CONCEPT OF HYDROGEN FUEL CELL TECHNOLOGY

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Abstract – *The aim of this report is conception of Hydrogen Fuel Cell Technology. A Hydrogen fuel cell is an electrochemical power generator that combines hydrogen and oxygen to produce electricity, with water and heat as by products. Simply put, hydrogen fuel cells form energy that can be used to power anything from commercial vehicles to drones.*

Key Words: Fuel Cell, FCEV, Stack Construction, PEM, Model.

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. 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.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.

HISTORY:

Hydrogen fuel technologies are not new, a hydrogen mixture was widely used as gas for street lamps in the 1800s, and the first cell was inverted by Sir William Robert Grove in 1839.

Within a fuel cell, hydrogen and oxygen are converted into heat and water, producing electricity in the process. This is quite similar to the wide array of batteries that we commonly use.

Currently, there are thousands of stationary fuel cell systems worldwide generating power for a wide variety of industrial and commercial applications, from utilities and hospitals to hotels and college campuses.

TYPES OF FUEL CELLS:

Types of fuel cells differ primarily by the type of electrolyte they employ. The type of electrolyte, in turn, determines the operating temperature, which varies widely between types. One is high-temperature fuel cells and another is low temperature fuel cells.

High-temperature fuel cells operate at greater than 1100 ^{0}F (600 ^{0}C). These high temperatures permit the spontaneous internal reforming of light hydrocarbon fuels such as methane into hydrogen and carbon in the presence of water.

Low-temperature fuel cells typically operate below 480 ^{0}F (250 ^{0}C). These low temperatures do not permit internal re-forming, and therefore require an external source of hydro-gen.

The most prominent high-temperature fuel cells are:

- Molten carbonate
- Solid oxide

The most prominent low-temperature fuel cells are:

- Alkaline
- Phosphoric Acid
- Proton exchange membrane

A.1 Molten Carbonate Fuel Cells:

Molten carbonate fuel cells use an electrolyte that conducts carbonate (CO_3^{2-}) ions from the cathode to the anode. This is the opposite of many other types of fuel cells, which conduct hydrogen ions from the anode to the cathode.

The electrolyte is composed of a molten mixture of lithium and potassium carbonates. This mixture is retained by capillary forces within a ceramic support matrix of lithium aluminate. At the fuel cell operating temperature, the electrolyte structure is a thick paste, and the paste provides gas seals at the cell edges.

Molten carbonate fuel cells operate at about 1200 ^{0}F (650 ^{0}C) and a pressure of 15 to 150 psig (1 to 10 barg). Each cell can produce up to between 0.7 and 1.0 VDC.

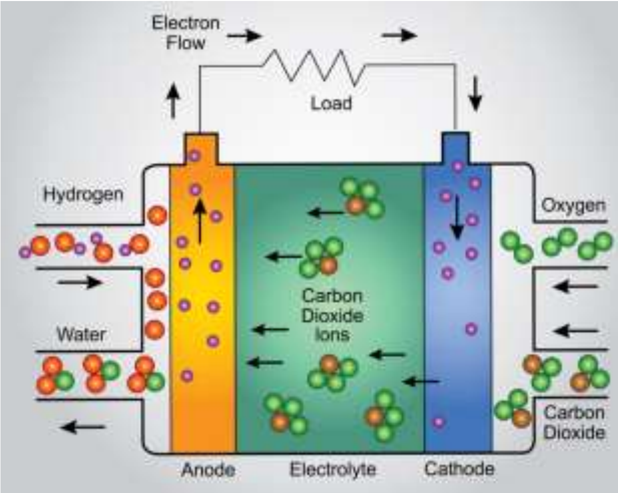

Fig-1 Molten Carbonate Fuel Cells Diagram

Advantages of Molten Carbonate Fuel Cells:

- It has support spontaneous internal reforming of light hydro-carbon fuels.
- It has generate high-grade waste heat.
- It has fast reaction kinetics.
- It has high efficiency.

Disadvantages of Molten Carbonate Fuel Cells:

- It has a liquid electrolyte, which introduces liquid handling problems.
- It has require a considerable warmup period.
- It has a high intolerance to sulphur. The anode in particular cannot tolerate more than 1-5 ppm of sulphur compounds in the fuel gas without suffering a significant performance loss.

A.2 Solid Oxide Fuel Cells:

Solid oxide fuel cells use an electrolyte that conducts oxide (O^{2-}) ions from the cathode to the anode. This is the opposite of most types of fuel cells, which conduct hydrogen ions from the anode to the cathode.

The electrolyte is composed of a solid oxide, usually zirconia (stabilized with other rare earth element oxides like yttrium), and takes the form of a ceramic.

Solid oxide fuel cells operate at about 1830 ^{0}F (1000 ^{0}C) and a pressure of 15 psig (1 barg). Each cell can produce be-tween 0.8 and 1.0 VDC.

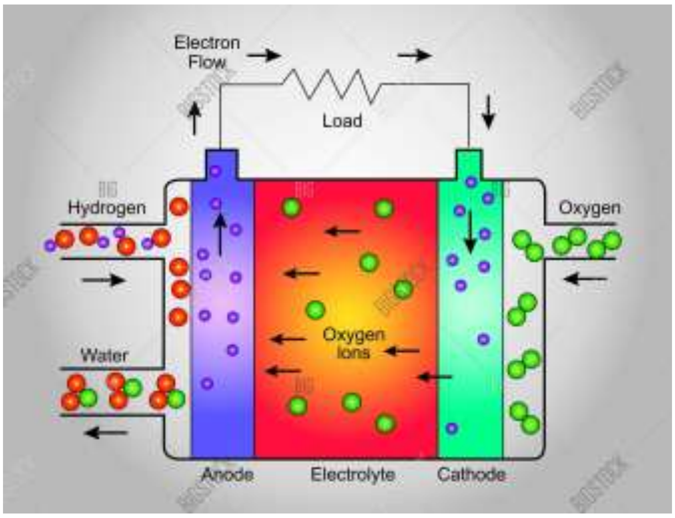

Fig-2 Solid Oxide Fuel Cells Diagram

Advantages of Solid Oxide Fuel Cells:

- It has support spontaneous internal reforming of hydrocarbon fuels.
- It operate equally well using wet or dry fuels.
- It has generate high-grade waste heat.
- It has fast reaction kinetics.
- It has very high efficiency.
- It can be operate at higher current densities than molten carbonate fuel cells.
- It has a solid electrolyte, avoiding problems associated with handling liquids.

Disadvantages of Solid Oxide Fuel Cells:

- It has require the development of suitable materials that have the required conductivity, remain solid at high temperatures, are chemically compatible with other cell components, are dimensionally stable, have high endurance and lend themselves to fabrication.
- Do not yet has practical fabrication processes.
- The technology is not yet mature.

B.1 Alkaline Fuel Cells:

Alkaline fuel cells use an electrolyte that conducts hydroxyl (OH^-) ions from the cathode to the anode. This is opposite to many other types of fuel cells that conduct hydrogen ions from the anode to the cathode.

The electrolyte is typically composed of a molten alkaline mixture such as potassium hydroxide (KOH). The electrolyte can be mobile or immobile.

Alkaline fuel cells operate at about 150 to 430 ^{0}F (65 to 220 ^{0}C) and a pressure of about 15 psig (1 barg). Each cell can produce up to between 1.1 and 1.2 VDC.

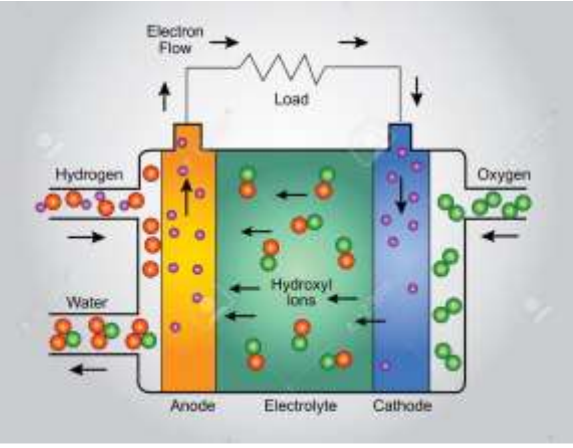

Fig-3 Alkaline Fuel Cells Diagram

Advantages of Alkaline Fuel Cells:

- This fuel cells operate at low temperature.
- It has high efficiency.
- This needs little or no expensive platinum catalyst.
- It has minimal corrosion.
- It has relative ease of operation.
- It has low weight and volume.

Disadvantages of Alkaline Fuel Cells:

- It has a liquid electrolyte, introducing liquid handling problems.
- It has require complex water management.
- It has a relatively short lifetime.

B.2 Phosphoric Acid Fuel Cells:

Phosphoric acid fuel cells use an electrolyte that conducts hydrogen ions (H+) from the anode to the cathode. As its name implies, the electrolyte is composed of liquid phosphoric acid within a silicon carbide matrix material.

Phosphoric acid fuel cells operate at about 300 to 400 ^{0}F (150 to 205 ^{0}C) and a pressure of about 15 psig (1 barg). Each cell can produce up to about 1.1 VDC.

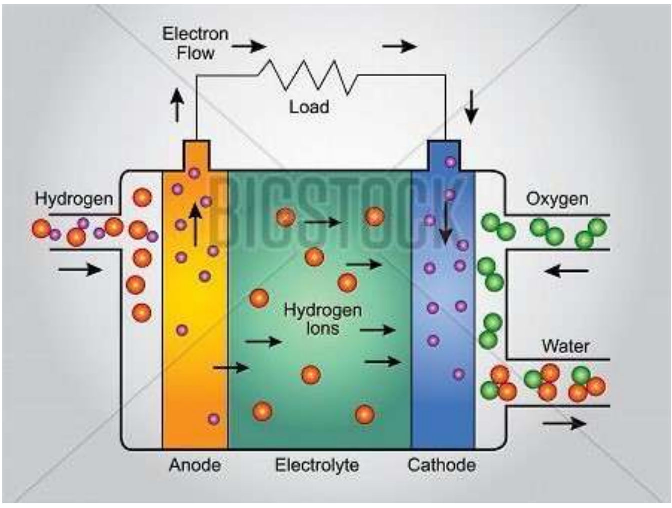

Fig-4 Phosphoric Fuel Cells Diagram

Advantages of Phosphoric Fuel Cells:

- This process has tolerant of carbon dioxide. As a result, phosphoric acid fuel cells can use un-scrubbed air as oxidant, and reformate as fuel.
- It has operate at low temperature, but at higher temperatures than other low-temperature fuel cells. Thus, they produce higher grade waste heat that can potentially be used in co-generation applications.
- It has stable electrolyte characteristics with low volatility even at operating temperatures as high as 392 � (200�).

Disadvantages of Phosphoric Fuel Cells:

- This type of fuel cells can tolerate only about 2% carbon monoxide.
- It can be tolerate only about 50 ppm of total sulphur compounds.
- It's use a corrosive liquid electrolyte at moderate temperatures, resulting in material corrosion problems.
- It have a liquid electrolyte, introducing liquid handling problems. The electrolyte slowly evaporates over time.
- This type of fuel cells are large and heavy.
- It cannot auto-reform hydrocarbon fuels.

B.3 Proton exchange Membrane Fuel Cells:

Proton exchange membrane (PEM) fuel cells use an electrolyte that conducts hydrogen ions (H+) from the anode to the cathode. The electrolyte is composed of a solid polymer film that consists of a form of acidified Teflon.

PEM fuel cells typically operate at 160 to 195 ^{0}F (70 to 90 ^{0}C) and a pressure of 15 to 30 psig (1 to 2 barg). Each cell can produce up to about 1.1 VDC.

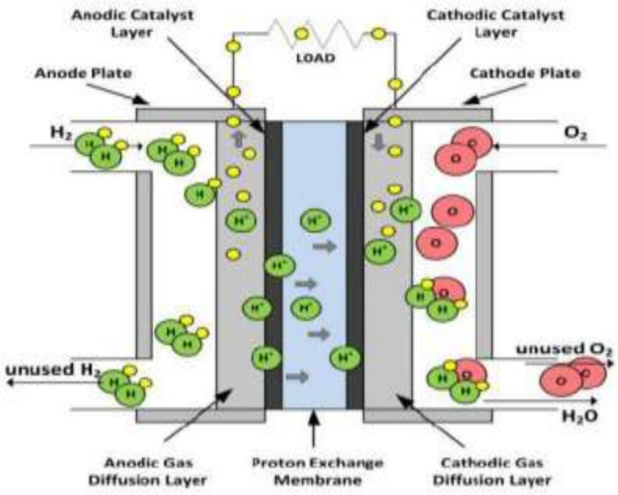

Fig-5 Proton Exchange Membrane (PEM) Fuel Cells Diagram

Advantages of PEM Fuel Cells:

- PEM fuel cells are tolerant of carbon dioxide. As a result, PEM fuel cells can use un-scrubbed air as oxidant, and reformate as fuel.
- This can operate at low temperatures. This simplifies materials issues, provides for quick start up and increases safety.
- It has high voltage, current and power density.
- These Fuel cells are compact and rugged.
- It has relatively simple mechanical design.

Disadvantages of PEM Fuel Cells:

- It can tolerate only about 50 ppm carbon monoxide.
- It can tolerate only a few ppm of total sulphur compounds.
- These fuel cells need reactant gas humidification.
- It uses an expensive platinum catalyst.
- It uses an expensive membrane that is difficult to work with.

PEM Fuel Cell Stack Construction:

Individual fuel cells have a maximum output voltage on the order of 1 VDC. Substantial voltages and power outputs are obtained by connecting many cells electrically in series to form a fuel cell stack, much like a loaf of sliced bread. Different designs of fuel cell stacks, use fuel cells of varying dimensions and in varying quantities.

1. Membrane Electrode Assembly:

A membrane electrode assembly (MEA) is an assembled stack of proton exchange membrane (PEM) or alkali anion exchange membrane (AAEM), catalyst and flat plate electrode used in fuel cells and electrolysers.

The MEA is the heart of the fuel cell. The MEA consists of a solid polymer electrolyte membrane sandwiched between two porous carbon electrodes. The electrode assemblies often include integral seals where they contact adjacent components.

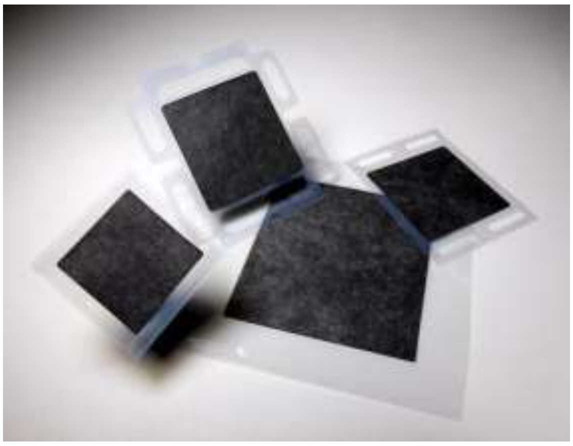

Fig- 6 Membrane Electrode Assembly

2. Flow Field Plates:

The flow field plates are designed to provide an adequate amount of the reactants to the gas diffusion layer and catalyst surface while minimizing pressure drop. The flow field plates channel fuel and oxidant to opposite sides of the MEA.

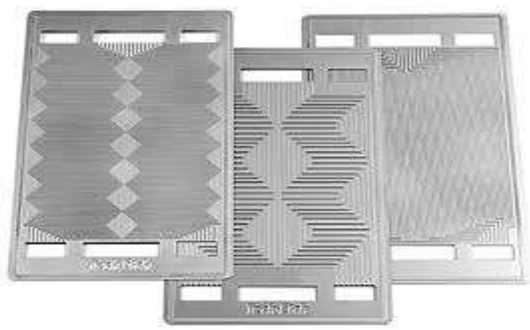

Fig- 7 Flow Field Plates

Each flow field plate contains a single gas channel of serpentine design that maximizes gas contact with the MEA. The specific shape of the gas channels is critical for uniform power generation, stable cell performance and correct product water management. Different flow field plate designs are tailored to various fuel cell applications.

3. Humidifiers:

Humidifiers provide heat and humidity to the incoming oxidant or hydrogen fuel steam of fuel cells and are critical to overall system performance and reliability. Without humidification, the fuel cell membrane becomes too dry and reduces the proton transport in the fuel cell stack and decreases the oxygen reduction reaction at the cathode – resulting in poor fuel cell function or even failure.

Fig – 8 Humidifiers

4. Hydrogen Fuel Cell Electric Vehicle Layout:

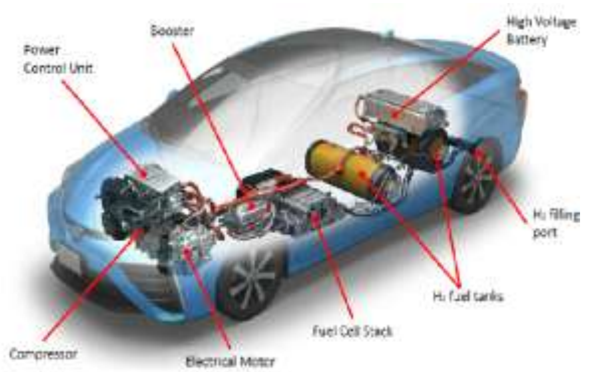

Fig – 9: FCEV Layout

Advantages of HFC:

- It offers an effective method of energy storage.
- This technology offers a high level of energy efficiency.
- The emissions from a hydrogen fuel cell are virtually zero.
- Vehicles using a hydrogen fuel cell achieve a better fuel economy rating.
- It has create greater level of consistency with hydrogen fuel cells.
- It is possible to create hydrogen fuel cells with a natural emissions cost.
- A hydrogen fuel cell provides us with energy flexibility.
- Hydrogen fuel cells are a safe technology for us to use in virtually any situation.
- This technology can reduce the risk of chemical exposure by using hydrogen fuel cells.

Disadvantages of HFC:

- Hydrogen fuel cells do not work in every situation as of yet.
- It must be regulated the temperature of a hydrogen fuel cell to maximize its use.
- There are still some risks to the environment to consider with hydrogen fuel cells.
- The cost to store hydrogen is expensive enough that it is prohibitive for most people.
- There are transportation losses to consider with hydrogen as well.
- It costs more to transport hydrogen than it does most other fuels.
- This technology is not widely available right now.
- It is not currently a complete renewable energy resource.

5. Model Name of HFCV:

Fig – 10: Hyundai TUCSON

Fig – 11: Honda Clarity

Fig – 12: Chevrolet Colorado ZH2

Fig – 13: Hyundai ix35

Fig – 14: Hyundai NEXO

Fig – 15: Toyota Mirai

Fig – 16: Toyota FCV Plus

Fig – 17: Toyota SORA – Fuel Cell Bus

Conclusion:

As the demand for electrical power grows, it becomes increasingly urgent to find new ways of meeting it both responsibly and safely. In the past, the limiting factors of renewable energy have been the storage and transport of that energy. With the use of fuel cells and hydrogen technology, electrical power from renewable energy sources can be delivered where and when required, cleanly, efficiently and sustainably.