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A Review on Hydrogen Fuel Cell Based Electric Vehicle

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ABSTRACT: The dangerous effects of pollutants from conventional fuel vehicles have caused the scientific world to move towards environmentally friendly energy sources. Though we have various renewable energy sources, the perfect one to use as an energy source for vehicles is hydrogen. Like electricity, hydrogen is an energy carrier that has the ability to deliver incredible amounts of energy. Onboard hydrogen storage in vehicles is an important factor that should be considered when designing fuel cell vehicles. In this Review paper, a recent development in hydrogen fuel cell engines is reviewed to the feasibility of using hydrogen as a major fuel in transportation systems. A fuel cell is an electrochemical device that can produce electricity. With anodes and electrolytes, the fuel cell splits the cation and the anion in the reactant to produce electricity. Fuel cells use reactants, which are not harmful to the environment and produce water as a product of the chemical reaction. As hydrogen is one of the most efficient energy carriers, the fuel cell can produce direct current (DC) power to run the electric car. By integrating a hydrogen fuel cell with batteries and the control system with strategies, one can produce a sustainable hybrid car.

KEYWORDS: hydrogen, fuelcell, battery, clean transportation, electric vehicle

I. INTRODUCTION

Energy is a factor determining a country's economy, infrastructure, transportation, and standard of life. The problem faced globally is the disparity between the consumption and the availability of energy. All nations are presently depending upon fossil fuel for the energy production, and these fossil fuels are not sustainable sources. To supply the energy demands of the more rapidly increasing global population, it is essential to upgrade to an alternative, sustainable energy source that does not negatively affect the environment. In recent decades, the United States has been putting emphasis on the environmental impact of the transportation sector and reducing petroleum dependence. Depletion on non-renewable conventional fuels is one of the main issues of the modern energy scenario, which makes the state of the energy industry unsustainable, and it also causes environmental problems such as the greenhouse effect. Today, the proportion of fossil fuel use is still high, and it is projected that it will account for approximately 75% of energy production in 2050. Overall, the current energy scenario has many downsides. However, there exist many sustainable energy sources, and if their use increases, the scenario will be much more optimistic for future generations. It is predicted by environmentalists that the worst-case scenario of global warming and its effect will not be reached because of different initiatives. Over the last two decades, vehicles have become more fuel efficient, and hybrid electric vehicles are becoming more common. One of the fastest growing alternative energies in vehicles is electricity. As with conventional energy sources such as petroleum and coal, electricity is not a primary energy source. A fully charged battery is an energy carrier. Battery electric vehicles (BEVs) are highly efficient at converting energy from the grid into tractive force, and they can recover energy during drives by utilizing regenerative braking. One major drawback of BEVs is that they usually have a limited range due to the size and the cost of batteries necessary for vehicle power and energy requirements. The "refueling" of the battery systems can also take several hours, rather than a few minutes with a conventional vehicle (CV). To use advantages of both electric and conventional vehicles and to bridge the gap between CVs and BEVs, an alternative is considered. Hydrogen is a chemical energy carrier that has the capability to produce electricity up to 39.39 kWh/kg, which surpasses the energy density of most batteries. A fuel cell (FC) has a direct analogy to an internal combustion engine (ICE). An ICE converts chemical energy stored in the fuel supplied

to the engine to produce rotational mechanical energy. The rotational energy produced is then either used to propel a vehicle or focused through a generator and converted into electrical energy. An FC acts much in the same way as an ICE in that chemical energy is directly converted into electrical energy in the FC, but in an environmentally friendly process. Unlike a battery that drains while it is used to power electrical components, internal combustion engines and fuel cells act as continually operational power sources as long as fuel is being provided to them. Hence, it is projected that the hydrogen fuel cell can overcome the disadvantages of BEVs, making hydrogen the transportation fuel of the future.

II. RELATED WORK

II. HYDROGEN AS A TRANSPORTATION FUEL:-Hydrogen is the simplest form of all molecules; it has the lowest energy content by volume, but it has the highest energy content of any fuel by weight. It is available in the atmosphere as gas and in water as liquid. Due to the high energy content of hydrogen, it is employed as a fuel in applications such as FCs and rockets. Hydrogen creates zero harmful emissions, which is one of the most significant drawbacks of fossil fuels, and the heating value of hydrogen is three times higher than

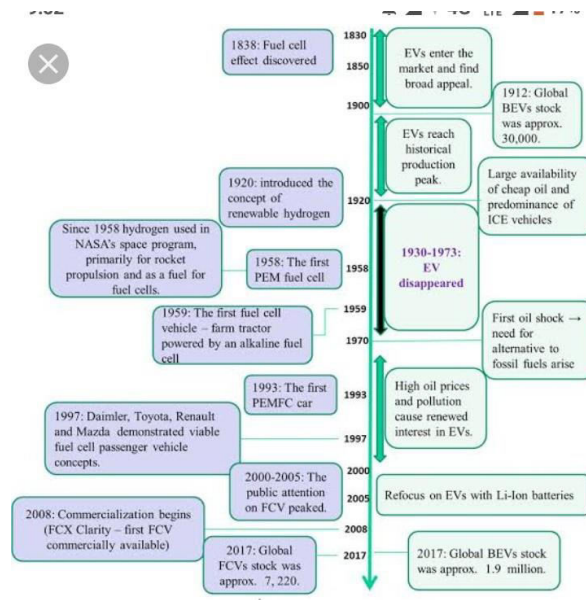


Figure 1. Economic and Environmental Prospects for Electric Vehicle

hat of petroleum. There is a hefty production cost involved with hydrogen, since it is a manmade fuel, costing about three times more than petroleum refining. Substantial amounts of research are dedicated to creating an efficient and sustainable way to produce hydrogen and applications for hydrogen in transportation engines. Automobile manufacturers such as Honda, Toyota, and Hyundai have started to manufacture fuel cell vehicles (FCVs) with hydrogen as fuel. These FCVs are currently available in North America, Asia, and Europe, and have primarily been bought by early adopters. The current consumers—early adopters—are primarily highly educated people, high income families, those with larger household units, those willing to change their lifestyle, and those with other similar attributes. As of June 2018, there have been over 6500 FCVs sold to consumers. California is the leading market for FCVs, with nearly 3000 FCVs being delivered there out of the 5233 vehicles sold globally due to the state housing the largest network of hydrogen refueling stations in the world and automakers selling the vehicles there. Presently, several automakers are promoting FCVs to consumers, which are often compared to BEVs. Both BEVs and FCVs offer zero tailpipe emissions, the ability to be fueled using renewable and sustainable energy sources, and use electric motors.



The most notable differences between FCVs and BEVs are the driving range and the refueling style. FCVs have above a 300-mile driving range and can be refueled in less than 10 min at a hydrogen refueling station, which is more comparable to a traditional ICE fossil fuel powered vehicle. Hydrogen has greater potential for use as a fuel in the future. It is estimated that, by the year 2030, the cost of fuel cells will be competitive with ICEs based on the technological improvements being made and the increased availability. One of the main hurdles that mass hydrogen use faces is more efficient storage. Because of the low density of hydrogen, it cannot be stored as easily as traditional fossil fuels. Hydrogen requires compression, cooling, or combination of them. The most favorable method of hydrogen storage is physical containment, specifically in compressed tanks, because they are readily available. All composites (Type IV) are primarily used, and sometimes metal lined composites (Type III) are used. The fill time of these tanks is competitive with fossil fuels when the hydrogen is pre-cooled. Cost is the main setback for the wide scale use of compressed hydrogen (CH₂) tanks, because the material and the assembly are expensive. Another potential setback is the public's concern of using such high pressure (70 MPa) storage tanks in vehicles. An alternative to traditional CH₂ tanks that is still being researched is a tank with an internal skeleton, which is a complex design of struts in tension within the tank to resist the forces of the compressed gas. Liquid hydrogen (LH₂) storage has improved significantly, achieving the best specific mass (15%) of any other automotive hydrogen storage system. Energy efficiency is decreased when liquid hydrogen is used. Boil off is an area that needs improvement before LH₂ systems can be widely accepted. A promising alternative design is a cryo-compressed tank in which hydrogen is highly compressed at cryogenic temperatures. More studies must be done on this method to determine long term durability and public acceptance of the system. Hydride storage systems require substantial research and progress to meet the requirements for large scale use. The most well studied hydride is NaAlH₄, but it does not have the capacity necessary for application. Based on the results of the few existing studies, it is indicated that tanks with no internal heat transfer elements could be constructed based on the moderate heat of absorption of hydrogen on surfaces. Though hydrogen presence is abundant in the atmosphere, it is not in the purest form. Hydrogen can be extracted from water, hydrocarbon fuel, hydrogen sulfide, and other chemical elements. The energy that is used to produce hydrogen from its associated elements requires external energy, such as thermal, electrical, photonic, and bio-chemical energy. The chemical element, ammonia, has a high percentage of hydrogen within and was proposed as a fuel for internal combustion engines through onboard decomposition to hydrogen and nitrogen. Hydrogen can be extracted from either non-renewable or renewable energy sources. Hydrogen production from renewables is always environmentally friendly, whereas the hydrogen produced from non-renewables emits greenhouse gases (GHG). Hydrogen production from the waste biomass using electrochemical reactions is GHG-less, and it does not require a large amount of energy or high production costs. Possible biomass feedstocks are bread residue, cypress sawdust, and rice chaff. Similar to these, newspaper could be used to produce hydrogen by direct electrolysis. Newspaper is composed of 69.2% cellulose and 11.8% lignin, and it is decomposed into monosaccharides and disaccharides as well as aliphatic keto acid in the solvent H₃PO₄ under conditions similar to electrolysis. Hydrogen can also be generated by the electrolysis of humidified methane. The wide scale use of compressed hydrogen (CH₂) tanks, because the material and the assembly are expensive. Another potential setback is the public's concern of using such high pressure (70 MPa) storage tanks in vehicles. An alternative to traditional CH₂ tanks that is still being researched is a tank with an internal skeleton, which is a complex design of struts in tension within the tank to resist the forces of the compressed gas. Liquid hydrogen (LH₂) storage has improved significantly, achieving the best specific mass (15%) of any other automotive hydrogen storage system. Energy efficiency is decreased when liquid hydrogen is used. 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III. METHODOLOGY

A fuel cell uses the chemical energy of hydrogen or another fuel to cleanly and efficiently produce electricity. If hydrogen is the fuel, electricity, water, and heat are the only products. Fuel cells are unique in terms of the variety of their potential applications; they can provide power for systems as large as a utility power station and as small as a laptop computer. Fuel cells work like batteries, but they do not run down or need recharging. They produce electricity and heat as long as fuel is supplied. A fuel cell consists of two electrodes—a negative electrode (or anode) and a positive electrode (or cathode)—sandwiched around an electrolyte. A fuel, such as hydrogen, is fed to the anode, and air is fed to the cathode. In a hydrogen fuel cell, a catalyst at the anode separates hydrogen molecules into protons and electrons, which take different paths to the cathode. The electrons go through an external circuit, creating a flow of electricity. The protons migrate through the electrolyte to the cathode, where they unite with oxygen and the electrons to produce water and heat

➤ WORKING OF SYSTEM

- **HYDROGEN TANK:-**

It is used to provide hydrogen to the fuel cells stack. It is mainly used to store and supply the hydrogen to the system.

- **PRESSURE REDUCTION SYSTEM:-**

This system is used to control the flow of hydrogen according to the amount of hydrogen energy developed depends on hydrogen flow so this pressure reduction system is used to adjust the flow of hydrogen

- **OXYGEN INPUT TO THE SYSTEM:-**

This system is used to provide oxygen to the fuel cell with the help of scrubber and compressor. So due to the input of this oxygen to the fuel cell stack in which hydrogen is already present so that the fuel cell converts hydrogen power into electrical energy by combining hydrogen and oxygen.

- **FUEL CELL STACK**

Fuel cell stack is one of the important parts in a hydrogen fuel electric vehicle. In which hydrogen energy is converted into electrical energy.

- **ELECTRIC MOTOR CONTROLLER :-**

Electric Drive Motors Hybrid electric vehicles use an electric driveline and motor to provide the power for propulsion. The electric motor is a simple, efficient and durable device that is used every day in all sorts of applications. Electric motors range from those with fractional horsepower that run small appliances, to 5000-horsepower giants used in paper mills and other industries. An electric motor converts electric energy to mechanical energy (motion) to drive the hybrid vehicle. Every motor can be used as a generator by rewiring it to transform mechanical energy into electrical current, but not all motors make efficient generators. For this dual use, the hybrid may use the electric motor to start the engine and then switch to generating electricity to keep the batteries charged. This reduces both the weight and cost of having two separate devices for engine starting and battery recharging. In conventional vehicles, engine size determines the total power available to a moving vehicle. Hybrids, on the other hand, have electric motors that provide additional power when needed by the vehicle. Both electric motors and engines can be rated in kilowatts (kW) — the preferred international standard — or in horsepower (hp). One hp equals 0.746 kW. When comparing horsepower ratings of a motor to an engine, it appears that electric vehicles are drastically under-powered. However, internal combustion engines are rated at the maximum power output, while electric motors are rated at their continuous power capabilities. A motor that can produce 10 hp continuously can easily produce three or four times that much power for a few minutes. Unlike internal combustion engines, electric motors emit zero harmful emissions.



- **DC TO DC CONVERTER :-**

A DC TO DC produces an electric current that always flows in the same direction. It is different from the AC generator in both the way it is built and how it is used. The commutator rotates with a loop of wire just as the slip rings do with the rotor of an AC generator. Each half of the commutator ring is called the commutator segment and is insulated from the other half. Each end of the rotating loop of wire is connected to a commutator segment. Two carbon brushes connected to the outside circuit rest against the rotating commutator. One brush conducts the current out of the generator and the other brush feeds the current back in. The commutator is designed so that no matter how current in the loop alternates, the commutator segment containing outward-going current is always against the “out” brush at proper time.

- **CONTROLLING SYSTEM:-**

The electronic control system regulates the high-intensity current, helping it work with the APU counterparts. It controls the power flow between the battery and the motor as well as regenerative braking. A control system contains two main components, namely the command and power components. The command component manages and processes the driver’s instructions. The power component chops power flows to control the motor’s power intake. There are two choppers to manage this power flow. The primary chopper is the startup phase and works at low motor speeds. The excitation chopper regulates the motor at medium and high motor speeds.

- **BATTERIES AND CAPACITORS:-**

Batteries are one of the most important parts of a hybrid vehicle. A battery produces electricity by means of chemical action. It consists of one or more electric cells. Each cell has all the chemicals and parts needed to produce an electric current. There are two types of batteries: primary and secondary (or storage) batteries. Primary batteries discharge and must be discarded after one or more of the chemicals is used up. Secondary batteries, on the other hand, can be recharged after they have delivered their electrical energy. Consequently, secondary batteries are ideal for hybrid application. They are able to supply power to the vehicle and be re-used. The criteria used for battery selection are: temperature, energy density, power density, service life, shelf life, cost, reliability, cell configuration, charge/discharge cycle, safety . A capacitor is a device that stores electrical energy in the form of an electrical charge. A capacitor consists of two metal plates with an insulating material called a dielectric between them. Wires usually connect the plates to a source of electric current such as a battery. When an electric charge flows through the wires from one plate of the capacitor to the other, both plates become charged — one with a positive charge, and the other with a negative charge. The two plates then have potential difference in energy — a voltage — between them. The plates release their charge when their wires are disconnected from the source and touched together. The ability of the capacitor to store electric energy is its capacitance. The main difference between a battery and a capacitor is that a capacitor can be rapidly charged and discharged.

- **EXHAUST SYSTEM:-**

The fuel pumped in electric vehicle is hydrogen gas the energy is created in fuel cell by reacting hydrogen with oxygen in the tank due to inlet of oxygen and combination with hydrogen energy is produced but after this process .hydrogen oxygen remain (To exhaust this exhaust system is provided.

• **COOLING SYSTEM:-**

This system can be heated during operation.so to provide cooling ,cooling system is used.

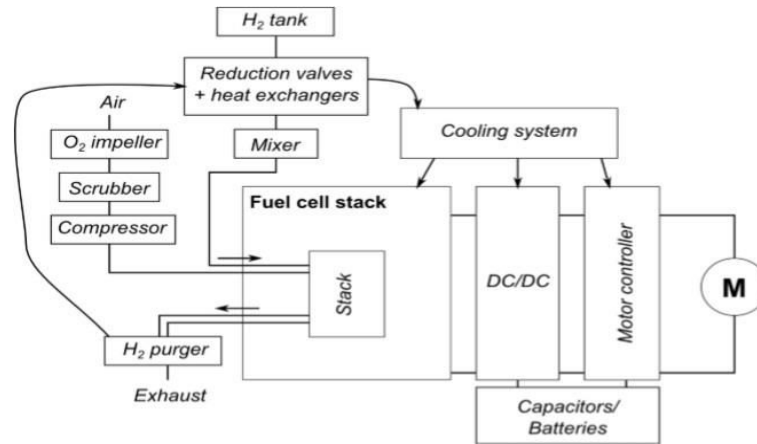


Figure 2. Block diagram of system

IV. RESULTS

• **ADVANTAGES OF SYSTEM**

Here are few of the top advantages of having a hybrid electric vehicle:

- **Environmentally friendly:** One of the biggest advantage of hybrid electric cars over gasoline powered car is that it runs cleaner and has better gas mileage which makes it environmentally friendly. A hybrid electric vehicle runs on twin powered engine (gasoline engine and electric motor) that cuts fuel consumption and conserves energy.
- **Less dependence on fossil fuels:** A hybrid electric vehicle is much cleaner and requires less fuel to run which means less emissions and less dependence on fossil fuels. This in turn also helps to reduce the price of oil in domestic market.
- **Regenerative braking system :** Each time you apply brake while driving a hybrid electric vehicle helps you to recharge your battery a little. An internal mechanism kicks in that captures the energy released and uses it to charge the battery which in turn eliminates the amount of time and need for stopping to recharge the battery periodically.
- **Financial benefits:** Hybrid electric cars are supported by many credits and incentives that help to make them affordable. Lower annual tax bills and exemption from congestion charges comes in the form of less amount of money spent on the fuel.
- **Built from light materials:** Hybrid electric vehicles are made up of lighter materials which means less energy is required to run. The engine is also smaller and lighter which also saves much energy
- **Higher resale value:** With continuous increase in price of gasoline, more and more people are turning towards hybrid electric cars.

• **DISADVANTAGES OF SYSTEM :**

There disadvantages to owning a hybrid electric vehicle, but they are probably not what people think. Contrary to popular myth, hybrid electric cars have just as much power as regular cars and have no issue with mountain driving or towing. Here are few of the disadvantages of a hybrid electric vehicle:

- **Less Power:** Hybrids are twin powered engine. The gasoline engine which is primary source of power is much smaller as compared to what you get in single engine powered car and electric motor is low power. The combined power of both is often less than that of gas powered engine. It is therefore suited for city driving and not for speed and acceleration.
- **Can be Expensive:** The biggest drawback of having a hybrid electric vehicle is that it can burn a hole in your pocket. Hybrid electric cars are comparatively expensive than a regular petrol car and can cost \$5000 to



\$10000 more than a standard version. However, that extra amount can be offset with lower running cost and tax exemptions.

- **Poorer Handling:** A hybrid electric car houses a lighter electric engine and a pack of powerful batteries. This adds weight and eats up the extra space in the car. Extra weight results in fuel inefficiency and manufacturers cut down weight which has resulted in motor and battery downsizing and less support in the suspension and body.
- **Higher Maintenance Costs:** The presence of dual engine, continuous improvement technology, and higher maintenance cost can make it difficult for mechanics to repair the vehicle. It is also difficult to find a mechanic with such an expertise.
- **Presence of High Voltage in Batteries:** In case of an accident, the high voltage present inside the batteries can prove lethal for driver. There is a high chance of driver getting electrocuted in such cases which can also make the task difficult for rescuers to get other passengers and driver out of the vehicle.

V. CONCLUSION

In this paper, an investigation into hydrogen-based energy generation using fuel cells and their utilization in hybrid vehicles was conducted. Various types of FCs and their applications were analyzed, namely the application of FCs in hybrid vehicles. FCs with adequate control strategies could become the more advantageous choice for applications in vehicles over batteries alone. Hydrogen fuel cells will play a significant role in the transportation industry in the near future. The price of fuel cells will reduce when producing fuel cells in coming decade.

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