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Fuel cell technology and usable Energy system for the future

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Abstract— The demand of fuel cell is ever increasing. In view of the depleting natural resources, it is essential that we explore alternative energy sources. The energy sources should be efficient, stable, clean and economical. Also the growth of the country directly depends on the energy resources. Therefore, every country is looking for alternatives for tra1ditional energy sources, being used today. Recently in JAPAN some of the developed countries signed Kyoto protocol under which they agreed to cut the % of emission of harmful gases. Although the traditional energy sources cannot be completely replaced, fuel cells are the most promising option for petrol, diesel, coal etc. We can call the fuel cell the future face of energy. A fuel cell works similar to a battery. A fuel cell can produce electricity as long as more fuel and oxidant is pumped through it there are numerous types of fuel cell that have been made, such as solid oxide (sofc), direct alcohol (dafc), polymer electrolyte (pefc), phosphoric acid (pacfc), molten carbonate (mcfc) & alkaline (afc), The application of Fuel cell ranges from simple batteries, cars to electric generators. dmfc & pefc are the most probable for automotive sector which will out do presence conventional gasoline engines & electric powered engines. sofc &mcfc are the most probable for medium range power plant, are more efficient than conventional small gas turbines. In the near future with extended research work the benefits of both conventional &fuel cell can be utilized by fusing them. The article introduces the concept of 'fuel cell', its working, types, application and research in India and other parts of world.

Keywords— Polymer electrolyte fuel cell, solid oxide fuel cell , molten carbonate fuel cell .

I. INTRODUCTION

If you want to be technical about it, a fuel cell is an electrochemical energy conversion device. A fuel cell convertsthe chemicals hydrogen and oxygen into water, and in the process it produces electricity. The other electrochemical device that we are all familiar with is the 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. With a fuel 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. The fuel cell will compete with many other types of energy conversion devices, including the gas turbine in your city's power plant, the gasoline engine in your car andthe battery in your laptop. Combustion engines like the turbine and the gasoline engine burn fuels and use the pressure created by the expansion of the gases to do mechanical work. Batteries converted chemical energy back into electrical energy when needed. Fuel cells should do both tasks more efficiently. A fuel cell provides a DC (direct current) voltage that can be used to power motors, lights or any number of electrical appliances. There are several different types of fuel cells, each using a different chemistry. The type of electrolyte they use usually classifies fuel cells. Some types of fuel cells work well for use in stationary power generation plants. Others may be useful for small portable application.

A. What is fuel cell?

A fuel cell is a device that converts the chemical energy from a fuel into electricity through a chemical reaction with oxygen or another oxidizing agent.[1] Hydrogen is the most common fuel, but hydrocarbons such as natural gas and alcohols like methanol are sometimes used. Fuel cells are different from batteries in that they require a constant source of fuel and oxygen/air to sustain the chemical reaction; however, fuel cells can produce electricity continually for as long as these inputs are supplied**.**

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II. HOW A FUEL CELL WORKS

A fuel cell works similar to a battery. In a battery there are two electrodes, which are separated by an Electrolyte. At least one of the electrodes is generally made of a solid metal. This metal is converted to another chemical compound during the production of electricity in the battery. The energy that the battery can produce in one cycle is limited by the amount of this solid metal that can be converted. In the fuel cell the solid metal is replaced by an electrode that is not consumed and a fuel that continuously replenishes the fuel cell. This fuel reacts with an oxidant such as oxygen from the other electrode. A fuel cell can produce electricity as long as more fuel and oxidant is pumped through it.

Fig 1 Alkaline fuel cell often uses hydrogen and oxygen as fuel

The alkaline fuel cell as shown in Fig 1 is one of the oldest and most simple type of fuel cell. This is the type of fuel cell that has been used in space missions for some time. Hydrogen and oxygen are commonly used as the fuel and oxidant. The electrodes are made of porous carbon plates which are laced with a catalyst...which is a substance that accelerates chemical reactions. The electrolyte is potassium hydroxide. At the anode, the hydrogen gas combines with hydroxide ions to produce water vapor. This reaction results in electrons that are left over. These electrons are forced out of the anode and produce the electric current. At the cathode, oxygen and water plus returning electrons from the circuit form hydroxide ions which are again recycled back to the anode. The basic core of the fuel cell consisting of the manifolds, anode, cathode and electrolyte is generally called the stack.

III. TYPES OF FUEL CELLS

There are numerous types of fuel cells that have been made. The most common are shown below. Each uses different materials and operates at a different temperature. type

Type	Abbreviation	Operating temp	Uses
Solid Oxide	SOFC	500- 1000°C	All sizes of CHP
Direct Alcohol	DAFC	50-100°C	Buses, cars, appliances, small CHP
Polymer Electrolyte	PEFC	50-100°C	Buses, cars
Phosphoric Acid	PAFC	200°C	Medium CHP
Molten Carbonate	MCFC	600°C	Large CHP
Alkaline	AFC	50-250°C	Used in space vehicles

A. Different types of fuel cells

The solid oxide fuel cell or sofc is the most likely contender for both large and small electric power plants in the 1 kw and above size. The direct alcohol fuel cell or dafc appears to be the most promising as a battery replacement for portable a the polymer electrolyte fuel cell pefc is the most practical if we have a developed hydrogen economy. Applications such as cellular phones and laptop computers many automobile manufacturers however believe that the dafc will be much simpler than the pefc so it will be the winner for vehicular applications. others say that the much higher efficiency of the sofc and its ability to use most any fuel will make it a logical choice for vehicular applications as well. Proponents claim the startup time problem of the sofc can be overcome by using super capacitor batteries for the first few minutes of operation. the phosphoric acid fuel cell pafc has been produced for several years already for medium sized electric power plants. the alkaline fuel cell afc has been used in space applications where hydrogen and oxygen are available. By using carbon dioxide scrubbers, several of these fuel cells are being operated successfully on hydrogen and air.

1) Direct Alcohol Fuel Cell (DAFC)

In this type of fuel cell, either methyl DMFC or ethyl DEFC alcohol is notreformed into hydrogen gas but is used directly in a very simple type of fuel cell. Its operating temperature of 50-100°C is low and so is ideal for **tiny** to midsize applications. Its electrolyte is a polymer or a liquid alkaline. . Efficiencies of the DMFC are much higher and predicted efficiencies in the future may be as high as 40% [6] for a DC automobile power plant. It is expected that the DMFC will be moreefficient than the PEFC for automobiles that use methanol as fuel. Fuelcrossingover from the anode to the cathode without producing electricity is one problem that has restricted this technology from its inception. Another problem however is that there are often chemical compounds formed during operation that poison the catalyst. There are already working DMFC prototypes used by the military for powering electronic equipment in the field. greater economy

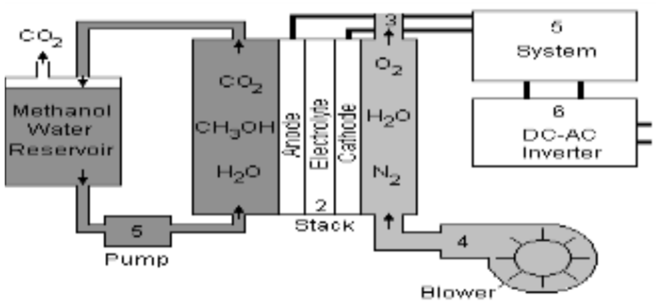

Fig 2 small simple 30 kw Direct Methanol Fuel Cell

2) *Polymer Electrolyte Fuel Cell* (PEFC)

The PEFC is considered the darling fuel cell by proponents of the hydrogen economy. Automobiles emitting pure water from their tailpipes are envisioned. While the efficiency of the PEFC when running on hydrogen and no air pressurization is high, practical systems that use fuel reforming and air compression suffer in efficiency. Small 30 kW AC power plants will likely be 35% fuel to electricityefficient, 200 kW units 40% and large units 45%. Figure 4 show that an automobile power plant including an electric motor would have an efficiency of about 35%. There has been some progress made in storing hydrogen in different materials such as hydrides or carbon **.**If such materials can be perfected this would dramatically increase the chances for the PEFC success for automotive applications.

IV. FUEL CELLS FOR TRANSPORTATION

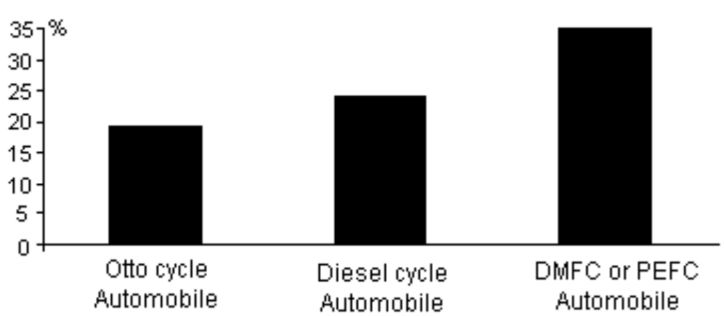

Fig 3.Estimated efficiencies of different automobiles using liquid hydrocarbon fuel

Fuel cells are being proposed to replace Otto or Diesel engines because they could be reliable, simple, quieter, less polluting, and have even. The internal combustion Otto or Diesel cycle engine has been used in automobiles for 100 years. It is a reasonably simple and reliable mechanical device which nowadays has a lifespan of up to 400,000 km or roughly 10,000 hrs of operation in automobiles and over 1,000,000 km or 25,000 hrs or more in larger placations such as buses, trucks, ships and locomotives. Therefore life span is not a problem. Automobile manufacturers are finding new ways of improving the Otto and Diesel engines. Toyota for example has unveiled an Otto cycle automobile that has tailpipe emissions that are 5 times cleaner than typical Los Angeles air. In other words the gasoline engine cleans up the air, at least the present dirty air. Fuel cells have the potential to be considerably quieter than Otto or Diesel cycle power plants. This would especially reduce the noise on quiet neighborhood streets. At speeds higher than 50 km/hr however there is still the problem of road noise. Fuel cells produce electricity. This is not the desired form of energy for transportation. The electricity must be converted into mechanical power using an electric motor. The Otto or Diesel cycle produces the required mechanical power directly. This gives them an advantage compared to fuel cell powered automobiles. Otto and Diesel cycle engines seem to be able to comply with extremely stringent pollution regulations are inexpensive to produce, produce reasonable fuel economy, and use readily available liquid fuels. It is not likely that the PEFC operating on methanol or gasoline will be able to compete with them easily. Such fuel cells using reformers do not produce much less pollution than the future advanced Otto and Diesel cycle engines with complex catalytic converters. If vehicles use hydrogen as fuel, a hydrogen supply systemwould need to be installed. This would be extremely expensive. The DAFC however would likely be simpler than the internal combustion engine, produce superior efficiency and be less polluting. The liquid fuel could be handled by slightly modifying the present distribution equipment. When the DAFC is perfected there may be a major swing away from the Otto and Diesel cycle automobiles. There are some vehicle manufacturers who are betting on this.

V. SECOND LAW ANALYSIS OF FUEL CELLS

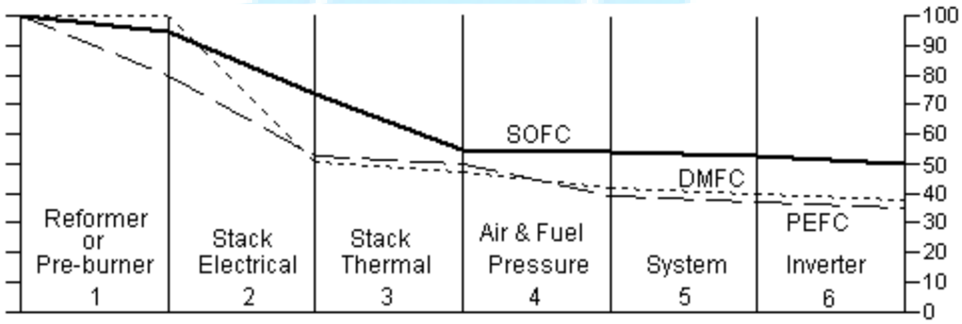

Fig 4.Exergic energy loss diagram for proposed 30 kw AC power plants operating on hydrocarbon fuel

The PEFC runs at a high air pressure. In a small 30 kw power plant this pressure energy cannot be readily recovered. The DMFC stack efficiency is very low, but because there are no reformer losses and less air pressurization and system losses, the final efficiency is still higher than the PEFC.

Subsystem	**PEFC**			**DMFC**		
	Yeff	**BE**	**YE**	**Y-eff**	**BE**	**YE**
0. Hydrocarbon fuel	-	-	100.00	-	-	100.00
1.Reformer/Burner	80.00%	20.00	80.00	100%	0	100.00
2. Stack electrical	64 %	28.50	**51.50**	47%	53.20	**46.80**
3. Stack thermal	0%	1.50	50.00	0%	1.40	45.40
4. Pressurization	78 %	10.80	39.20	90%	4.60	40.80
5. System	95 %	2.00	37.20	98%	0.80	40.00
6. Inverter	94 %	2.20	35.00	94%	2.50	37.50

VI. GASOLINE AND BATTERY POWER

A. Gasoline-Powered Car

The efficiency of a gasoline-powered car is surprisingly low. All of the heat that comes out as exhaust or goes into the radiator is wasted energy. The engine also uses a lot of energy turning the various pumps, fans and generators
that keep it going. So the overall efficiency of an automotive gas engine is about 20 percent. That is, only about 20 percent of the thermal-energy content of the gasoline is converted into mechanical work

B. *Battery-Powered Electric Car*

This type of car has a fairly high efficiency. The battery is about 90-percent efficient (most batteries generate
some heat, or require heating), and the electric motor/inverter is about 80-percent efficient. This gives an overall efficiency of about 72 percent. But that is not the whole story. The electricity used to power the car had to be generated somewhere. If it was generated at a power plant that used a combustion process (rather than nuclear, hydroelectric, solar or wind), then only about 40 percent of the fuel required by the power plant was converted into electricity. The process of charging the car requires the conversion of alternating current (AC) power to direct current (DC) power. This process has an efficiency of about 90 percent
So, if we look at the whole cycle, the efficiency of an electric car is 72 percent for the car, 40 percent for the power
plant and 90 percent for charging the car. That gives an overall efficiency of 26 percent. The overall efficiency varies considerably depending on what sort of power plant is used. If the electricity for the car is generated by a hydroelectric plant for instance, then it is basically free (we didn't burn any fuel to generate it), and the efficiency of the electric car is about 65

C. Solid Oxide Fuel Cell (SOFC)

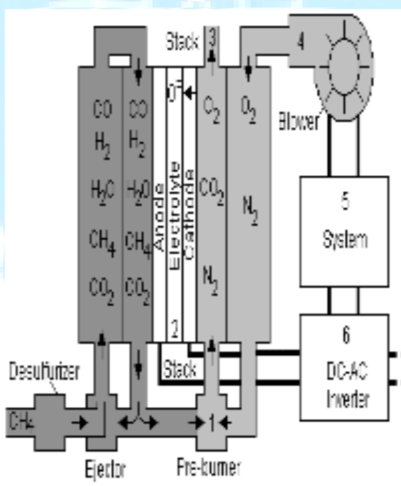

Fig 5.Simple type SOFC suitable for 1-30 kw power plants

The Solid Oxide Fuel Cell is considered to be the most desirable fuel cell for generating electricity from hydrocarbon fuels. This is because it is simple, highly efficient, tolerant to impurities, and can at least partially internally reform hydrocarbon fuels. Because of the high temperatures of the SOFC, they may not be practical for sizes much below 1,000 watts or when small to midsize portable applications are involved. Small SOFC will be about 50% efficient [4] from about 15%-100% power. To achieve even greater efficiency, medium sized and larger SOFC are generally combined with gasturbines. The fuel cells are pressurized ad the gas turbine produces electricity from the extra waste thermal energy produced by the fuel cell. The resulting efficiency of the medium SOFC could be 60% and large one's up to 70%.

D. Molten Carbonate Fuel Cell (MCFC)

The Molten Carbonate Fuel Cell has also been under development for 15 years as an electric power plant. The operating temperature of 600-650°C is lower than the SOFC. It is considerably more efficient that the PAFC. It already has the advantage of reforming inside the stack. Its disadvantage is the corrosiveness of the molten carbonate electrolyte. Large AC power plants using gas turbine bottoming cycles to extract the waste heat from the stack could be up to 60% efficient when operating on natural gas.

E. Fuel Cells For Electric Power Production

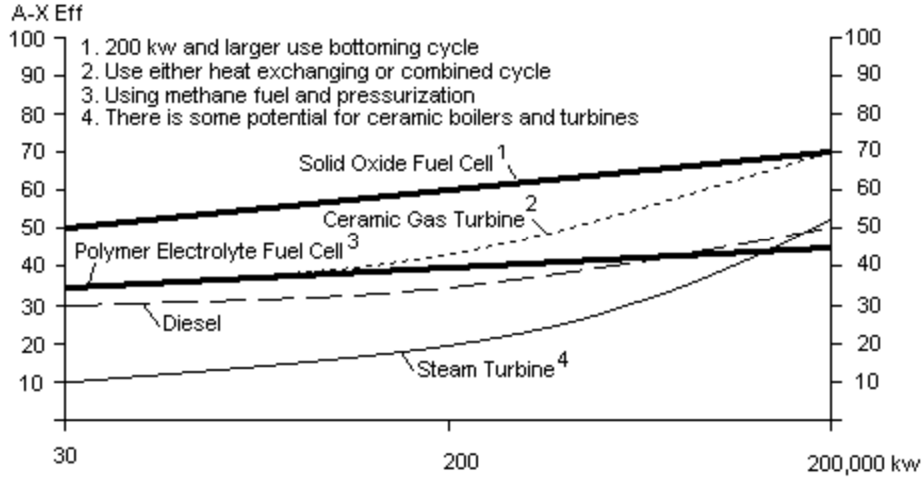

Fig 6.Chart showing projected efficiencies of different future electricity generating power plants

There is a rapid trend in developed countries to deregulate the production of electric power. One of the benefits of deregulation is that it will promote CHP...combined heat and power, also known as cogeneration. CHP will conserve fuel by utilizing the thermal energy that is produced as a result of generating electricity. Because thermal energy cannot be piped efficiently for long distances, CHP power plants will generally need to be much smaller than the present ones which are often around 200,000 kw.

Fuel cells will likely be the favored technology of the future for small electric power plants. Not only do they produce reasonable efficiencies in 30 kw sizes, they will likely be able to run quietly, need infrequent maintenance, emit little pollution and have high efficiency even at part load conditions. Electricity is used by many of our modern high technology devices. Presently batteries are used in these devices. Batteries do not have a long enough life for these applications. Fuel cells could provide continuous power for these devices. Fuel cells are most ideal for electric power production because electricity is both the initial and final form

VII. FUTURE OF FUEL CELL

In the future, medium and large power plants using SOFC will be fuel cell gas turbine combined cycles. In this way the benefits of each type of conversion technology is utilized. Fuel cells are still a few years away from commercialization on a large scale. It is very difficult to tell which fuel and which technology will be predominant in the future. There are some problems to be solved in the SOFC and the DAFC. If these can be solved then these will become the predominant fuel cells being developed in the future.

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