazardous emission. As a solution for all these above said inconveniences, component manufactures, transport providers, energy industry and even the house holders are looking at alternative source of energy, which will be reliable and a clean technology, especially the fuel cells using hydrogen as fuel.

II. PEM FUEL CELLS

A. *PEM Fuel Cell History*

Proton Exchange Membrane(PEM) fuel cells were invented by General Electric in 1960s, through the work of Thomas Grubb and Leonard Niedrach. This was developed for the U.S. Navy and the U.S. army signal corps. The hydrogen fuel was generated by mixing water and lithium hydride. This was expensive since platinum catalyst was used. When these were tried in a space shuttle program of NASA, they failed. Hence Alkali cells were replaced instead of hydrogen cells. GE redesigned and gave a new model p3. In 1970's it was used by the British royal navy as an oxygen generating plant for their submarines. Recently, the fuel cells have come with less platinum usage and also with a coating of weather proofing to strengthen their electrolyte.

B. *PEM Fuel Cell Technology*

PEM (Polymer electrolyte membrane (PEM) fuel cells—also called proton exchange membrane) fuel cells work with a polymer electrolyte in the form of a thin, permeable sheet. This membrane is small and light and it works at low temperatures about 80 degrees C. To speed up the reaction, platinum is used as catalyst on both sides of membrane. Hydrogen atoms ionize at anode and protons pass towards the cathode.

The electron passes through the external circuit and produce power. At cathode these electrons combine with hydrogen proton and oxygen from atmosphere producing water. The important thing to be noted here is that this electrolyte membrane must allow protons but not the electrons and other gases. The efficiency of PEM cells reach upto 50%. Currently 50kw power can be produced. Further researches are made to produce upto 250kw power.

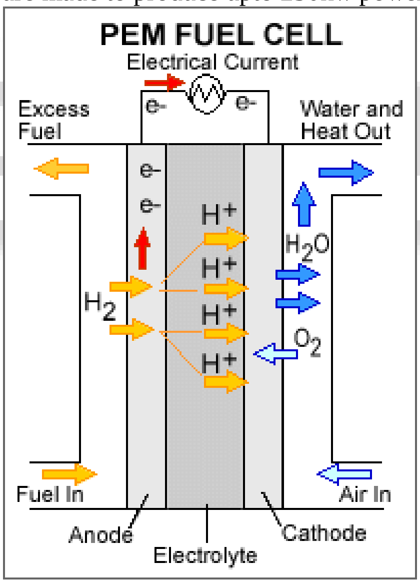


Fig. 1: Fuel Cell Technology

III. COMPONENTS OF PEM FUEL CELLS

A. *Fuel Cell Stack*

A single fuel cell is only capable of producing only about 1 volt. Hence these fuel cells are stacked together to produce more voltage. Many such stacks are connected in series or parallel to get the required voltage. The basic components of a fuel cell stack are given below. Apart from these it contains additional components required for electrical connection and insulation.

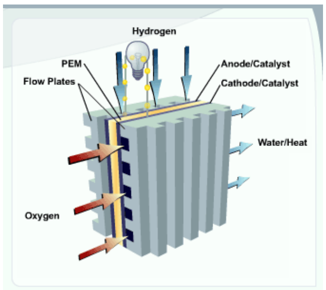


Fig: 2: Fuel Cell Stack Arrangement

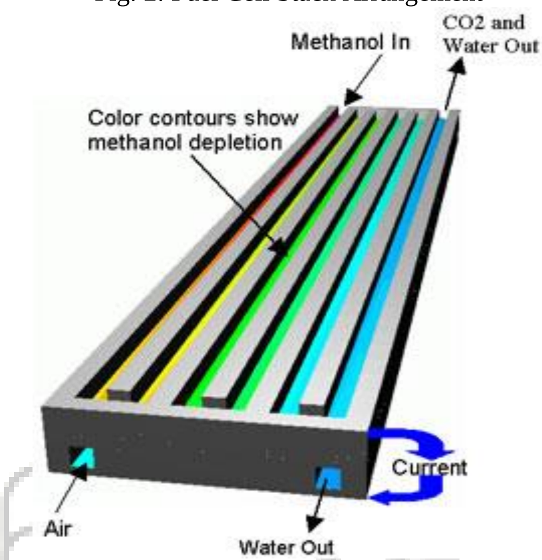


Fig. 3: Methanol depletion contours

1) *Electrolyte*

In PEMFC, the electrolyte acts as a separating layer that separates proton and electron. It acts as a barrier for other gases to enter the compartments of fuel cell.

2) *Electrode*

It is the medium through which the electric current leaves or enters. It can be a solid or electrolytic solution or even a gas. Anode is the place where oxidation occurs and cathode is the place where reduction occurs.

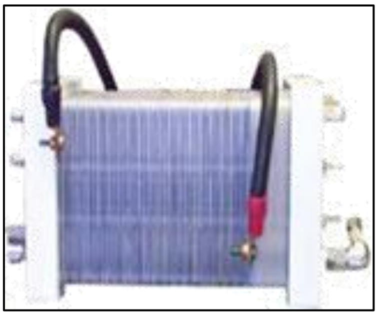


Fig: 4: Arrangement of Electrode

3) *Catalyst*

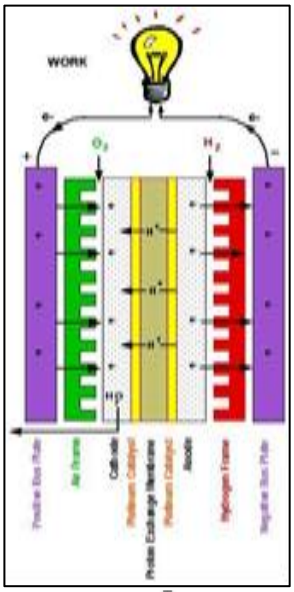
It is the chemical used to increase the rate of reaction by decreasing the energy of activation. This can be recovered chemically unchanged after the reaction.

4) *Bipolar Plates or Separator Plates*

Often the two current collectors and the separator plate combine into a single unit called bipolar plate. These conductive plates in a fuel cell stack that acts as a anode for one cell and cathode for adjacent cell. The plate is usually a conductive polymer and has channels for flow and conduits for heat transfer.

IV. WORKING OF PEM FUEL CELLS

A. *PEM Schematics*



Anode: $2H_2 \longrightarrow 4H^+ + 4e^-$
Cathode: $4H^+ + 4e^- + O_2 \longrightarrow 2H_2O$
Over all: $2H_2 + O_2 \longrightarrow 2H_2O$

Fig. 5: Working of PEM Fuel Cells

At anode the hydrogen molecules give up electrons and form hydrogen ions, a process that is made possible by platinum catalyst.

- The proton exchange membrane allows protons to flow through, but not electrons. As a result the hydrogen ions flow directly through the proton exchange membrane to the cathode, while the electrons flow through the external circuit.
- As they travel through the external circuit, the electrons produce electric current. This current can be used to run an electric drive.
- At cathode, the electrons and hydrogen combine with oxygen to form water.
- In a fuel cell, hydrogen's natural tendency to oxidize and form water, besides producing electricity.
- No pollution since the bye products are water and heat.

V. FUELS FOR PEM FUEL CELLS

A. *Fuel Requirements*

A fuel is a high energy substance that can be consumed to produce useful work. Examples include gasoline used to propel an automobile and coal used to generate electricity at a power plant. In theory, any substance that is capable of being chemically oxidized at a sufficient rate at the anode of the fuel cell may be used as a fuel. In the same sense, any substance that is capable of being reduced at the cathode of the fuel cell at a sufficient rate may be used as an oxidant. Hydrogen is the best fuel for PEM fuel cells.

B. *Why Hydrogen Fuel?*

Hydrogen is a chemical that can be produced using any primary energy source. Its use as a fuel could lead to lower emissions of pollutants and greenhouse gases. It is an energy carrier. The oxidation of hydrogen is a simple and environmentally benign reaction that makes zero emissions power systems possible initially, it will be produced using existing energy systems based on different conventional primary energy carriers and sources. In the longer term, renewable energy sources will become the most important source for the production of hydrogen.

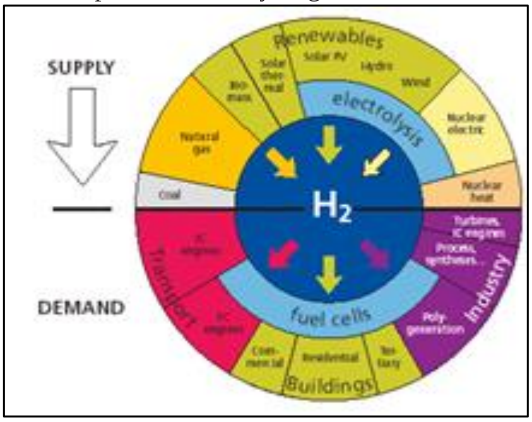


Fig. 6: Hydrogen: Primary Energy Sources, Energy Converters And Applications

C. Sources of Hydrogen

One key advantage of using hydrogen as a fuel is that virtually any primary energy source can be used to generate it. Potential sources of hydrogen include, such as fossil fuels (coal, oil, or natural gas), a variety of chemical intermediates (refinery products, ammonia, methanol), and alternative resources such as bio-mass, bio-gas, and waste materials. Reforming hydrocarbons such as methane, natural gas or methanol through a series of chemical reactions can produce hydrogen. Hydrogen can also be produced by water electrolysis, which uses electricity to split hydrogen and oxygen elements. The electricity for the water electrolysis can be generated from conventional sources or from renewable sources.

A potential breakthrough in hydrogen production would be the discovery of an efficient and cheap photo catalyst, a substance that directly harnesses the energy in solar radiation to electrolyze water and thus produce hydrogen. This type of hydrogen generation systems could allow hydrogen power to realize its full potential of emissions reduction in a cheaper and more efficient manner than any other non-polluting generating technique.

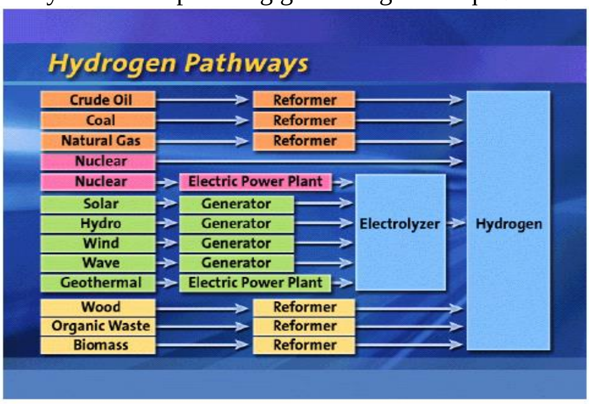


Fig: 7: Source of Hydrogen.

D. Hydrogen Economy

The emergence of a true hydrogen economy, based upon hydrogen for energy storage, distribution, and utilization would be a major advantage for the wide spread application of fuel cells. Although there is already an existing manufacturing, distribution, and storage infrastructure of hydrogen, it is limited. The infrastructure costs associated with a large scale hydrogen distribution, is often cited as the major disadvantage for the wide spread use of hydrogen as “a major world fuel and energy vector”. In addition there are concerns that because of the relatively low density of hydrogen it is not viable for energy storage, particularly in mobile applications, and there is also concern in regard to the safety of hydrogen.

It can be argued however, that with good integration practices for both distributed fuel cell power supplies and mobile power applications, natural gas or off peak electricity can initially be used for hydrogen production, removing the initial requirement for the large infrastructure costs associated with a hydrogen distribution system. In this case, the hydrogen can be produced as needed, in quantities to match the incremental growth of fuel cells applications. The reforming of natural gas and the use of electricity from coal fired power plants can be used as an intermediate step and does not constrain the hydrogen use to a particular fuel type

VI. HYDROGEN STORAGE

Once the H_2 molecule has been separated from fuel, it must be stored in the vehicle.

There are three methods of hydrogen storage options as viable storage within vehicles. They are storage as a liquid, storage as a gas, and storage in nanotubes. At room temperature and pressure, hydrogen takes up some 3,000 times more space than gasoline containing an equivalent amount of energy. Hydrogen storage systems need to enable a vehicle to travel 300 to 400 miles and fit in an envelope that does not compromise storage space.

The most mature storage options are liquefied hydrogen and compressed hydrogen gas.

1) Liquid hydrogen
2) Compressed hydrogen

A. Liquid Hydrogen

Liquid hydrogen is widely used today for storing and transporting hydrogen. They have high energy density, are easier to transport, and are typically easier to handle. Hydrogen, however, is not typical. It becomes a liquid only at -423 °F, just a few degrees above absolute zero. It can be stored only in a super-insulated cryogenic tank. Some 40% of the energy of the hydrogen is required to liquefy it for storage. Liquefying one kg of hydrogen using electricity release some 18 to 21 pounds of carbon dioxide into the atmosphere, roughly equal to the carbon dioxide emitted by burning one gallon of gasoline.

B. Compressed Hydrogen

Compressed hydrogen storage is used by all hydrogen vehicles today. Hydrogen is compressed up to pressures of 5,000 pounds per square inch (psi) or even 10,000 psi in a multistage process that requires energy input equal to 10% to 15% of the hydrogen's usable energy content. Working at such high pressures creates overall system complexity and requires materials and components that are sophisticated and costly. And even a 10,000-psi tank would take up 7 to 8 times the volume of an equivalent-energy gasoline tank (since the fuel cell vehicle will be more fuel efficient than current cars).

C. *Nanotubes*

Nanotubes consist of complicated carbon chain arrangements which permit hydrogen storage. Basically, hydrogen is adsorbed in a nanotube by a vaporized carbon material. The limiting factor for material and nanotube storage of hydrogen is the material density. The more dense the material, the less hydrogen it will accept into its structure. However, if the material has a large specific volume, it might not be stable enough to retain its own structure. Nanotubes can range from 4-65wt% hydrogen.

VII. FUEL REFORMING

Fuel reforming is required in order to produce useful hydrogen rich gas from another source. Most of the hydrogen currently reduced on the industrial scale is through the steam reforming of natural gas, which produces carbon dioxide as a byproduct. While this method of hydrogen production is generally the most economic, it is not sustainable in the long term and can serve only as an intermediate step, as is the same for all fossil fuels.

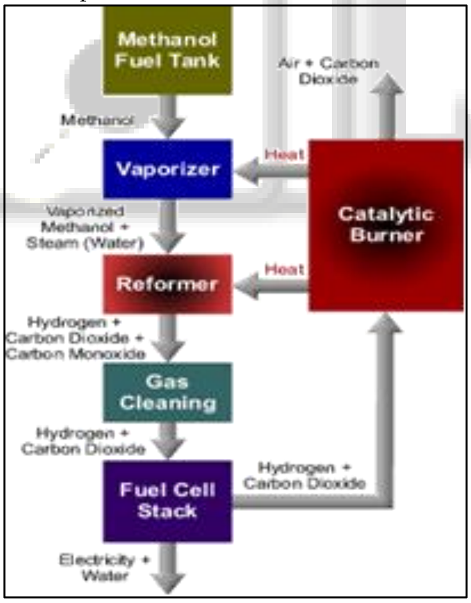


Fig. 8: Process of fuel reforming
Typical Fuel Reformer

A. *Need for Fuel Reformer*

Argonne National Laboratory has developed a fuel processor (or reformer) that can efficiently convert methanol, ethanol, natural gas, gasoline, and diesel into hydrogen that can be fed to a fuel cell to produce electricity. The fuel processor produces high-quality hydrogen fuel within two minutes of startup and at temperatures that are several hundreds of degrees centigrade below those required for reformers based on a noncatalytic reaction. This fuel flexibility, shorter startup time, and lower operating temperatures will help make fuel-cell-powered automobiles practical.

The fuel reformer will allow fuel-cell-powered cars to run on conventional fuels, rather than on pure hydrogen, making them more attractive to consumers. With a recent improvement in the catalyst, the reformer can be 25 times smaller than previous models, making it less expensive, less of a drain on fuel economy, and easier to integrate into a car. Unlike most conventional catalysts which are poisoned by sulfur, the Argonne catalyst tolerates the sulfur present in petroleum-derived fuels.

B. *Advantages*

1) Low emission to environment
2) The chemical fuel can be produced easily
3) Outlet of the emission is water only
4) Can also used for domestic purpose

VIII. CONCLUSION

Thus we have seen about the PEM fuel cells, their working principle, construction, with some other details. This is one field which is growing silently. A large unexplored portion lies before us in near future. With this basic idea, we shall do our best to implement these as major power producing units. Let's hope our future will be free from pollution causing gases and a stage will come where each house or an industry produces power itself using these fuel cells.

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