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Comparative study on different types of fuel cell

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Abstract— *Nowadays, the use of non-conventional sources is increased as compared to the use of conventional sources to generate electricity. The commonly used sources are wind, tidal, solar, biomass energy, etc. But the use of fuel cell can play a vital role in producing electricity. Fuel cell is an electro chemical cell which converts the chemical energy of the fuel combined with an oxidizing agent to form electricity through a pair of redox reactions. This paper shows a comparative study of different types of fuel cell along with its advantages, disadvantages, applications and importance in the industry.*

Keywords—Solid oxide fuel cells, Alkaline fuel cells, Molten carbonate fuel cells, Phosphoric acid fuel cells, fuel cell.

I. INTRODUCTION

Fuel cells are classified initially by the type of electrolyte they employ. This given classification determines which type of electro-chemical reactions happen in the cell and the which kind of catalyst is required for the temperature range in which the cell can operate, the fuel required, other factors, etc. This characteristic also affects the applications for which these type of cells are largely suitable. There are several other types of fuel cells which were currently under development, each having its own advantages, disadvantages, and applications.

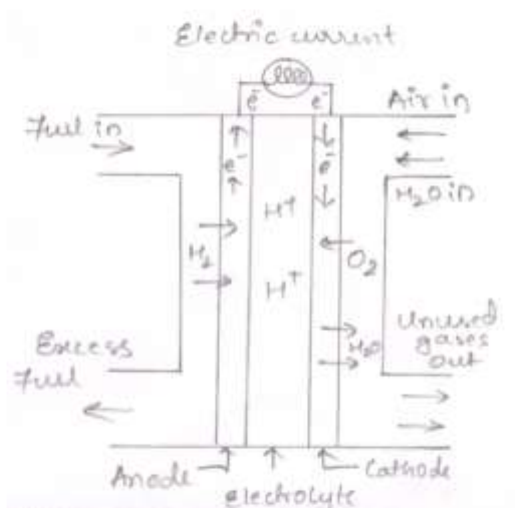

FIGURE 1: Fuel cell

II. ALKALINE FUEL CELLS

Alkaline fuel cells also called as AFC was one of the very first fuel cell technology developed, and they were the first type which was widely used in U.S. space program to produce source of electrical energy and water on the board spacecraft. These fuel cells were used as a solution to potassium hydroxide in the water as an electrolyte and they can also be used as a variety of common metals and a catalyst at the anode and/or cathode. In recent years, novel AFC were developed as a polymer membrane which acted like an electrolyte. AFC can be closely related to Proton exchange membrane (PEM) fuel cells. The only difference is AFC use alkaline membrane and PEM use acid membrane. AFC has high performance rate as compared to other fuell cells because of

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its rate at which the electro-chemical reactions occur in the cell. It can also be demonstrated that AFC have 60% efficiency in space applications.

This type of AFC cell face major challenge is viable to poisons gas such as CO2. Even a small portion of CO2 present in the air can majorly affect fuel cell performance and its durability because of the carbonate formation. Alkaline fuel cells with electrolytes in liquid form can be operated in recirculating mode, which allows the electrolyte for regeneration and it helps to reduce the effects from carbonate formation used in the electrolyte, but the recirculation mode also introduces issues with the shunt currents. The electrolyte systems in liquid form also suffer from major additional concerns which include wetness, increased level of corrosion, and difficulties in handling the differential pressures. Alkaline membrane fuel cells (AMFCs) are used to address such type of concerns and they have lower susceptibility to CO2emmision poisoning than the liquid-electrolyte AFCs. However, CO2 gas still affects its performance and the durability of AMFCs still lag then that of PEMFCs. AMFCs can be used for the applications in Watt to kilo Watt scale. Various challenges faced by AMFCs are membrane conductivity, tolerance to carbon dioxide, durability, operation in higher temperature, waste water management, power density.

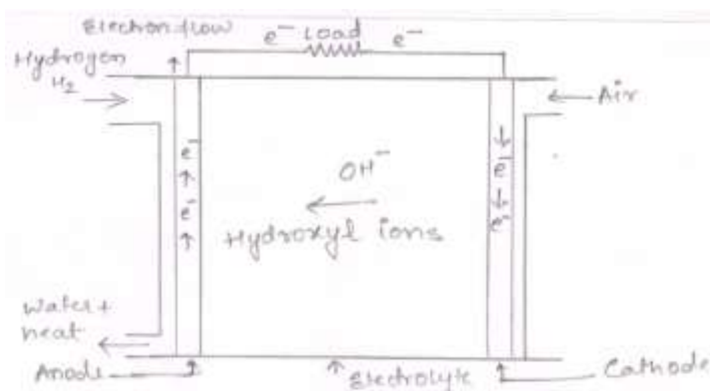

FIGURE 2: Alkaline fuel cell

III. MOLTEN CARBONATE FUEL CELLS

Molten carbonate fuel cells (MCFCs) are currently being under high pressure for natural gas and coal-based power plants for generation of electricity for utility, industrial application etc. MCFCs are operated at very high temperature based fuel cells that are used like an electrolyte composed of molten carbonate and mixture with salt suspended in a porous and chemically inside ceramic lithium aluminum oxide matrix. Because they can be operated at very high temperatures of the range 650°C, non-precious metals that can be used as catalysts at the side of anode and cathode. This also reduces costs.

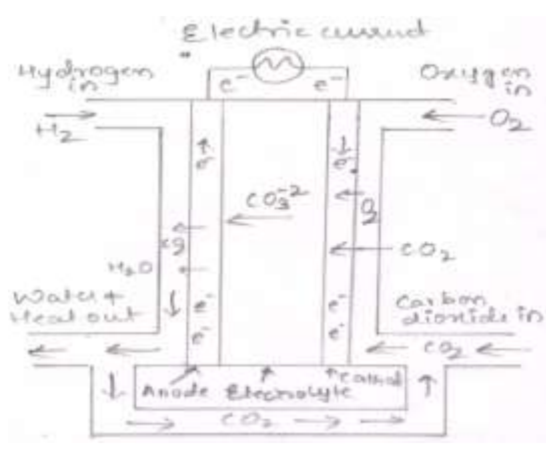

FIGURE 3: Molten carbonate fuel cell

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Increased efficiency is one more reason for which the MCFCs offer significant reductions in cost as compared to phosphoric acid fuel cells. Molten carbonate fuel cells (MCFC), when operated with a turbine, it can reach efficiencies approximately upto 65%, considerably greater than phosphoric acid fuel cell plants. When the waste heat is collected and used its overall efficiencies can be increased over 85%. Unlike the AFCs, PAFCs, PEM fuel cells, molten carbonate fuel cells MCFCs do not require any external reformer to convert its fuels such as natural and biogas to hydrogen. At the very high temperatures in which the MCFCs operate, methane and other such light hydrocarbons in such fuels can be converted in to hydrogen within the cell itself by a process called internal reforming. This helps to reduce the cost.

The main disadvantage of current molten carbonate fuel cells technology is its durability. In the high temperatures at which such cells operate and corrosive electrolyte they use accelerate the component breakdown and its corrosion. This results in decrement of cell life.

IV. PHOSPHORIC ACID FUEL CELLS

Phosphoric acid fuel cells (PAFCs) are used in liquid form of phosphoric acid which is an electrolyte. This acid is filled in a Teflon coated silicon carbide matrix sheet and porous carbon electrodes contain a platinum catalyst. The PAFC (Phosphoric acid fuel cells) is determined as the very "first generation" of modernize fuel cells. It is said as one of the most mature type of cells and it is considered to be used commercially for first time. This type of fuel cell is basically used for the power generation which is stationary, but some of the PAFCs have also been used to provide power in large vehicles. City buses are one of the best examples where PAFCs are used.

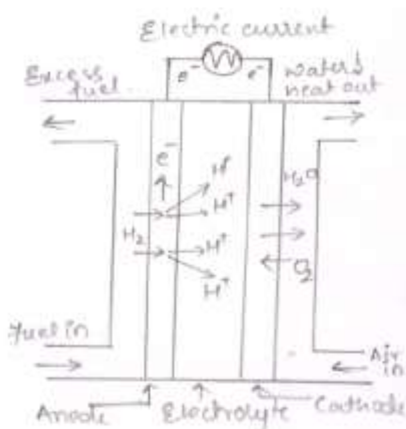

FIGURE 4: Phosphoric acid fuel cell

PAFCs have more tolerance to sustain the impurities in fossil fuels that are transformed into hydrogen (H2) from the PEM cells. This hydrogen can be easily poisoned by the use of carbon monoxide as they bind to the platinum which is used as a catalyst at the anode. This decreases the efficiency of fuel cell. The efficiency of PAFCs is approximately 85% when they are co-generated with some other sources for generation of electricity and heat. But, when they are used solemnly then they have the efficiency of around 37-42% only. When we use combustion based power plants, with the use of PAFCs we can increase the efficiency more than 33%. PAFCs are large and heavy because they prove less powerful when prone to same weight and volume as compared to other fuel cells. This makes PAFCs more expensive. The cost increases further when expensive catalyst like platinum is used with higher loading.

V. SOLID OXIDE FUEL CELLS

Solid oxide fuel cells (SOFCs) are used in hard form. It is non-porous ceramic compound in nature which is used as the electrolyte. SOFCs have efficiency around 65% when it is used to generate electricity. The applications in which the waste heat is captured and then utilized which is also referred to as co-generation, the efficiency increases up-to 85%. The operating

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temperature where SOFCs can operate is as high as 1000°C (1,830°F). when it is operated at high pressure and temperature, the use of catalyst can be boycotted, therefore, the overall cost can be reduced. SOFCs can retain the fuel internally, which allows us to use large variety of fuels. This also helps to reduce the cost as the necessity of another component known as reformer can be eliminated from the system.

SOFCs are said to be most sulfur resistant type of fuel cell which can tolerate several powers of more sulfur as compared to other types of fuel cell. In addition to this, they cannot be poisoned with carbon monoxide which can also be used as a fuel. Other sources like natural gas, biogas, and gases made from coal can be used with SOFCs due to the above mentioned property. The disadvantages of operation in high temperature is that it results in low startup. It also requires large thermal shielding to retain its heat which can also be used for utility applications but it cannot be use for transportation. SOFCs have to be more durable when they are working under high temperature conditions. In matter of cost, low cost materials having high durability is the major challenge.

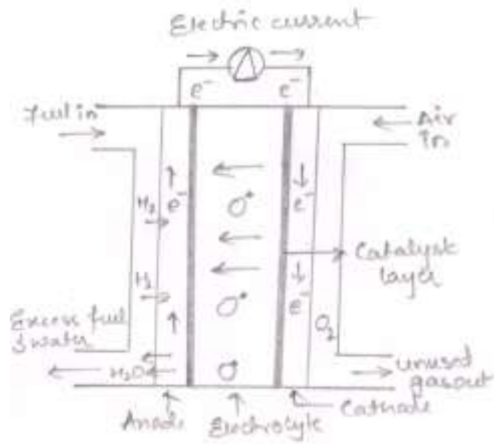

FIGURE 5: Solid oxide fuel cell

VI. TABLE 1

COMPARATIVE STUDY

Parameter	Alkaline fuel cells	Molten carbonate fuel cells	Phosphoric acid fuel cells	Solid oxide fuel cells
Electrolyte	KOH, NaOH + water	High temperature carbonate like sodium / magnesium	Phospheric Acid	Hard ceramic compound like calcium oxide
Efficiency	70%	60 – 80%	40 – 80%	60 %
Operating temperature	150-200 C	650 C	150-200 C	1000 – 1800 C
Cell output	300 W to 5 KW	2 MW	200 KW – 11 MW	100 KW
Catalyst	Potassium	Nickel	Potassium	Pure hydrogen

VII. CONCLUSION

From the above papers, it can be concluded that alkaline fuel cells are majorly used due to its efficient properties. Also, the other fuel cells which are discussed above can be used in the absence of alkaline fuel cell due to its distinct properties. The advancement in the field of fuel cells can be proved very beneficial in the world of science as it can be completely replaced by the ever-growing demand of non-renewable energy sources. Fuel cells are much more compatible then the other renewable energy sources.

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