International Journal of Research Publication and Reviews, Vol 4, no 5, pp 4068-4073, May 2023

International Journal of Research Publication and Reviews

Journal homepage: www.ijrpr.com ISSN 2582-7421

A REVIEW ON HYDROGEN FUEL CELL TECHNOLOGY FOR MODERN VEHICLES

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ABSTRACT—

A viable replacement for gasoline-powered engines in cars is hydrogen fuel cell technology. Vehicles powered by hydrogen fuel cells have the potential to significantly lower the transportation industry's contribution to climate change because they emit no greenhouse gases, in contrast to petrol engines. A fuel cell vehicle's motor is powered by electricity created in a fuel cell stack by the reaction of airborne oxygen and hydrogen gas. Water vapour is the only result of this operation. Although the cost of producing hydrogen fuel cell vehicles is still high and there aren't many refuelling stations around, government incentives and technological developments are predicted to boost the uptake of this eco-friendly mode of transportation in the years to come.

I.INTRODUCTION

A sustainable energy device known as a hydrogen fuel cell produces electricity by electrochemically reacting hydrogen and oxygen. The process generates heat, power, and water as byproducts, making it a highly effective and greener substitute for conventional fossil fuel combustion engines.[7] The first cell was inverted by Sir William Robert Grove in 1839, and hydrogen fuel technologies are not new. In the 1800s, a hydrogen mixture was frequently utilised as the gas for street lamps. In a fuel cell, the conversion of hydrogen and oxygen into heat and water results in the generation of electricity. This is quite similar to the variety of batteries that we frequently employ Thousands of stationary fuel cell systems are currently operating in industrial and commercial settings all over the world, powering everything from hospitals and utilities to hotels and college campuses. In the course of an electrolysis experiment, the principle was unintentionally found. Sir William saw a current flowing in the opposite direction, consuming the gases of hydrogen and oxygen, when he detached the battery from the electrolyzer and linked the two electrodes. He called the contraption a "gas battery" His gas battery was made up of platinum electrodes set within hydrogen and oxygen test tubes that were submerged in a solution of diluted sulfuric acid. It produced voltages of approximately one volt. Grove created a "gas chain" in 1842 by connecting several gas batteries in succession. He powered an electrolyzer that separated water into hydrogen and oxygen using the electricity generated by the gas chain[8]. Modern automobiles can use hydrogen fuel cell technology as an alternative to conventional petrol and diesel engines. It functions by turning the chemical reaction between hydrogen and oxygen into electricity, with the only byproducts being heat and water. As a result, hydrogen fuel cells are a desirable choice for lowering greenhouse gas emissions and enhancing air quality the anode and cathode of a fuel cell are two electrodes that are separated by an electrolyte. The anode side of the fuel cell receives hydrogen, while the cathode side receives oxygen. The protons and electrons from the hydrogen molecules are then separated, with the protons moving from the anode to the cathode side through the electrolyte, and the electrons moving through an external circuit to produce electricity. A fuel cell stack, which is in charge of producing the electricity required to power the vehicle, is a requirement for using hydrogen fuel cell technology to power a vehicle. Every cell in the stack has an anode, a cathode, and an electrolyte membrane. The anode receives hydrogen while receiving oxygen from the air.

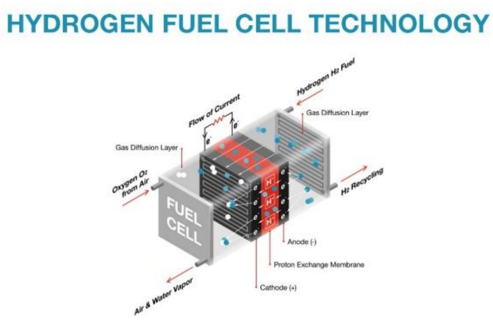

Fig 1: Hydrogen Fuel cell technology

II.WORKING

A hydrogen fuel cell works by converting the chemical energy in hydrogen into electrical energy, which can then be used to power a vehicle. The process involves several steps:

- The car has a high-pressure tank that holds hydrogen.
- The fuel cell stack, which consists of a succession of cells with an anode, a cathode, and an electrolyte, is then fed with the hydrogen.
- The hydrogen molecules are divided into protons and electrons at the anode. An electrical current is then produced by sending the electrons through an external circuit.
- As the protons move through the electrolyte and interact with airborne oxygen at the cathode, they leave behind water and heat.
- An electric motor that moves the car can be powered by the electrical energy produced by the fuel cell.

Principles of Fuel Cell

Different kinds of fuel cell systems exist. However, the fundamentals of how they work are similar. An anode, a cathode, and an electrolyte are the three fundamental components of a fuel cell system. The material employed as the electrolyte distinguishes different types of fuel cells. Although a fuel cell can be made up of hundreds of individual cells, they all have the same three essential parts. Between the cathode and the anode is where the electrolyte is placed. shows a schematic for the operation of a polymer electrolyte fuel cell (PEMFC). Proton exchange membrane fuel cells are another name for this kind of fuel cell. In mobile power applications, such as those used in vehicles, the PEMFC is what is most frequently employed. Fuel (pure hydrogen) is fed into the anode compartment of the fuel cell while air or pure oxygen is pumped into the cathode side of the fuel cell, however the electrolyte material employed changes depending on the kind of fuel cell[18]. As the gas tries to get through the electrolyte membrane on the anode side of the cell, electrons are divided. The membrane serves as a filter, preventing the passage of electrons and allowing only the passage of hydrogen ions. The hydrogen ions that made it past the membrane in the cathode compartment interact with the oxygen atoms from the air supply to create H2O as a byproduct, along with heat. information for identifying In contrast to internal combustion engines, which combine fuel with air, fuel cells separate the fuel from the oxidant without burning the fuel. As a result, internal combustion engines do not emit the toxic pollutants that fuel cells do.

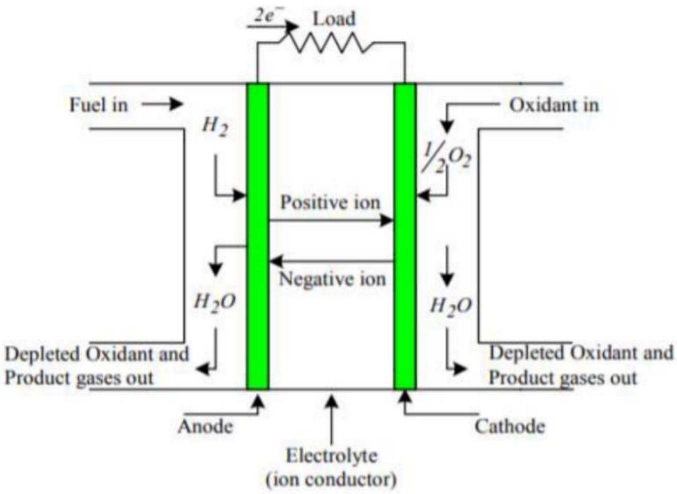

Fig 2: fuel cell operation system

Operations of Hydrogen fuel cells

i. Solid Oxide Fuel Cell (SOFC):

Solid oxide fuel cells are a typical type of stationary power fuel cell. In SOFCs, ions are conducted at high temperatures in a ceramic membrane. The ceramic used in SOFCs is typically yttrium stabilised zirconia (YSZ), which conducts oxygen ions (O2), while other ceramics also do. Solid oxide fuel cells typically function at temperatures between 650 and 800 °C. An advantage of a SOFC is that it can burn a wide range of fuels thanks to the high temperature ranges and oxidising ion (O-O) movement. These fuel cells are frequently used to power cell phone tower backup systems.

ii. Direct Methanol Fuel Cell (DMFC)

In a DMFC system, methanol can be used directly as fuel in the fuel cell. An organic fuel made from coal or agricultural goods is methanol. Both the cathode and the anode in DMFCs are catalysts made of platinum or platinum-adopted materials. Triflurომethane sulfonic acid is the electrolyte solution that is employed. A low temperature non-fuel flexible fuel cell is an example of a DMFC. Initially, these fuel cells were used in compact portable electronics like laptops and cell phones. The DMFC is less efficient and has a lower density than the PEMFC.

iii. Phosphoric Acid Fuel Cell (PAFC)

Similar to PEMFCs, PAFCs use an acidic electrolyte to conduct hydrogen ions. The PEMFC reactions also take place in the anode and the cathode. The FC in a porous silicon carbide matrix contains the viscous liquid phosphoric acid (H3PO4) through capillarity. Since PAFCs are medium-temperature fuel cells that transport hydrogen ions rather than oxidising ions (such as O, CO3O, or CO), they are less fuel-flexible than high-temperature fuel cells. Although PAFCs are mostly used for stationary electricity, certain large vehicles, including public buses, have adopted them.

iv. Polymer Electrolyte Membrane Fuel Cell (PEMFC)

As the source of driving power in the FC electric car, the PEMFC in an electric vehicle assumes the function of the internal combustion engine in a conventional vehicle. The PEMFC is the only fuel cell that has been determined to be suitable for autos thus far. A hybrid car that competes with battery-electric and fossil-fuel vehicles is produced by combining PEMFCs with rechargeable batteries. The three interconnected components of this hybrid car are the electric motor, the battery, and the PEMFC. PEMFCs employ solid polymer membranes as their electrolyte. The Nafion polymer membrane is made of perfluorosulfonic acid. Because of the acidity of this polymer membrane, protons or hydrogen ions are the ions that are transferred. Pure oxygen or air serves as the oxidant in the PEMFC, which is powered by pure hydrogen. Low temperature fuel cells known as PEMFCs conduct hydrogen ions (H+)(H+), which prevents them from being fuel-flexible. These low temperature fuel cells, which operate at roughly 80 °C, offer relatively quick starting and stopping times, making them the most popular fuel cells in the transportation industry.

V. Alkaline Fuel Cells (AFC)

In order to conduct ions between electrodes, AFCs employ an aqueous solution of potassium hydroxide (KOH) as the electrolyte. Because the electrolyte is alkaline, PEMFCs' ion conduction mechanism is not applicable. The hydroxide ion (OH), which is carried by the alkaline electrolyte, has an impact on a number of other features of the FC.Water management is a significant problem that can occasionally be overcome by utilising waterproof electrodes and maintaining the water in the electrolyte because water is required at the cathode for the oxygen reduction process. The anode reaction rejects the water it produces, whereas the cathode reaction takes the water from the electrolyte. Outside the stack, the extra water (2 mol per reaction) evaporates. AFCs can function in a variety of pressure and temperature conditions, from 80 to 230 °C and 0.22 to 4.5 MPa, respectively. Additionally, high-temperature AFCs use an electrolyte that is so concentrated that the ion transport mechanism switches from an aqueous solution to molten salt.

vi. Unitized Reversible Fuel Cell

A unitized reversible fuel cell (URFC) is an energy-storage system that operates in fuel cell mode to create electricity and in water-electrolysis mode to make hydrogen. A reversible electrochemical process that occurs during the URFC's mode switching is what changes the temperature. The oxygen gas pushes the water in the channel, yet the water on the oxygen side is still there because of the for the majority of electrical applications. Power converters, inverters, and control systems are frequently found as power electronics parts in fuel cell systems. In order to adjust the voltage of the fuel cell's DC output to the demands of the load, power converters are required. This is significant because a fuel cell's typical voltage output is insufficient for the majority of applications. By optimising power transfer and lowering losses, the power converters can also be employed to raise system efficiency[15].The fuel cell's DC output is transformed by inverters into AC power that may be used for electrical equipment including motors, appliances, and lighting. you can also use inverters.

ELECTRIC MOTOR:

A machine that transforms electrical energy into mechanical energy is an electric motor. It functions according to the electromagnetic induction principle, which involves the interaction of an electric current and magnetic field. Electric motors are widely employed for a wide range of tasks, including powering everything from modest home appliances to massive industrial gear.

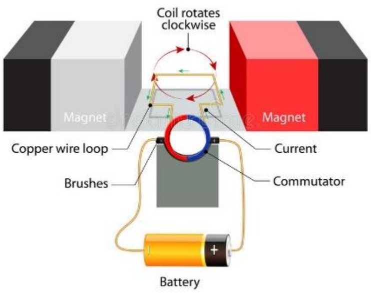

Fig 4: a simple electric motor

III.TECHNOLGY

ELECTROLYSIS:

An electrical current is used in the chemical reaction known as electrolysis to separate a substance into its component elements. A solution or molten substance is subjected to an electric current in the procedure, which causes the compound's ions to travel in the direction of the electrodes and undergo oxidation or reduction reactions[17].Since it is used to create hydrogen gas from water, electrolysis is a key technology for hydrogen fuel cell technology. After that, the hydrogen gas can be utilised to fuel fuel cells, which produce electricity. Using an electric current, water molecules are divided into their component hydrogen and oxygen atoms during the electrolysis process. After that, high-pressure tanks are utilised to store the hydrogen gas, which is subsequently used as a fuel for hydrogen fuel cells. Alkaline electrolysis and proton exchange membrane (PEM) electrolysis are the two main electrolysis processes used to produce hydrogen. PEM electrolysis uses a proton exchange membrane to separate the hydrogen and oxygen from the electrolyte, whereas alkaline electrolysis uses a strong alkaline solution as the electrolyte.

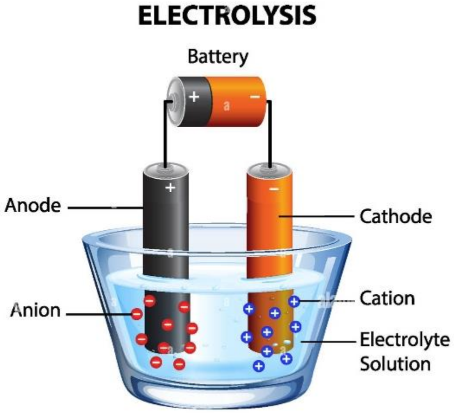

Fig 5: Electrolysis

POWER ELECTRONICS:

The operation of hydrogen fuel cell systems relies heavily on power electronics, particularly when converting the fuel cell's direct current (DC) output to the alternating current (AC) required for the majority of electrical applications. Power converters, inverters, and control systems are frequently found as power electronics parts in fuel cell systems. In order to adjust the voltage of the fuel cell's DC output to the demands of the load, power converters are required. This is significant because a fuel cell's typical voltage output is insufficient for the majority of applications. By optimising power transfer and lowering losses, the power converters can also be employed to raise system efficiency[15]. The fuel cell's DC output is transformed by inverters into AC power that may be used for electrical equipment including motors, appliances, and lighting. The frequency, voltage, and phase of the AC power output can also be adjusted by inverters to meet the needs of the load and the electrical grid.

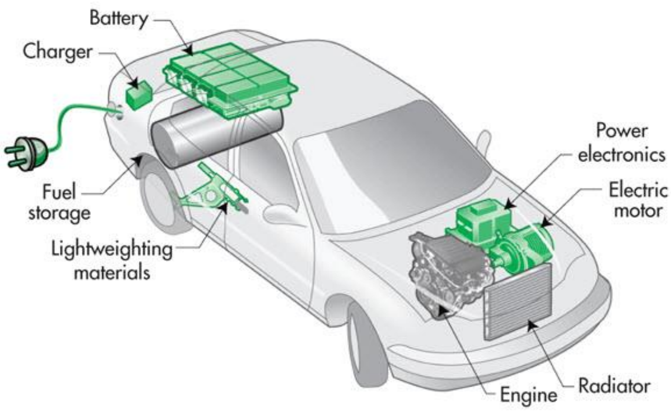

Fig 6: Power electronics

HYDROGEN STORAGE:

The process of storing hydrogen gas for later use in a variety of applications, including as stationary power production, fuel cell cars, and industrial processes, is known as hydrogen storage. Since hydrogen has a poor volumetric energy density compared to other fuels with comparable energy contents, it occupies a lot more space. Therefore, for hydrogen to be widely used as a clean energy source, it is essential to discover effective and secure methods of hydrogen storage.

There are several methods for hydrogen storage, including:

Storage of compressed hydrogen gas: At pressures of generally 350 to 700 bar, compressed hydrogen gas is kept in high-pressure tanks. This technique, which is frequently employed in fuel cell cars, calls for specialised high-pressure storage tanks.

Storage of liquid hydrogen: Liquid hydrogen is created by chilling hydrogen gas to an extremely low temperature (-253°C) and then storing it in cryogenic tanks. Some fuel cell vehicles employ this technique, which calls for specialised storage tanks and insulation.

Solid-state hydrogen storage: Hydrogen gas is absorbed into a solid material, such as metal hydrides, carbon nanotubes, or zeolites. This method has the potential for high-density storage but requires further research and development to be commercially viable.

FUEL CELL STACKS:

Hydrogen is divided into protons and electrons when it is delivered to the anode of a fuel cell stack. While the electrons are compelled to flow through an external circuit to the cathode, the protons travel through the electrolyte to do so. Electrons create electrical energy as they go across the external circuit, which can be utilised to run an electric motor or recharge a battery. The protons and electrons recombine with oxygen at the cathode, where the only by-product is water.

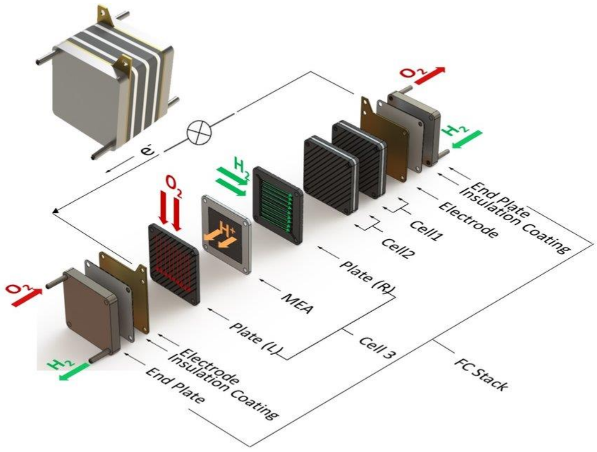

Fig 7: Fuel cell stack

IV ADVANTAGES

1. Zero Emissions: Hydrogen fuel cell vehicles produce no emissions other than heat and water vapour. In terms of lowering greenhouse gas emissions and enhancing air quality, this is a considerable benefit.
2. High Efficiency: Fuel cell cars are very effective at turning the energy from the hydrogen fuel into electricity, which powers the car roughly 60% of the time. Internal combustion engines normally convert less than 25% of the fuel's energy into usable energy, which is a significant improvement over this.
3. Quick Refuelling: A hydrogen fuel cell vehicle can be refuelled in a matter of minutes, much like a traditional petrol or diesel vehicle. Battery electric vehicles, on the other hand, may need several hours to recharge.
4. Long Range: Compared to battery-electric vehicles, hydrogen fuel cell vehicles offer a greater driving range. For instance, the Toyota Mirai can travel more than 300 miles on a single hydrogen tank.
5. Versatility: Hydrogen fuel cell technology can be applied to a wide range of vehicles, such as cars, buses, trucks, trains, and ships.
6. It provides a useful way to store energy.
7. Sustainable and easily accessible.
8. Extremely Effective in Relation to Other Energy Sources.

V. APPLICATIONS

1. Passenger Cars: One of the hydrogen fuel cell technology's most widespread applications is in automobiles. These vehicles only emit water as a byproduct while using fuel cells to create electricity to run an electric motor.
2. Buses: Around the world, hydrogen fuel cell buses are becoming more and more common in various places. They provide zero-emission public transport options that lessen smog in cities.
3. Forklifts: In distribution centres and warehouses, forklifts driven by hydrogen fuel cells are gaining popularity. Compared to conventional battery-powered forklifts, they offer longer running times and quicker refuelling.
4. Trucks: Hydrogen fuel cell-powered trucks provide an alternative to diesel-powered cars and have the ability to transport huge loads over great distances.
5. Marine Vessels: In order to provide zero-emission propulsion solutions for water-based transportation, hydrogen fuel cell technology is also being employed to power boats and other marine vessels.
6. Backup power generation: Stationary fuel cells are employed locally as a component of UPS systems, when continuous uptime is essential. A growing number of hospitals and data centres are turning to hydrogen to meet their needs for uninterruptible power supplies.

7. Portable electricity: Hydrogen provides a variety of alternatives for portable power generation. In fact, NASA was responsible for the development of some of the first hydrogen fuel cells.

VI. REFERENCES:

1. Xiaotong Zhang, Fangqin Li, Jian xing Ren, Haijun Feng, Chuang Mal and Xin Hou, “Progress in the application of Hydrogen fuel cells”, ICAEER 2019, pp. 1-3, 2019.
2. N Shakeri, M Zadeh and J Bremnes Nielsen, “Hydrogen fuel cell for ship electric propulsion moving toward greener ships”, IEEE, vol. 8, pp. 27-43, June 2020.
3. X Chen, W cao and S Hu, “Artificial Intelligence- Aided model predictive control for a grid tied wind Hydrogen fuel cell system”, IEEE, vol. 8, pp. 92418-92430, 2020.
4. G D Nam, L D Vuong, H J Sung, S J Lee and M Park, “Conceptual design of an aviation propulsion system using hydrogen fuel cell and superconducting motor”, IEEE, vol. 31, pp. 1-7, Aug 2021.
5. Yogesh Manoharan, Syed Eshan and Hosseini Brayden Butler, “Hydrogen Fuel Cell Vehicles”, Research gate, pp. 9-12, May 2019.
6. https://www.power-technology.com/comment/standing-at-the-precipice-of-the-hydrogen-economy/ accessed on March 14, 2023.
7. https://www.azocleantech.com/article.aspx?ArticleID=29#:~:text=In%20the%20future%2C%20hydrogen%20will,electricity%2C%20and%20to%20fuel%20aircraft accessed on March 14, 2023
8. Ujwal Zore, Sivakumar Manickam, Sripadh guptha Yedire and Shirish H sonawane, “A review on recent advances in hydrogen energy, fuel cell, biofuel and fuel refining via ultrasound process intensification”, Research gate, pp. 2-24, 22 March 2021.
9. N Bassat, M Casas-Cabanas, and A Tarancon, "Recent advances in the design and engineering of solid oxide fuel cells", Nature Reviews Materials, 2020.
10. S Azadi and M Mehrpooya, "Hydrogen fuel cells: From fundamentals to applications", International Journal of Hydrogen Energy, pp. 2-6, 2019.
11. K N Kadirgama, M M Noor, and W H Azmi, "A review on the development of hydrogen fuel cell technology", Renewable and Sustainable Energy Reviews, 2019.
12. Prem Gajjar, Priyanshu Jha, Dhruvil Jadawala and Umar Valiullah, “Review paper on fuel cell technology”, International journal of engineering research and technology (IJERT), vol. 11, Issue 01, Jan 2022.
13. L Weiming, W Jiekang, C Jinjian, M Yunshou and C Shengyu, "Capacity Allocation Optimization Framework for Hydrogen Integrated Energy System Considering Hydrogen Trading and Long-Term Hydrogen Storage," IEEE, vol. 11, pp. 15772-15787, 2023.
14. N A Iskandar and A Maheri, "Techno-economic Assessment of Hydrogen Refuelling Station: Case Study of Hydrogen Train," 2022 7th International Conference on Environment Friendly Energies and Applications (EFEA), pp. 1-6, Dec 2022.
15. T Sun, G Chen, H Lan, J Guo, X Wang and D Hao, "Experimental Study on Fuel Economy of Fuel Cell Truck Under Different Driving Cycle," 4th Asia Conference on Energy and Electrical Engineering(ACEEE), pp. 38-43, Oct 2021.