Performance Evaluation of Fuel Cell

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***Abstract* —The focus of this study is to compare fuel cells with different systems and demonstrate that these cells environmentally friendly and useful. This project also includes fuel cell and its historic developments. Furthermore, the similarities and differences between the fuel cell and other systems such as batteries and internal combustion engines are demonstrated in more detail. Additionally, some evaluations and discussions are figured out in the following pages. The general purpose of the research is to find and analyze alternative sources for energy production from chemical energy to electricity.**

Keywords— fuel cell, hydrogen fuel cell, ICE, batteries, types of fuel cells, comparison with internal combustion engines

I. INTRODUCTION

Increasing population and living standards have caused an increase in energy consumption. In today's world, energy demand is generated from sources primarily from fossil fuels such as oil, natural gas and coal that are limited in supply [1]. Unfortunately, fossil fuels are not environmentally friendly and cause pollution due to their harmful gases emission to the atmosphere [2]. In recent years, the importance of fuel cells has received much more attention around the world as a result of world`s energy shortage with environmental issues.

Fuel cell comprises as a result of combining oxygen that might obtain from air, and hydrogen from some sources. Principally, a fuel cell is composed of an electrolyte and two electrodes which wrap electrolyte as a sandwich form (Figure 1). In a fuel cell, commonly palladium and platinum electrodes are used as a catalyst. Electrolytes, which conduct fuel cell at high temperature and low temperature, could be both solid and liquid. In principle, although there are lots of fuels and oxidants which can be conducted by fuel cell, the most effective and useful fuel is hydrogen which has higher electrochemical reactivity than other fuels[3].

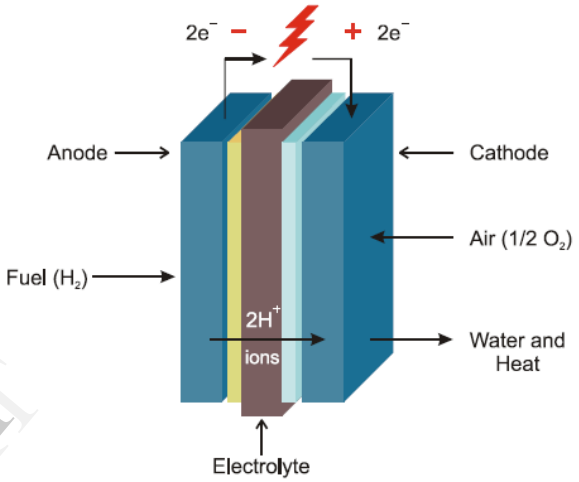

Figure 1- Generic Hydrogen Fuel Cell Operation

II. HISTORIC DEVELOPMENT

Sir William Robert Grove discovered generating electricity from electrolysis of water in around 1839 [4]. Fuel cell was used firstly by Ludwig Mond and Langer in 1889 while trying to provide a practical fuel cell included coal gases such as mixture of carbon monoxide, hydrogen, carbon dioxide, nitrogen oxygen and air. After that, about beginning of 20th century, carbon and coal were used to produce electricity from fuel cell. Then, in 1932 both nickel electrodes and alkaline electrolyte were used in a same form, hydrogen-oxygen cell, by Francis Bacon. At the end of the year 1932s Hary Karl Ihrig developed a tractor that has 20 horsepower which come from fuel cell [4]. After this development in the early 1951s NASA started to use a generator of electrical energy on space mission and electricity and water have been obtained on spacecraft from fuel cells since almost 1960s. Presently, many governments and companies have supported the studies of fuel cells and they have attempted to increase fuel cell usage, especially at homes, small electronic devices like mobile phones and any vehicles because today most of the countries have to imported oil, that's reserves have decreased day by day, which is so expensive. Thus, they want to conventional and sustainable sources as fuel cell [5].

Table 1- Types of Fuel Cells and Characteristics

Type of fuel cell	Electrode composition	Electrolyte composition	Operating temperature	Fuel	Elecrical output	Portability of fuel cell	Potential problems	Potential uses
Phosphoric acid	Platinum on carbon paper	Phosphoric acid	150–200°C	Hydrogen	As much as 200 kilowatts	Not portable	Too heavy for many uses	Stationary installations
Alkaline solution	Insufficient information	Alkaline solution—potassium hydroxide in water	150–200°C	Hydrogen	300 watts to 5 kilowatts	Portable	Containers of liquids can leak	Vehicles
Molten carbonate	Anode: nickel-chromium. Cathode: nickel oxide (lithium doped)	Molten carbonate salt—sodium, potassium, lithium, or magnesium carbonate	About 650°C	Methane	As much as 2 megawatts	Not portable	Too heavy for many uses; salts are highly corrosive	Stationary installations—power stations and industrial uses
Solid metal oxide	Anode: nickel zirconia. Cathode: lanthanum manganate	Solid metal oxide—calcium or zirconium oxide	Nearly 1,000°C	Methane	As much as 100 kilowatts	Not portable	Too heavy for many uses; leakage and sealing pro-blems	Stationary installations—power stations and industrial uses
PEM (proton-exchange membrane)	Unknown	Solid, fluorocarbon–polymer film (a thin, flexible, permeable sheet)	About 80°C	Hydrogen	Unknown	Portable	Unknown	Homes and vehicles
Direct methanol	Unknown	Polymer membrane	50–100°C	Methanol	Unknown	Portable	Unknown	Vehicles
Reversible—unitized regenerative	Unknown	PEM (proton-exchange membrane) in water	Unknown	Hydrogen	Unknown	Portable	Unknown	Vehicles

III. TYPES OF FUEL CELL

The different types of electrolytes illustrate the operating temperature that changes broadly between types. For instance, high temperature, which allows internal reforming hydrocarbon, fuels as methane, fuel cells control at higher than 600 °C. Unlike high temperature fuel cell, low temperature, which is usually below 250 °C, fuel cells do not allow internal reforming. Hence, during processing of these fuel types are used external oxygen. Table 1 shows features of high-temperature fuel cells, molten carbonate and solid oxide and low-temperature fuel cells which are alkaline, phosphoric acid and proton exchange membrane or solid polymer, PEM [5].

IV. COMPARISON OF FUEL CELL WITH INTERNAL COMBUSTION ENGINES

Unlike internal combustion engines, fuel cell manages at high specific thermal efficiency. For instance, chemical energy is converted into heat with processing of combustion by heat engines and this heat is used to do useful work. Therefore, it is known that heat engine work as a principle of Carnot cycle, so maximum thermodynamic efficiency equation for heat engine is;

$$\eta_{max} = \frac{T_L}{T_H}$$

Where; T_H : High-temperature reservoir (K)

T_L : Low- temperature reservoir (K)

This equation explains that heat engine efficiency depends on high-temperature and low-temperature. Nevertheless, in a real heat engine high temperature is limited by some materials. In addition to this, inlet temperature (T_H), that is the operating temperature, is lower than ignition temperature [6]. On the other hand, there is no combustion section in a fuel cell, so efficiency does not relate to high temperature.

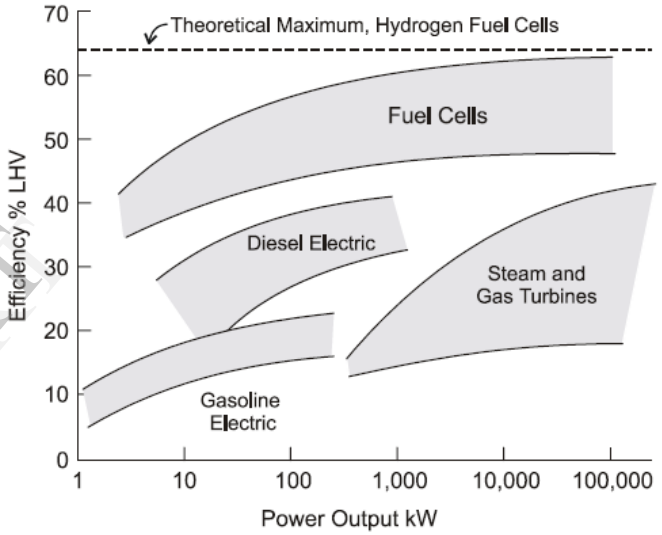

Figure 2- Power Generating Systems Efficiency Comparison [3].

Moreover, fuel cells and internal combustion engines demonstrate different processes. For example, while internal combustion engines use the fuel and oxidant with combustion, fuel cell uses these sources electrochemically during the reaction. Furthermore, internal combustion engine produces mechanical energy but fuel cell, which is solid state applicants, generates electricity directly. The last but not least, reaction temperature and types of fuel deal with pollution in internal combustion engine whereas there is no emission in a fuel cell because of the operating on pure hydrogen. On the other hand, there are some similarities of such systems. Both of them utilize gaseous fuel such as hydrogen that is used pure-hydrogen in fuel cell and hydrogen-including fuel in an internal combustion engine directly. Besides, compressed air is used on both system but in a fuel cell it is compressed as an external compressor [3].

V. COMPARISON OF FUEL CELL WITH BATTERIES

Fuel cell and batteries have many similarities because both of them are galvanic cells. Their form includes cathode and anode with an electrolyte that provide connection to each other. Additionally, both systems generate electricity from chemical energy with electrochemical reaction. In this reaction, initially they convert commonly minimal DC (direct current) voltages and then these voltages combine with other voltages like a chain. Eventually producing of big power capacities and voltages are completed successfully. Nonetheless, there are same different parts of their structure as an anode and cathode. For example; while in a fuel cell anode and cathode are commonly composed of gases as hydrogen gas mixture and oxygen to increase power generation like a catalyst. However, in a battery these are usually metals such as lithium for anode and metallic oxide for cathode. Also, fuel cells and batteries are fundamentally different because chemical reactants are stored in a fuel cell but these materials are only conducted and consumed in a battery. Hence, "in e fuel cell the chemical reactants are supplied from external source so that its materials of construction are never consumed and do not need to be charged. A fuel cell continues operate as long as reactants are supplied and reaction products are removed"[3].

VI. ADVANTAGES AND DISADVANTAGES OF FUEL CELLS

Currently, governments, large and small companies have encouraged developing fuel cells for generating electricity, for vehicles and for many devices in different size and shape. In the last decade, resources have increased and described different forms of fuel cell systems. These systems have some benefits and drawbacks; for instance, when pure-hydrogen is used, fuel cells operate without pollution; the only by product is water. In addition, once usage of hydrogen, which is extracted from the electrolysis and water, production size is not important for fuel cell. Fuel cells work silently, whilst compared other systems as an internal combustion engine. For military applications DMFC (direct-methanol fuel cells) and PEM (proton exchange membrane), low temperature fuel cell, are usually used, because of low heat transmission.

Unfortunately fuel cells have some disadvantages; for example, hydrogen, which is environmentally used in a reaction of fuel cell, manufacturing and storing is too difficult. Presently, hydrogen commonly derives from fossil fuels and this process is expensive. Liquid hydrogen can be stored in a small and light tank but these systems have to conduct at cryogenic temperature. Furthermore, hydrogen gaseous requires large storage systems which are so heavy for transporting. Fuel cell might be used for automotive systems whereas these systems require platinum that is rare metal and expensive. Fuel cells are not suitable when the weather is cold. Although fuel cell systems produce sufficient heat to change low temperature to high temperature to prevent freezing, this is not enough especially in bad winter conditions. Thus, fuel cell has to beshut down before freezing. In a fuel cell, support systems and fuel storage is heavier than the other systems [7].

VII. EVALUATIONS

Some production problems of fuel cells have not been solved yet. As it is mentioned before, fuel cells can not work in cold weather because of freezing temperature [8]. Once this situation might cause of dramatic results such as traffic accident when vehicles on the road. Another problem is small hydrogen storage tank in vehicles because small tank could only provide maximum 600 kilometer in a normal car. Hence, hydrogen storage tank must be large for the vehicle [9]. Steel and Heinzelassumed that "fuel cells have to be designed for operation on hydrocarbon or alcohol fuels to ensure that the technology" will provide markets[10]. Once hydrogen is necessary materials for fuel cells, how the cheapest hydrogen can be generated! According to the Steel and Heinzelthe cheapest method is "steam reforming of natural gas, which provides significant emissions of greenhouse gases"[10].

Another technical issue is electricity generating from fuel cell. "Fuel cells are relatively expensive to manufacture and operate in relation to their output"[11]. As a result of this, fuel cell engines probably will be too expensive for vehicles during the next 20 years. However, manufacturing cost of fuel cell cars will be cheaper than a new traditional car [8].

VIII. CONCLUSION

In this project as it is mentioned above some descriptions, examples, analysis and comparison were used to explain what fuel cell is. Although there are some drawbacks for fuel cells, it can be clearly seen that fuel cells will be essential source within five years. They operate without combustion, works almost silently, do not have harmful gases emission so do not pollute environment therefore, they are reliable. Furthermore, hydrogen can be obtained in many ways like processing of electrolysis and gasification.

Fuel cell plants are now environmentally friendly and economical so, these plants have increased presently. Probably, pure-hydrogen will be available more than present and the much more electricity will be generated from fuel cell. It is also known that many companies with their scientist and engineers have offered new applications presently. They have tried different types of materials as catalyst, electrolysis, electrodes and fuels to improve efficiency of fuel cells.

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