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Topologies of Electric Vehicle: A Review

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***Abstract*: The use of fossil fuel in vehicles is a rising concern due to its harmful environmental effects. Several alternative energy resources are being studied for hybrid vehicles in preparation to replace the exhausted supply of petroleum worldwide. Among other sources battery, fuel cell (FC), supercapacitors (SC), and solar photovoltaic cells are studied for powering electric vehicles. This paper explores an overview of different electric propulsion systems composed of energy storage devices for different topologies of electric vehicles.**

***Keywords*: battery electric vehicle, electric vehicle, hybrid vehicle, plugin hybrid vehicle.**

1. Introduction

Because of the ever-increasing consumption of fossil fuels in IC engine-based vehicles, there are serious environmental concerns about air and water pollution along with global warming. The fossil fuel reserve is depleting day by day because of the irrational use of petroleum in automobiles. Growing environmental concerns and the depletion of fossil fuels have prompted automakers to shift their focus away from IC engine-powered vehicles and toward vehicles that run on electricity.

This paper covers a elaborated review of power conversion topologies, ESS (energy storage system) in electric vehicles. Section C briefly discusses the categorization of electric vehicles. Section D explores different sources of energy for EV. Section E elaborates about different topologies of electric motors (EMs) employed in EVs. Recent trends in the charging mechanism for electric vehicles are discussed in section F. Last but not the least various opportunities, confronts in electric vehicles, are discussed in section G along with conclusions in Section H.

2. Classification of Electric Vehicles

A. All Electric Vehicle

1) Battery electric vehicle (BEV)

They are powered by motor powered by a battery or ultra-capacitor as the energy source. Zero emission come as an advantage for such motors whereas intermittency of battery charging, and the running capability come as a disadvantage for such motors. They have several advantages, including reduced conversion loss, low vehicle weight, and environmental friendliness. However, the demand for a high torque traction motor, a long recharging period, and battery management are all disadvantages. BEVs include the Tesla Model 3, Jaguar I-Pace, Nissan Leaf, MG ZS EV, and others.

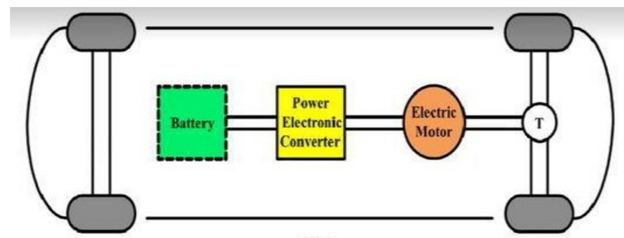

Fig. 1. Battery electric vehicle

2) Fuel cell electric vehicles (FCEV)

They are powered by an electric motor and use a fuel cell as their energy source. Have a high efficiency and low fuel emission. Among the several types of commercially available FCs, the (proton exchange membrane fuel cell) is favored. The high cost of fuel is the biggest downside of FCHEV (H2). Some examples of FC-based automobiles include the Honda FCX Clarity, Toyota Mirai, and Hyundai Tuscan.

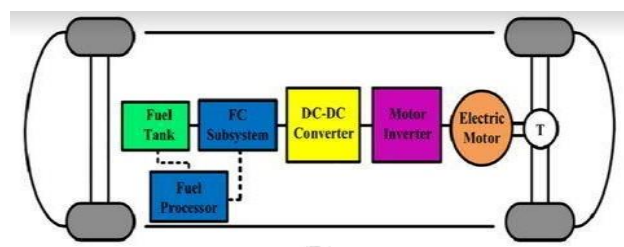

Fig. 2. Fuel cell electric vehicles

3) Fuel Cell Hybrid Electric Vehicles (FCHEV)

They are powered by an electric motor and use a fuel cell with a battery or ultra-capacitor as their energy source. Have a low-emission and high-efficiency system. Hydrogen, a fuel system, and a fuel processor are all expensive.

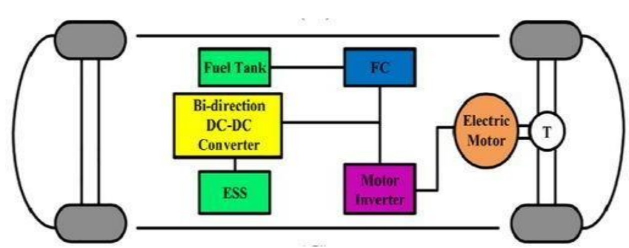

Fig. 3. Fuel cell hybrid electric vehicles

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B. Hybrid Electric Vehicle

1) Series hybrid electric vehicle

EMs supply all of the tractive effort in this example, whereas ICE is used in conjunction with a generator to produce electricity to power EMs for vehicle propulsion. Here, IC is at its most productive. However, it necessitates large electrical machinery and a battery pack. The Chevrolet Volt is an example of a series hybrid electric vehicle (HEV).

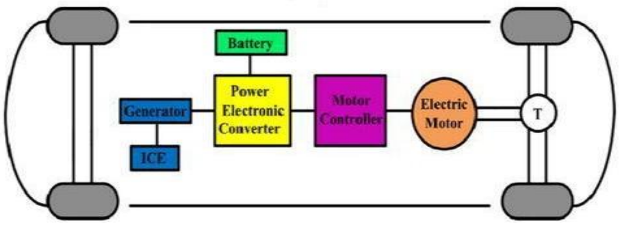

Fig. 4. Series HEV

2) Parallel hybrid electric vehicle

In addition to their concurrent parallel action during accelerating and braking, ICE and EM can be used to provide tractive effort to move the vehicle wheel. Parallel hybrid electric vehicles include the Honda Civic Hybrid and Honda Insight.

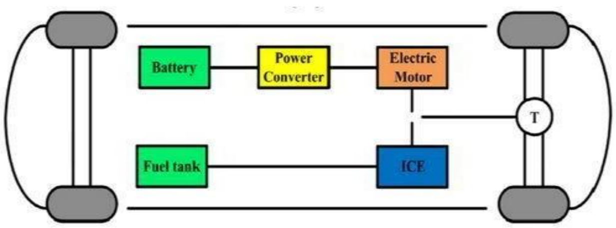

Fig. 5. Parallel HEV

3) Series-Parallel hybrid electric vehicle

It's also known as dual-mode HEV since it combines elements of both series and parallel hybrids. For delivering power to the wheels, there are two pathways (series and parallel). Apart from direct parallel coupling between the ICE and the EM, the ICE is also linked to a generator to generate energy, which is used to charge the battery and move the car through a power [electronics interface (series mode).

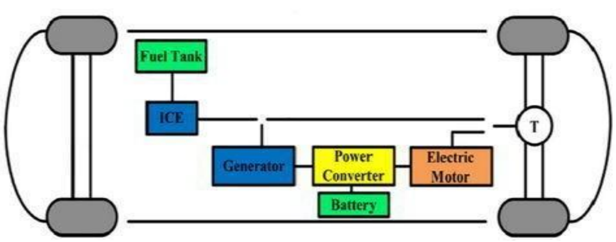

Fig. 6. Series-Parallel HEV

4) Plug-in Hybrid Electric Vehicle (PHEV)

It is powered by batteries or other energy storage devices that can be recharged by connecting to a power source external to it. It can also be powered by ICE if the battery runs out. Low fuel consumption and pollution are two of its advantages, which are compensated by the battery's high cost. The Ford C-MAX Energi, Chevy Volt, and Toyota Prius are all examples.

3. Energy Storage System

1) Fuel cell

It's an electrochemical device that generates electrical energy from the chemical energy of the reactants. The main inputs are hydrogen (H2) and oxygen (O2). Because the sole byproduct of FC is water, it has a high conversion efficiency and creates no emissions. The PEMFC is the chosen FC in vehicle applications among numerous FC technologies due to its low operating temperature, compact size, high power density, and rapid starting.

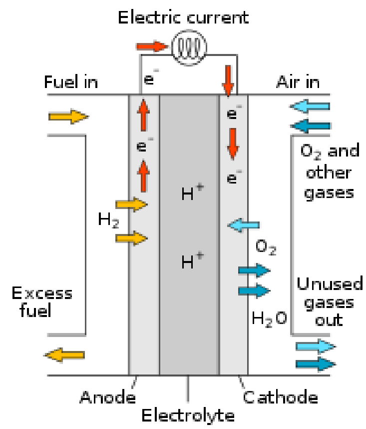

Fig. 7. Fuel cell

2) Battery

It's an electrochemical device that stores chemical energy and converts it to electricity. (There are two types of batteries: primary and secondary, with the secondary being used since it can be recharged.) It should be high in energy density, modular, flexible, cheap in cost/affordability, minimal maintenance, and have a long service life. Lithium-ion batteries are commonly used in electric cars due to their low weight, high energy density, and inexpensive cost when compared to other batteries on the market.

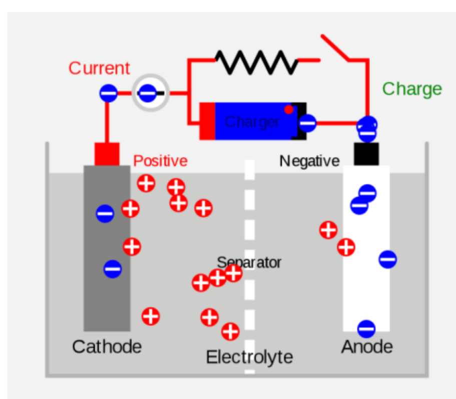

Fig. 8. Battery

3) Ultracapacitor (UC)

It offers a high energy and power density, as well as a long-life cycle and efficient operation. It can survive millions of charging/discharging cycles due to the charge storage method. It may be used as a battery alternative in a number of applications due to its high efficiency (>90%), high capacity, and higher working temperature. It cannot be utilized to replace batteries in electric cars because to its low energy storage capacity.

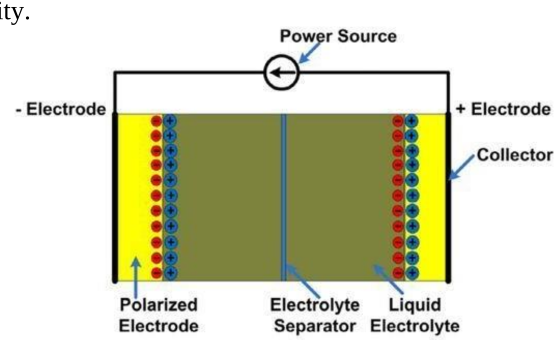

Fig. 9. Ultra-capacitor

4) Flywheel Energy Storage System (FEES)

It's an electro-mechanical energy storage system that acts as a mechanical battery by storing rotating kinetic energy. The inertia wheel and motor-generator set known as machine, the rotor bearing, and the power electronic circuit or interface are the three primary devices. Low-speed FEES and high-speed FESSs are two types of FESSs.

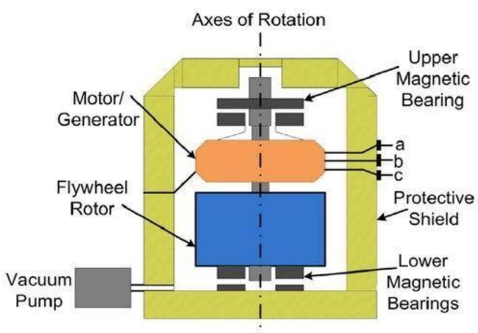

Fig. 10. Flywheel energy storage system

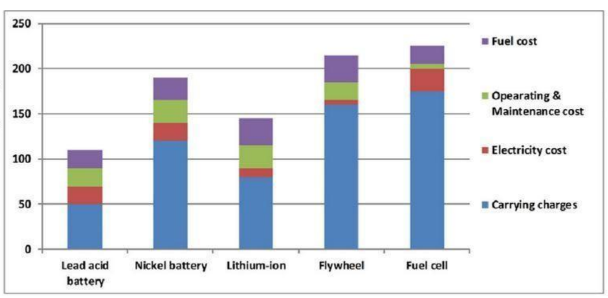

Fig. 11. Comparison of the annual cost of different energy sources

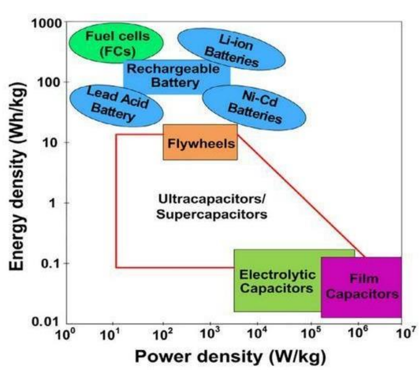

Fig. 12. A plot of energy density v/s power density for energy sources

4. Motors in the Electric Vehicle

1) Brushless DC motor (BLDC)

The upgraded variants of DC series motors are these motors. Brushes and commutators are not used. Permanent magnets are utilized instead, which have a high starting torque, excellent efficiency, and require less maintenance. BLDCs have been increasingly popular in recent years, either because of the hub motor or because they are belt-driven.

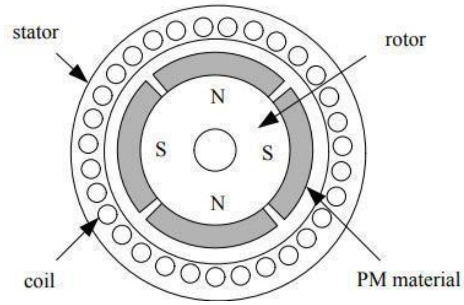

Fig. 13. Brushless DC motor

2) Induction Motor (IM)

The torque is produced by an electromagnetic interaction between the magnetic field of the stator windings and the induced rotor field. Copper-iron losses in the stator and rotor, as well as friction and windage losses, account for the power losses. It offers increased power density, efficiency, and low maintenance, as well as a simple and durable structural arrangement that delivers high torque, making it suitable for electric vehicles. It is used for propulsion in the Tesla Model S.

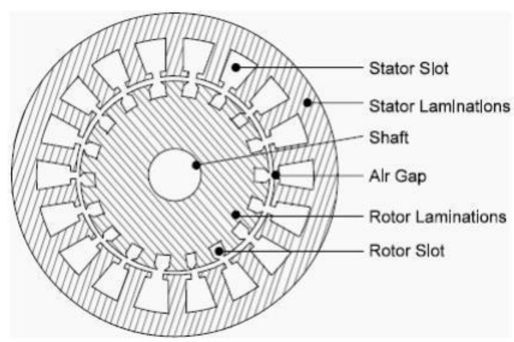

Fig. 14. Induction motor

3) Permanent Magnet Synchronous Motor (PMSM)

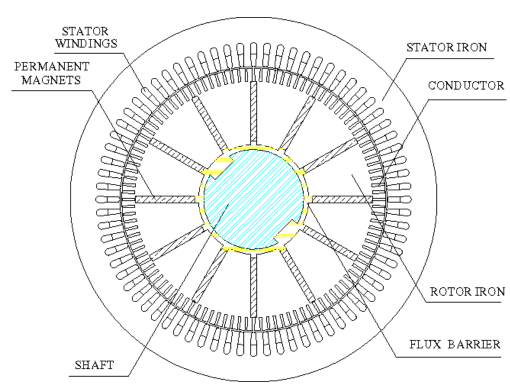

Fig. 15. Permanent magnet synchronous motor

The structure is fairly similar to that of BLDCs, but the back emf formation differs. The back emf in PMSM is sinusoidal, whereas the back emf in BLDC is trapezoidal. It has a high-power rating and can be used in high-performance vehicles such as sports cars, buses, and other vehicles. Nissan Leaf uses it for propulsion.

4) Switch Reluctance Motor (SRM)

These motors have the ability to run at high speeds and at high temperatures. It has a simple salient type configuration with concentric stator windings and no rotor winding. It features a lower rate of idle losses and a solid structure that can withstand challenging operational conditions. When compared to an induction motor, it is significantly easier to manage at greater speeds.

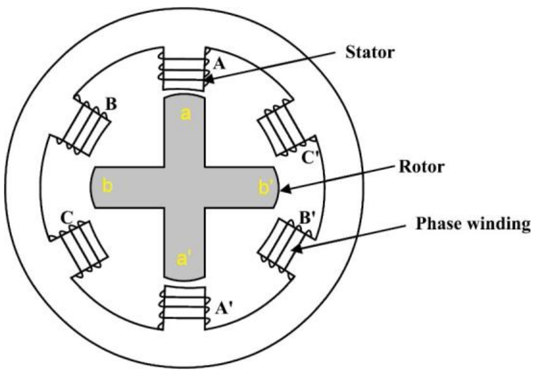

Fig. 16. Switch reluctance motor

5. Charging of Electric Vehicles

Figure 17 shows a diagram of the electric vehicle charging system. The charger control unit, charging cable, and vehicle control unit are the three primary components of this system.

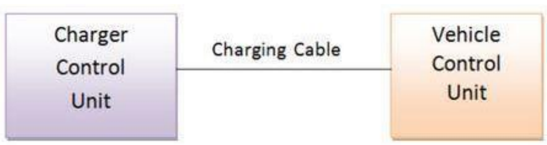

Fig. 17. Block diagram of EV charging system

Types of charging methods:

1) Inductive Charging

Energy is transferred between two things via an electromagnetic field. Energy is delivered to a device via inductive coupling, which can subsequently be used to charge batteries or power the vehicle. Induction chargers use a coil within a charging base to create an alternating electromagnetic field, and a second coil within the portable device transforms the power from the electromagnetic field back to an electric current to charge the battery. A transformer is formed by the coupling of these two coils. When resonant inductive coupling is used, the distance between the transmitter and receiver coils is increased.

The current resonant system uses a mobile transmission coil and various materials for the receiver coil, such as silver-plated copper or aluminium, to reduce weight and resistance due to the skin effect, which is a recent advancement in this field. Its disadvantage is that it charges slowly and is costly.

2) Conductive Charging

A cable connects the battery to a power source, which is immediately plugged in. The driver must plug in the cable, which is a disadvantage of this arrangement.

3) Changing Battery

A switching station is used to replace drained batteries with new ones. However, the size and internal connections of the batteries must be standardized in order for this to be possible.

6. Technologies and Challenges

The performance of the vehicle is determined by the batteries, which are a significant factor. Higher-capacity batteries will encourage the adoption of the fastest and most powerful charging modes, as well as more advanced wireless charging technologies. Another issue that would aid the deployment of EVs is the construction of a single connector that would be utilised globally. The electric vehicle (EV) will play a significant role in future Smart Cities, with various charging schemes that will adapt to the demands of the users and will be of particular importance. As a result, various modifications to BMS should be made in order to improve its overall efficiency.

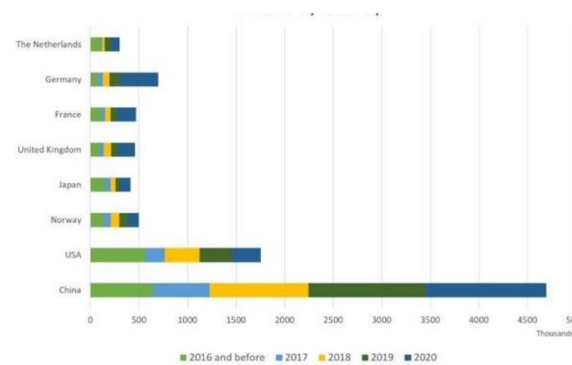

Fig. 18. Electric vehicle sale worldwide

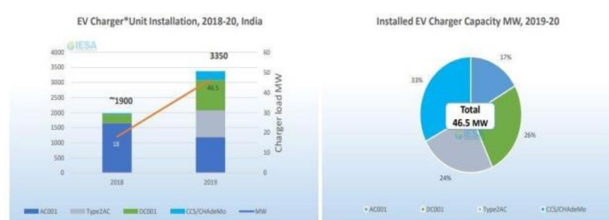

Fig. 19. EV chargers installed in India (2018-2020)

Fig. 20. EV sales in India (2019-2020)

7. Conclusion

EVs will play a critical role in the future smart grid and will be required to reduce harmful gases in cities. The introduction of electric vehicles onto the market has received a lot of attention in recent years.

In vehicle applications, Li-ion batteries are one of the most suitable battery technologies. Though Li-ion batteries are the current trend in electric vehicles, battery technology is continuously being investigated for better options, making it a popular research topic. To power the wheels of HEVs with the best energy management system, current EVs are built around FC, UC, and lithium-based batteries. Apart from their potential role as backup and emergency power sources, the UCs (rated in Farads) are suited for supplying transitory power demand at the time of starting and braking of EVs. The usage of hybrid capacitors in vehicle applications is currently popular.

The complex hybrid architecture of EVs, according to the literature assessment, will deliver greater efficiency, lower costs, and more complicated designs.

According to the results of the study, there is a rising interest in creating superior traction motors for hybrid vehicles, and there are numerous traction motors on the market. However, induction motors and permanent magnet AC motors are typically chosen based on the trade-offs supported performance, robustness, dependability, and cost. Motor technology is still being researched for better options, thus it's still a hot topic.

In comparison to previous years, electric vehicles are more readily available on the market. As a result, electric vehicles have a promising future.

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