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TOPOLOGIES OF PROPULSION SYSTEMS FOR FUEL CELL ELECTRIC VEHICLE: A BRIEF REVIEW

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Review

A B S T R A C T

Due to recent technological advancements and the implementation of international regulations to reduce greenhouse gas emissions, automakers are now focusing on electric/hybrid and electric fuel cell vehicle technologies. Fuel Cell Hybrid Electric Vehicles (FCHEVs), which combine the benefits of electric propulsion and fuel cell technology, have drawn much interest as a possible option for sustainable transportation. For these cars to operate efficiently and with as little pollution as possible, energy flows must be managed effectively inside the vehicle. This study focuses on electric fuel cell cars to effectively fulfil the dynamic power demand required by the electric motor and auxiliary systems. These vehicles combine the fuel cell system with hybrid energy storage systems, represented by batteries and ultracapacitors. This paper provides valuable insights into the cutting-edge EMS control methodologies for improving the performance of FCHEVs by combining results from recent research and real-world implementations.

1. INTRODUCTION

A potential answer to the environmental and energy issues in the transportation in-dustry is the use of fuel cell technology in hybrid electric cars (Emadi et al., 2006). The energy source cost, which accounts for roughly one-third of the vehicle's overall cost, is the biggest obsta-cle to the development of EVs. Several energy source types are utilized to lower stor-age costs while improving efficiency, leading to various Ev configurations (Sulaiman et al., 2015).

Battery electric cars (BEV), fuel cell electric vehicles (FCEV), and fuel cell hybrid electric vehicles (FCHEV), which employ a combination of fuel cell and battery/ultra-capacitor storage technology as an energy source, are the three varieties of all-electric vehicles (Sorlei et al., 2021). Designing vehicle parts and enhancing vehicle efficiency are two research processes for FCHEV. Several studies are being carried out to increase FCHEV's pop-ularity in the automotive market. However, few publications cover all the significant recent advancements in this hybrid vehicle technology (Hannan et al., 2014; Yong et al., 2015; Sarlioglu et al., 2016; Hannan et al., 2017).

Clean energy source refers to fuel cells (FC). FCs are very efficient, portable, and have adjustable power ratings (Stambouli, 2011). As a result, they may be applied in several industries, including transportation and power generation. FCs may be effectively used in vari-ous vehicles, including light commercial vehicles, passenger cars, trucks, and buses (Hannan et al., 2014). Therefore, the widespread usage of FCs worries researchers. William Groove made the initial fuel cell discovery in the year 1843. To generate electricity for fuel cell electric vehicles, these FCs can be utilized alone or in conjunction with other gen-erating sources such as batteries or ultracapacitors (Yong et al., 2015). Compared to conventional cars, these FCEVs generate less

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pollutants and use less fuel. Along with the discharge of electricity, this FCEV produces heat and water.
This evaluation is focused on the latest energy sources, power conditioning tech-niques, and FCHEV systems, as well as their advantages and disadvantages.

2. A REVIEW OF TYPICAL TOPOLOGIES OF FCHEVS

Rane et al. (2023), conducted a Parametric Study on Other energy sources, such as battery systems, ultra-capacitors, or fuel cells, represent the substitute for fossil fuels that automakers have developed to power cars. The most practical ways to reduce greenhouse gases (GHG) and other environmentally hazardous gases are electric vehicles (EVs) and fuel cell electric vehicles (FCEVs). Even if EVs and FCEVs can cut emissions to a certain level, they cannot eliminate them (Xun et al., 2018).
Due to their popularity in the road and rail transportation sectors (and beyond) and lack of reliance on fossil fuels, FCEVs are made preferable by the infrastructure for renewable energy sources (Mihet-Popa & Saponara, 2018). A mix of Fuel Cells (FC), batteries (B), and ultracapacitors (UC) is used by FCEVs and FCHEVs (Das et al., 2017). Creating vehicles and increasing their efficacy are both research steps for FCHEVs. They utilize the battery and ultracapacitor pack as an additional power source in addition to the fuel cell system to supply the necessary power on the DC bus. Lui et al. (2018) provides a detailed description of FCEV topologies. FCHEVs are often categorized according to five topological categories: entirely FC, FC + battery hybridization, FC + UC hybridization, FC + battery + UC hybridization, and FC + other hybridization.

2.1 Fully FCEV

The fuel cell is an electrochemical energy conversion device where the chemical energy is converted directly into electrical energy along with the heat and water as byproducts. An electrolyte is present during the reaction in the presence of the input reactants (fuel and oxidant), and electricity is produced as the reaction's byproduct. It is a zero-emission system since the reactions only waste heat and water instead of emitting exhaust gases.
With no additional energy source, fuel-cell electric vehicles exclusively employ fuel cells to power the transmission system. This topology's sole components—seen in Figure 1 are a fuel cell stack, a DC/DC converter, an inverter, and an electric motor. Due to its absence of moving components, this vehicle configuration provides several unique characteristics, including quick charging times, quiet operation, long driving ranges, minimal emissions, and the ability to start cold. Forklifts, aviation, maritime, and low-speed vehicles like buses and trams are all good candidates for full FCEVs.

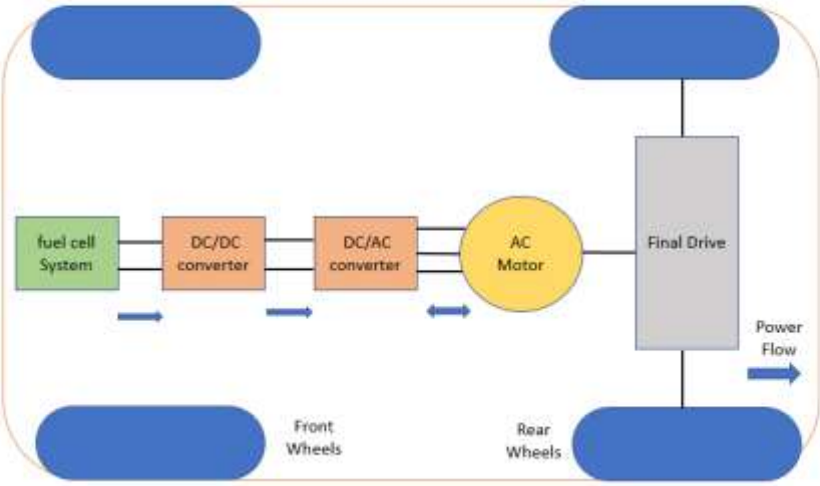

Figure 1. Topology of full FCEVs

2.2 FC + Battery Hybridization

A battery is a storage unit that stores electrical energy as chemical energy. Batteries come in two varieties: primary batteries, which cannot be recharged, and secondary batteries, which can. Secondary batteries are favoured for vehicle applications since they are acceptable for numerous uses. The FC and battery set architecture is frequently utilized in FCEV hybrid systems (Xu et al. 2009). Here, two different converter kinds are employed. As shown in Figure 2, there are two converters: a unidirectional converter linked to FC and a bidirectional converter used to connect the battery. The battery gives the hybrid system its first kick-start, allowing FC to avoid functioning in a low-efficiency zone. As a result, the electric motor receives a large current when it starts. As soon as the car begins, the FC is turned on, maintaining the operation of the electric motor. During this time, the battery is charged following the demands of the charge status.

2.3 FC + UC Hybridization

The ultracapacitor is an energy storage device with a high energy density, a derivation of the normal capacitor. It is also known as an electrochemical or supercapacitor (Burke, 2000).

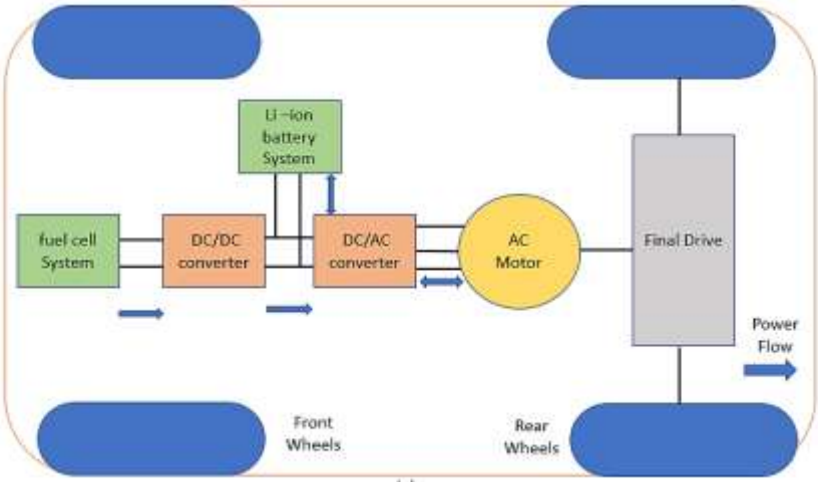

Figure 2. Topologies of FC + battery

Farads (F) are used to measure the range of ultracapacitor capacity, as opposed to milli-, micro-, and pico-farads (mF), which are used to measure the range of conventional capacitors (Shirhatti et al., 2019). In the type III hybrid architecture, an ultracapacitor (UC) is used in place of the battery, as seen in Figure 3. The bidirectional converter is linked to the UC. This UC meets the FC's brief power requirement in emergency scenarios (Uzunoglu & Alam, 2007). Ultracapacitors offer the advantages of quick charge and discharge and being able to be used more often when compared to the drawbacks of batteries, such as poor energy density, big size, and tiny instantaneous charge and discharge current. Furthermore, the typical lifespan of UC is 12–20 years. The hybrid system may also be separated into two variants based on whether the ultracapacitor is linked to the DC bus through a DC/DC converter, as illustrated in Figure 3. A completely active architecture is typically used since the ultracapacitor's voltage fluctuation is too great. The advantages of this method include improved dynamic responsiveness to sudden high-power demand and more effective power recovery. It is less popular than hybrid power systems using fuel cells and batteries since it also has the drawbacks of high economic cost and low energy density.

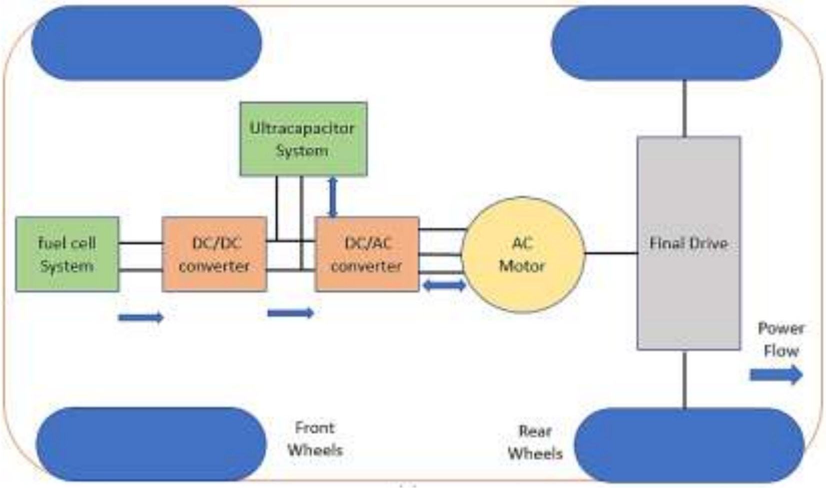

Figure 3. Topologies of FC + UC

2.4 FC + Battery + UC Hybridization

Figure 4 depicts the structure of the fuel cell + battery + UC hybrid power system. To meet the average power requirements of the load, the hybrid system continues to rely on fuel cells as its primary energy source. For batteries and ultracapacitors to function in various states, their features are considered in their entirety. Ultracapacitors can charge and discharge with high current but have limited energy storage. When the power needed by the load has significant abrupt variations, ultracapacitors can be employed to deliver immediate power or energy recovery. Nevertheless, this system's control approach is complicated by the hybrid system's intricate structure and the power sources' tight coupling.

Fuel cells and other supplementary energy sources are still used in a limited number of hybrid power systems in hybrid automobiles. Batteries can be replaced with flywheels as supplemental power sources. When the motor requires power, the flywheel's high-speed mechanical energy is transformed into electrical energy. However, flywheel operation is not frequently employed since it necessitates high security. Similar to SMES, which is not widely utilized because of its exorbitant cost. Due to its reliance on solar energy and the high degree of supply uncertainty, SPVs are also not commonly employed. This study doesn't go into great detail on various auxiliary energy sources because it primarily focuses on hybrid power systems made up of fuel cells, batteries, and ultracapacitors.

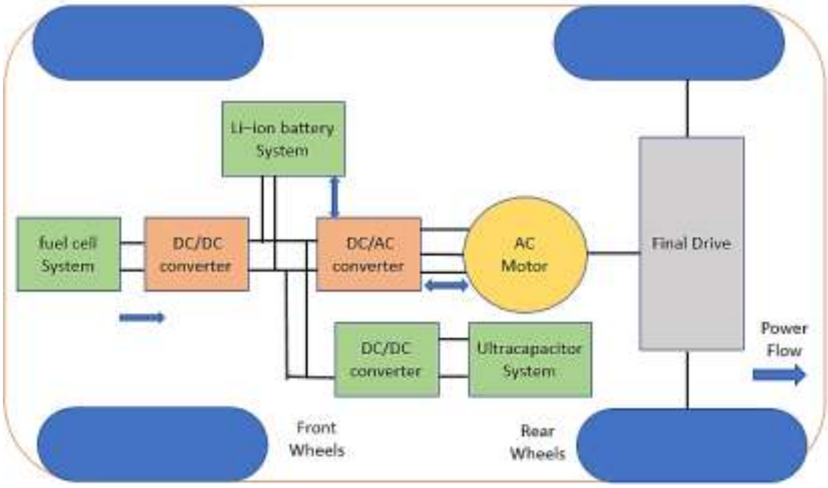

Figure 4. Topologies of FC + battery + UC

3. CONCLUSIONS

The purpose of this essay was to present cutting-edge FCHEV technology, including its many elements, technological configurations, current conditions, challenges, and prospects for the future. In conclusion, this extensive research offers an in-depth analysis of EMS control approaches for fuel-cell hybrid electric vehicles. This paper advances effective energy management tactics and eventually encourages broader use of FCHEVs for sustainable transportation by assessing current methodologies, emphasizing recent advancements, and identifying essential difficulties.

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