# A SURVEY OF FUEL CELL BASED APPLICATION IN HEV

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**ABSTRACT**:

*Due to regular use of renewable energy the power sector widely categories into two categories: grid connected and stand alone. The emission and fuel consumption favourable operation of the Hybrid Electric Vehicles (HEVs) have resulted in tremendous popularity increase of these vehicles during the last two decays. Even if large advance has already been made, there are still many aspects to be considered and problems to be solved regarding the HEVs before they can be fully commercialized. Two such aspects are the cost and performance of these vehicles. Various research and development activities have resulted in a variety of different hybrid solutions, from the electric motor assisted bicycles to more advanced plug in hybrid cars and the fuel cell vehicles (FCV). In this paper a brief review is done for the Fuel Cell architecture and control.*

**KEYWORDS**: *AFC, DER, Fuel Cell, HEV, PEMC, SOFC, etc.*

## 1. INTRODUCTION

The emission and fuel consumption favourable operation of the Hybrid Electric Vehicles (HEVs) have resulted in tremendous popularity increase of these vehicles during the last two decays [1]. The electric vehicle is however not a new concept and the manufacturing of such vehicles started as early as before 1900. Ferdinand Porsche's first hybrid vehicle produced in 1899 was for instance propelled by four wheel-mounted electric motors with a series driveline solution [1].

The lack of insight in the finite nature and in the environmental impact of the fossil fuels, as well as the fast development of the internal combustion engine (ICE) during the First Word War and the low fuel prices, pushed the electric vehicles aside [2]. Since then, the ICE vehicles have dominated the roads and have now probably done that far longer than any of those driving them today can remember. The infrastructure, performance demands, manufacturing process and many other aspects have been influenced and formed by this dominance. Now however, when the environmental impactof the traffic caused pollution is becoming visible and the fossil fuel reserve of this planet fades rapidly, new possibilities to developed alternative power train concepts arise. This development may even be considered as necessary if the freedom of using fast and flexible personal and goods transports are not to be abandoned meanwhile the planets environment is preserved for the future generations.

A substantial amount of research and development time, as well as financial means is now invested by the manufacturers and political organs in order to meet the demands from a constantly more aware public. Even if large advance has already been made, there are still many aspects to be considered and problems to be solved regarding the HEVs before they can be fully commercialized. Two such aspects are the cost and performance of these vehicles. Because even if the environmental concern has been brought to attention, the customers must be able to afford the product and the product needs to fulfil its purpose. Another aspect is the origin of a substitution fuel and its distribution. Various research and development activities have resulted in a variety of different hybrid solutions, from the electric motor assisted bicycles to more advanced plug in hybrid cars and the fuel cell vehicles (FCV).

## 2. BACKGROUND OF FUEL CELL

A fuel cell converts chemical energy to electrical energy with the help of an electrochemical reaction. Out of the many clean source of energy, fuel cell is considered as one of the most efficient and reliable as it don't consists any moving parts and have water and heat as the only by products. A fuel cell can be classified according to the type of electrolyte used. Out of different types of fuel cell, proton exchange membrane fuel cell (PEMFC) is widely used because of its low operating temperature, low noise, high efficiency and low pollution. In present day 1 kW to 2 MW powerranges of fuel cell are used in various applications.

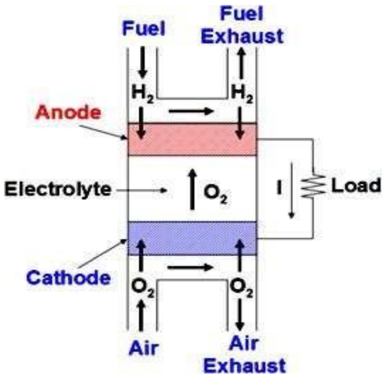


**Fig 1:** Configuration of Fuel Cell

Fig.1 shows a block diagram of basic fuel cell operation. As illustrated in this figure, the fuel such as natural gas, coal, methanol, etc. is fed to the fuel electrode (anode) and oxidant (oxygen) is supplied to the air electrode (cathode). The oxygen fed to the cathode allows electrons from the external electrical circuit to produce oxygen ions.

The ionized oxygen goes to the anode through the solid electrolyte and combines with hydrogen to form water. Even though chemical reactions at anode and cathode may be a little different according to the types of fuel cells, the overall reaction can be described as follows:

**Overall Reaction:** $2H_{2(gas)} + O_{2(gas)} \rightarrow 2H_2O + energy$

Since hydrogen and oxygen gases are electrochemically converted into water and energy as shown in the above overall reaction, fuel cells have many advantages over heat engines: high efficiency and actually quiet operation and, if hydrogen is the fuel, no pollutants are released into the atmosphere. As a result, fuel cells can continuously generate electric power as long as hydrogen and oxygen are available.

As stated in [3], a fuel cell system has five basic sub systems these include fuel processor, water management, air management, thermal management and power conditioning sub system.

### A. Fuel Processor

As hydrogen is the most preferred fuel for the fuel cells, so a fuel processor is used to produce hydrogen from various sources like hydrocarbons. But storing and transportation of high pressure hydrogen remain the issues in implementation of fuel cell technology [4]. The nature of fuel processor depends on the type of fuel cell used. As mentioned above PEMFC is a low temperaturefuel cell, therefore a relatively complex fuel processor is used which includes a desulfurizer and a gas cleanup system for the removal of CO (carbon monoxide). For the fuel cells operating at higher temperature like MCFC and SOFC preheating of fuel is required before it is injected into the fuel cell. Therefore fuel processor for such types of fuel cells contains desulfurizer as well as pre heater.

### B. AIR MANAGEMENT

For the oxidation of fuel, the fuel cell requires air as the oxidant. So air management is a very important aspect of fuel cell system. Either blower or air compressor is used for the providing air to the fuel cell. The choice of using either blower or air compressor depends on whether to give low pressure air or a high pressure air to the fuel cell. The main advantage of giving high pressure air to the fuel cell is that it increases that stack efficiency and improves the electrochemical reactions kinetics. In [5], an ultra-high speed compressor was used for better air management of fuel cell. The centrifugal compressors are compact in size and have advantage of low noise pollution. However increasing the air pressure has some disadvantages like it decreases the capacity of air to hold water thus affecting the humidification processes of the fuel cell. Also the power required for compressing the air to high pressure is derived from the fuel cell itself. Thus power required by air compressor is more than any of the other auxiliary devices that are connected with the fuel cell.

### C. WATER MANAGEMENT

As mentioned in [6], the removal of water from cathode of lower operating temperature fuel cells like PEMFC is a major challenge. The common practice is to purge the cathode flow fields. A flow field tapered channel is presented which separates water produced from the air flow that is needed for fuel oxidation. Water is produced as a byproduct in the electrochemical reactions that undertake place inside the fuel cell. This means even in case where large amount of water is produced, the air management of fuel cell does not get affected. Water is required for a variety of applications in the fuel cell. In the fuel processor water is required to react with hydrocarbons for the steam reforming reactions. Moreover in the PEMFC pre humidification of reactant gases is required to prevent the drying of fuel cell membrane. For the automotive applications it is very important that water produced in the fuel cell is sufficient for humidification of reactants. If water produced is not sufficient then it must be externally added for the reactant humidification.

### D. THERMAL MANAGEMENT

Thermal energy released by the fuel cell depends upon the output power of the fuel cell. This thermal energy can be used for a variety of applications including cogeneration. Low temperature fuel cells require air to be flown through cathode to drive out the excess heat. In high temperature fuel cells like MCFC and SOFC the excess heat is removed by liquid coolant. However in this case the thermal energy generated by the fuel cell is used to pre heat the reactant gases and fuel reforming in the fuel processor. Extra heat generated by the fuel cell can be used for cogeneration. Therefore fuel cells must be properly integrated for the optimal use of the thermal energy of the fuel cell.

### E. POWER MANAGEMENT

The output of the fuel cell is dc. The direct current produced by the fuel cell at a voltage varies with the change in load. Therefore a dc-dc converter is required for the protection of fuel cell from overvoltage and over current originating with the load variations. For the AC load an inverter is required for transforming DC output to AC. Again as the response of fuel cell is slow to the load variations so a battery or super capacitor is required for supplying the initial power to the load. As mentioned in [2] as the load changes, there is increase in the inrush current to the battery or the super capacitor. Therefore to protect the storage device it is important to use bi-directional converter. The bi-directional converter protects the storage device by controlling the charge and discharge current.

## 3. TYPES OF FUEL CELL

There are many types of Fuel cell line PEMFC, MCFC, AFC, SOFC. But only PEMFC can be operated at normal air temperature. PEMFC is lightweight so it can be easily transported, used for distribution power generation. There are a number of fuel cells that can be chosen according to the power rating. 1kW FC has the output voltage range of about 25-50 V and 30 kW and above Fuel cells have output voltage of about 200-400V [2].

As explained in [7] PAFC technology is commercially available as well as technologically more advanced in comparison with other type of fuel cells. MCFC still needs some improvement to overcome technical and economic barriers before they could be commercialized at par with other type of fuel cells. SOFC is very useful particularly in stationary fuel cell. They are very much commercialized. If economic issues are resolved then SOFC can be very successful in distributed generation applications. PEMFC have become very popular in the recent years due to technological breakthroughs in the field of cell power density as well as reduction in the cost. These are the only type of fuel cells which are being tested for the vehicular applications. Table 1 shows the differenttype of fuel cell and their comparison.

**Table 1**.Comparison of Different Types of Fuel Cell [8]

| **Fuel Cell Type** | **Operating Temp$^r$. ($^0$C)** | **Fuel Compatibility** | **Power Range** | **Application** |
|---|---|---|---|---|
| PEMFC | 60-80 | Hydrogen, Methanol | 1W-100kW | Space, Portable Transport, Stationary |
| AFC | 40-60 | Hydrogen, Methanol | 1kW-100kW | Space, Portable Transport, Stationary |
| MCFC | 600-700 | Hydrogen, Methnol | 1kW-10MW | Transport Stationary |
| SOFC | 750-1050 | Hydrogen, carbon monoxide | 500kW-10MW | Transport Stationary |

## 4. APPLICATION OF FUEL CELL

The increasing demand for clean sources of energy due to fast depleting fossil fuels has put use of unconventional sources of energy more in demand. Among the unconventional sources of energy, Fuel Cell is becoming more popular because of virtually silent operation, environment friendly and higher efficiency [9]. Also the hydrogen is used as fuel in the fuel cells which is abundant in the earth and less prone to depletion as compared to other hydrocarbon fuels used for electricity production like diesel, coal, natural gas etc. The application of Fuel Cell can be broadly categorized into three broad areas in [10] as mentioned below:

- **A.** Portable power generation.
- **B.** Stationary power generation.
- **C.** Power for transportation.

As Portable power generator, Fuel Cell is used to charge up movable products as auxiliary power units (APU). Portable fuel cell has longer run time as compared to batteries. Stationary Fuel Cell is not designed to be moved. Their sole purpose is to provide electricity. Stationery Fuel Cells are used as backup power supply system. These include uninterrupted power supply (UPS) and primary power generation. Stationery Fuel Cells are very useful in remote power application like in spacecraft, rural locations and remote research facilities. These Fuel Cells can also be used to provide power to those areas which do not have access to grid like refugee camps after natural or manmade disaster. Transport Fuel Cell is used to provide propulsive power to vehicles. Fuel cell propelled light duty vehicles (LDV) has seen limited growth but it is the main target for the automakers in 2014[11].

In [12] explained the use of fuel cells in the automotive applications and the drawbacks associated with it. Electric vehicles are particularly used in the mines or indoor areas, where air or noise pollution is prohibited due to health hazards. Fuel cell based electric vehicles can drastically reduce the air pollution as well as dependence on fossil fuels. However there are still some technological barriers such as vehicles with onboard fuel processor need time to produce hydrogen which is not useful for practical applications. Also these fuel processors are not emission free.

Sakka et al. [13] reported that HEVs use two energy storage devices, one with high energy storage capability that extends the driving distance and another with high power reversibility that aids in acceleration and regenerative braking. Regenerative braking is a condition in which brakingelectrical energy is passed to a rechargeable battery for later usage, unlike the common dynamic braking in which motion energy is converted into electrical energy [14].

Shuang et al. [15] conducted a study on power management strategy integrating serial regenerative braking. Power management was performed by a controller, which consists of two modules: (1) power distribution module to divide demand power into DC power and battery power and (2) braking strategy module that can be either serial or parallel. The serial braking strategy was chosen because the serial braking strategy has a higher percentage of regenerative energy. Simulation was performed by using MATLAB/ Simulink for the China Urban Bus Driving cycle. Results revealed that relative to the objective of minimizing power loss, the revised optimal strategy achieved a reduction of 79%, whereas the existing optimal strategy achieved a reduction of 60%. However, the highlight of this study was on minimizing power loss on the basis of serial regenerative braking. Thus, the emphasis on power splitting algorithm was not apparent. Moreover, the results only showed simulation performance relative to the comparison between regenerative and non-regenerative braking,as well as power loss and state of charge (SOC) for the rule-base, existing optimal, and revised optimal strategies.

Alloui et al. [16] and Kelouwani et al. [17]. Illustrate the general block diagram for the structure of a fuel cell–battery HEV. The concept of the EMS involving fuel cell and battery is that load sharing occurs between these two energy sources. The energy is then fed to the DC bus. The DC voltage will then be fed into an inverter to convert the DC voltage into AC voltage, which can move the AC motor.

Matopan et al. [18] reported on a research about an EMS for a fuel cell–battery–SC HEV, which compared five different control strategies: (1) state machine control strategy, (2) rule-based fuzzy logic strategy, (3) classical PI control strategy, (4) frequency decoupling and fuzzy logic strategy, and (5) equivalent consumption minimization strategy (ECMS). The simulations were performed via Matlab/Simulink using the SimPowerSystems toolbox, and the simulations were also tested in real-time through LabVIEW on NI-PXI 8108, which illustrated a DC bus voltage of 280 V,as rated.

## 5. CONCLUSION

Due to limitation of the fissile fuel new source of power generation is required. On the behalf of them many researches work in finding the new type of power generation. Among of them acceptation of the fuel cell get increases day by day. The application of fuel cell is not limited in grid interfacing but also increased in the electrical vehicle application. In this paper discuss the basic fundamental of the fuel cell and its major application in the field of electrical vehicle.

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