A Review Paper on Batteries used in Electric Vehicles and Charging Methods

Sarika Satpute[1], Swati Joshi[2], B.S. Gujar[3], Priyanka Mahajan[4]

1. Assistant Professor, Department of Electrical Engineering , Dr. D. Y. Patil Institute of Engineering , Management & Research, Akurdi, Pune – Maharashtra, India-411017.
2. Assistant Professor, Department of Electrical Engineering , Dr. D. Y. Patil Institute of Engineering , Management & Research, Akurdi, Pune – Maharashtra, India-411017.
3. Assistant Professor, Department of Electrical Engineering , Dr. D. Y. Patil Institute of Engineering , Management & Research, Akurdi, Pune – Maharashtra, India-411017.
4. Lab Technician, Department of Electrical Engineering , Dr. D. Y. Patil Institute of Engineering , Management & Research, Akurdi, Pune – Maharashtra, India-411017

Corresponding Author-

Sarika Satpute

Assistant Professor, Department of Electrical Engineering

Dr. D. Y. Patil Institute of Engineering, Management & Research, Akurdi, Pune – Maharashtra, India-411017

E-mail: sarikadypiemr@gmail.com

Mobile N.o: 7756909712

ABSTRACT: Now a days, electric vehicle are the most popular vehicles around the world. The use of electric vehicle Is reducing carbon footprints & greenhouse effect. In many research papers the disadvantages of fuel vehicles and their effect on human life & atmosphere is discussed. With this consideration & requirement many electric vehicles are developed and used by the consumers. The most important advantage of electric vehicle is, it can be easily charged from anywhere & cost of charging is reduced as compared to the fuel vehicles. Electric vehicles are the future, not because their many advantages but they are also beneficial for better environment.In this review paper, super capacitor & Battery technology is discussed to increase the energy capacity of plug-in hybrid electric vehicle & hybrid electric vehicle. The different types of batteries and their methods of charging is a reviewed. Also the battery management & maintenance is discussed.

Keywords: Energy management System (EMS), Electric Vehicles, Batteries

INTRODUCTION:

What are electric vehicles?

Electric vehicle" or "EV" refers to any vehicle that uses an electric motor or traction motor for propulsion, in contrast to vehicles that rely on an Internal Combustion Engine (ICE). While electric cars, both hybrids and all-electric, are the most common type of electric vehicle that comes to mind, the concept extends to a wide range of transportation options beyond cars. Electric vehicles include;

Electric Trucks: Electric trucks, also known as electric Lorries, are gaining popularity for their potential to reduce emissions and operating costs. These can be used for transporting goods and are often used in delivery and freight operations.

Electric Planes: Electric planes are emerging as a more environmentally friendly option for short-haul and regional flights. They can significantly reduce carbon emissions and noise pollution compared to traditional jet engines.

Electric Trains: Electric trains have been in use for many years in various forms, from light rail systems to high-speed trains. They are known for their efficiency and lower environmental impact compared to diesel-powered trains.

Electric Boats: Electric boats, sometimes referred to as electric watercraft or boats, use electric propulsion systems and are employed for both recreational and commercial purposes. They are eco-friendly alternatives for water transportation.

How do electric vehicles work?

The fundamental workings of electric vehicles (EVs) regardless of the specific type of EV, whether it's a battery-electric , hybrid, or fuel cell electric vehicle, they all share some common characteristics in their operation; following are the components of HEV system;

1. Electric Motor: All EVs use electric motor as a drive system. This motor is responsible for converting electrical energy into mechanical energy to drive the vehicles. Electric motors are known for their efficiency and high staring torque, which makes the EVs responsive and smooth in functioning.

2. Battery Stack: EVs rely on a stack of batteries to store electrical energy. These batteries are the energy source for the electric motor. As you mentioned, modern electric vehicles predominantly use lithium-ion batteries due to their superior energy storage capacity, energy density, and cycle life compared to older lead-acid batteries. Lithium-ion batteries also have the advantage of being lighter and more compact, which is crucial for electric vehicle design.

3. Recharging: To replenish the energy in the batteries, electric vehicles need to be recharged. This is typically done by plugging the vehicle into an electrical charging point. Depending on the type of EV and the charging infrastructure, recharging times can vary from a few hours for standard home charging to much faster charging times at dedicated fast-charging stations. Some EVs can also be charged wirelessly in certain situations.

4. Regenerative Braking: Most of the EVs incorporated with regenerative braking, which allows them to recover energy during braking or coasting. When you lift off the accelerator pedal or apply the brakes, the electric motor acts as a generator, it converts the kinetic energy back into electrical energy, which is then stored in the batteries. This process improves energy efficiency and extends the vehicle's life span.
Hybrid Electric Vehicles (HEVs) consist with internal combustion engine, an electric motor and a small battery. These vehicles can run on electric power at low speeds and use the engine for longer trips. Battery Electric Vehicles (BEVs) are purely electric, relying solely on electric power stored in their batteries. They have no internal combustion engine and need to be plugged in for recharging. Fuel Cell Electric Vehicles uses hydrogen fuel cells to generate the electricity to give powers to electric motor. These vehicles emit only water vapor as a byproduct and it offer longer ranges compared to many battery-electric vehicles. The transition to lithium-ion batteries and advancements in electric vehicle technology has made EVs more practical, efficient, and accessible to consumers, contributing to the growing popularity of electric transportation.

Challenges facing EV technology:

1. Nowadays, the daily activities are depending on use of vehicle so the density of vehicle in the city area is increasing day by day. Many of these vehicles are depending on non renewable energy sources like petrol and diesel. These sources are reducing day by day and there is a crisis of oil around the country with political instability.
2. Considering these factors the prices of the oil going very high which is not bearable for the common man.
3. The design and development of automobile plays a vital role in present generation which reduces time and energy of human being. Many research works is going on with several hands in picture to design different automobiles with efficient utilization with several applications.
4. In concern with energy conservation and environmental issues, the whole world should look towards the use of EV and HEV in future.
5. Recently in concern with environment, GO green concept are introduced for redesign, redevelopment and application of electric vehicles. For this purpose a many researchers in different countries are working on batteries, power electronic devices and electric motors.
6. The hybrid electric vehicles are not only reduces the air pollution in the environment but also helps in conservation of natural resources and useful in keeping the balance of environmental life.

Batteries used in Electric Vehicle

The different types of electric vehicle batteries are explained below. Each type of batteries has different characteristics, advantages, and limitations. These factors are important in the development and performance of electric vehicles.
The following are the various types of batteries use in EV.

Lithium-Ion Battery: It is a type of rechargeable battery first proposed in 1970's. These batteries are commonly used for portable electronics and electric vehicle. It is a most widely used battery in electric vehicles. It has high energy density, no memory effect and low self discharge and power-to-weight ratio. Also they have high recyclability and long cycle life.

Nickel-Metal Hybrid Batteries: This battery is more common in hybrid-electric vehicles (HEVs). It has longer life cycles and better safety compared to lead-acid batteries. It has greater tolerance to unfavorable conditions. Nickel based system have higher energy density lower cost and longer life cycle. Typically used in hybrid vehicles due to limitations in scaling for full-fledged electric vehicles. This battery is preferred for EV due to its lowest self heating rate.

Solid State Batteries: Similar to Li-ion batteries but use solid electrolytes. These batteries have lower risk of catching fire and higher energy density. Longer lifespan compared to traditional Li-ion batteries. Still in experimental stages but hold potential for future EVs.

Lead-Acid Batteries: It has older rechargeable battery technology .These batteries have less manufacturing cost but higher discharge rate. It is less common in modern EVs due to limitations in energy density and performance.

Aluminum-Ion Battery: Under research, with potential advantages for EV production. It can offer very high capacity, faster charging, and greater energy density. In the experimental stage, with cost considerations it affects adoption.

Ultra capacitors: It is also called as Super capacitors as it stores and releases the energy. It stores the energy in the form of chemicals in static state and makes them better for rapid charging and discharging of battery. It is suitable to use as secondary storage devices in electric vehicles. It can deliver high power and useful for regenerative braking and acceleration. Super capacitors are often used in combination with traditional batteries for performance enhancements. The choice of battery technology depends on factors like energy density, weight and safety, as well as the intended use and design of the electric vehicle. Manufacturers and researchers are continuously exploring new battery technologies to improve the range, efficiency, and sustainability of electric vehicles while addressing their limitations

Different types of electric vehicle

1. **Battery Electric Vehicles:**

Battery Electric Vehicles are powered by rechargeable batteries from external source and no gasoline engine and they are fully electric. It stores the electricity on board with good capacity battery pack. They have no internal combustion engine (ICE) and produce no tailpipe emissions. It stores electricity in high-capacity battery, typically using lithium-ion technology. The battery charging is done by electricity through external power sources, with various charging speeds.
Examples of BEVs include the Tesla Model 3, BMW i3, Volkswagen e-Golf, and Hyundai Ionic.

2. **Plug-in Hybrid Electric Vehicles:**

PHEVs combine a battery and electric motor with an internal combustion engine (usually gasoline or diesel). It is hybrid vehicle which has rechargeable batteries that can be restored charge by connecting a plug to external electricity source. Plug-in Hybrid Electric Vehicles can operate on electricity alone for shorter distances but have a smaller battery capacity compared to Battery Electric Vehicles. PHEVs can recharge the battery by regenerative braking and plugging in an

external source. When the battery is depleted, the internal combustion engine takes over, offering extended range.
Examples of PHEVs include the, Toyota Prius Plug-in, Ford C-Max Energy, BMW i8 and Mini Cooper SE Countryman.

3. Hybrid Electric Vehicles:

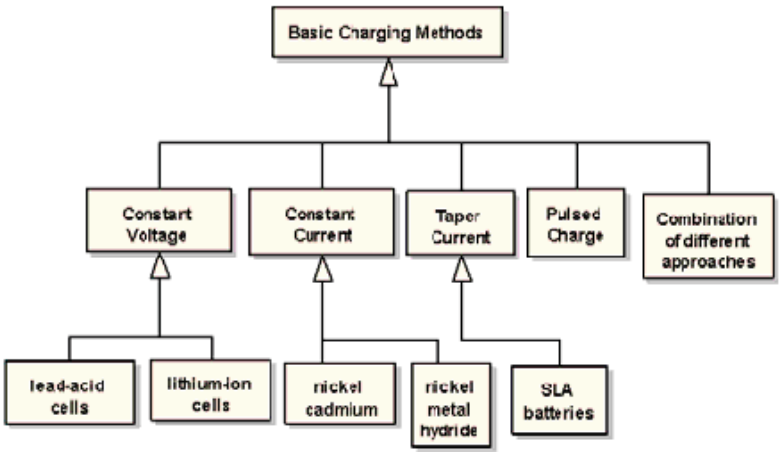
HEVs are powered by a combination of gasoline and electricity. The gasoline engine cuts the load and rises the speed. In this vehicle the electricity is generated through regenerative braking, not from external charging. HEVs start off by using the electric motor and switches to the combustion engine as needed for higher speeds and additional power. Unlike PHEVs, HEVs cannot be charged externally, and their electric-only range is limited.
Examples of HEVs include the Honda Civic Hybrid Toyota Prius Hybrid, and Toyota Camry Hybrid.

Understanding the differences between these electric vehicle types is important for consumers to choose the one that best suits their needs, considering factors such as driving habits, range requirements, and access to charging infrastructure. The electric vehicle market continues to evolve with advancements in technology and the introduction of new models, offering more choices for environmentally friendly transportation.

Battery Charging Methods

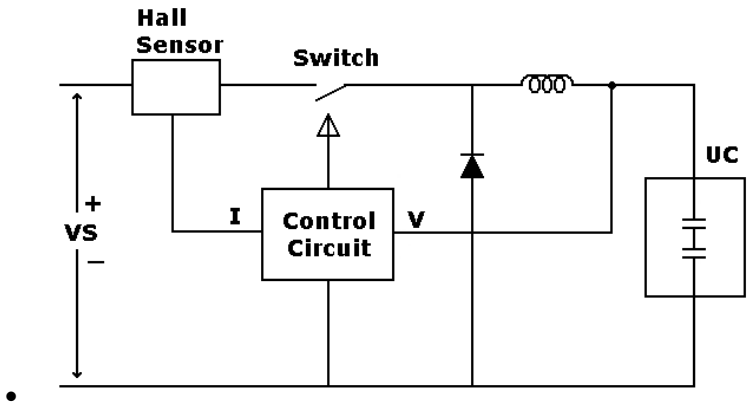
Constant Voltage Charger method:

It provides a fixed and changing voltage during the charging process. It consists of a step-down transformer from the mains followed by a rectifier to convert AC voltage to DC voltage. It is suitable for lead-acid cells used in cars and backup power systems. This mode of charging is known as float or trickle charging. It is used for lithium-ion cells as well, although these chargers are usually more complex. Following fig 1 shows the method of constant voltage charging.



Constant Current Charger:

It maintains a consistent current flow to the battery during charging by varying the voltage. The voltage as the battery charges to maintain a constant current to be adjusted. It switches off or reduces the voltage when the battery reaches a full charge to prevent overcharging. This method of charging is used for nickel-cadmium (NiCd) and nickel-metal hydride (NiMH) cells. The choice of charger depends on the battery chemistry, as each type of battery may require a specific charging method to ensure efficient and safe charging. The charging current of battery is kept constant by varying the supply voltage for overcoming the increasing cell voltage. The use of the right type of charger helps to extend the battery life, maintain performance, and prevent damage from overcharging or over-discharging. The method of constant current charging is shown in fig 2



Several additional charging methods and profiles beyond constant voltage and constant current charging. These methods are used for specific battery chemistries and have various benefits and applications. Let's summarize each of them:

Taper Current Charging:

Taper current charging starts with certain current limited by internal resistance of the cell. It is not a controlled charge and it is a unregulated constant voltage source. During this charging method, the current decreases the cell voltage. In this method of charging there is a risk of damaging the cells through overcharging, so the charging rate and duration need to be limited. It is typically suitable for sealed lead-acid batteries.

Pulsed Charge:

It is a fastest method of charging for lithium Ion Battery. In this technique the current pulses are applied with certain pulse width for the fully charging of the battery. The pulse charging is the intelligent charging method. It is not only used to control the charging current but also has temperature monitoring. A short rest period between pulses allows chemical reactions in the battery cell to stabilize the power. This method of charging is useful for reducing unwanted chemical reactions at the surface of electrode of the cell. It is suitable for the various battery types and is used for specific applications, particularly when precise control of battery charging is required.

Burp Charging:
The burp charging method is used in coexistence with pulse charging and it involves a very short discharge pulses, usually 2 to 3 times of the charging current. These pulses help to remove the gas bubbles which may have rest on the electrodes during fast charging It is added to the overall charging process and hence the battery stability. It has the benefits in terms of charge rate and battery lifetime.

Maintenance of Batteries for Electric Vehicle

The maintenance is required for different types of electric vehicles (PHEVs, HEVs). Some key points are highlighted about battery maintenance. Here's a recap of the maintenance considerations for each type is mentioned.

Plug-in Hybrid Electric Vehicles (PHEVs) and Hybrid Electric Vehicles (HEVs):

PHEVs and HEVs have internal combustion engine so it requires the maintenance. The electrical system usually requires minor scheduled maintenance. Braking systems is very much effective due to regenerative braking. Routine maintenance includes tasks like oil changes, filter replacements, and periodic check-ups of the internal combustion engine components.

All-Electric Vehicles (BEVs):

As compared to conventional vehicles Electric vehicles require less maintenance. Main reasons include lesser maintenance for the battery, motor, and evolved electronics. Engine oil needs regular maintenance. Due to regenerative braking it reduces brake wear. It has few moving parts as contrast to conventional internal combustion engines. Maintenance for BEVs is generally easy and require less frequently.

Battery Maintenance:

Electric vehicles batteries have a limited number of charging cycles. Manufacturers may provide information about battery life and warranties. To maintain safe operating temperatures for the battery some electric vehicles use liquid coolant. While replacement battery pricing is not typically published by manufacturers, it can be a significant expense if needed outside the warranty. However, as technology advances and production volumes increase, battery prices are expected to decline.

In summary, electric vehicles, especially all-electric vehicles, offer the advantage of reduced maintenance requirements compared to conventional vehicles. Battery maintenance and replacement costs can be a concern, but as the technology matures, prices are expected to become more competitive. It's important for owners

of electric vehicles to follow manufacturer recommendations for maintenance and consult owner's manuals for specific guidance on caring for their vehicles.

Benefits of EVs in India

The various benefits of electric vehicles in are elaborated below;

1. Lower running costs

The electric vehicle has lesser running cost as comparable to petrol or diesel vehicle. To charge their batteries it needs electricity rather than using fossil fuels like diesel and petrol. Electric vehicles are more coherent and economical instead of filling petrol or diesel for the travel needs. The use of EV is more eco-friendly by using renewable energy sources. The electricity forfeit can be reduced remoter if charging is done with the help of renewable energy sources installed at home, such as solar panels.

2. Lower cost of maintenance

Electric vehicles have very low maintenance as they have less moving parts as an internal combustion. It requires less maintenance than the conventional petrol or diesel vehicles. Therefore, the yearly charges of running cost of EV is very low

3. More Tax and financial benefits

Enrolling fees and road tariff on investing in the EV are very fever than fossil fuel vehicles. There are multiple plans and inducement provided by the government. As there are many tax benefits given by the government, so more consumers are attracting towards usage of electric vehicles. .

4. Better performance of vehicles

The performance of EV is largest than conventional vehicles. Electric Vehicles are lighter in weight, and their velocity is perfect as compared to fuel-powered vehicles.

5. Low emissions

In general, all electric vehicles produce very less emissions than conventional vehicles. EVs emit zero tailpipe emissions, helping to reduce the stat footprint. You can remoter reduce your stat footprint by utilizing renewable energy to tuition your EV.

6. Easy to drive and no noise pollution

Electric vehicles do not have engine under the hood so that they have the silent functioning sufficiency. The wise use of EV, we are helping to reduce the harmful air pollution. As there is no engine in the electric vehicle, no noise pollution. Whenever we want to charge EV we can charge it in public or home charging station.

7. Low tailpipe emissions

To momentum an electric vehicle may reduce stat footprint considering there will be zero tailpipe emissions. By choosing the renewable energy options for home electricity the environmental impact of charging Electric vehicle is remotely charged.

8. Future scope of Electric Vehicle:

It is seen that many countries are gradually reducing their dependence on petrol and diesel with a sustainable alternative of electric vehicle.

HEV is vehicle which is combination of internal combustion engine propulsion system and electric motor. These vehicles are useful to overcome the disadvantages of electric motor propelled vehicles. Also gives the better performance in only ICE driven vehicle.

Designed vehicle should be increasingly consumer friendly with energy conversion. All over the world it is seen that the Electric vehicles are widely used to fulfill the requirement of electrical energy of power sources, which include wind power, solar power, and hydroelectric power. Due to this the various energy producing companies are rising & increasing day by day to fulfill the energy requirement.

REFERENCES:

Lander, L.; Kallitsis, E.; Hales, A.; Edge, J.S.; Korre, A.; Offer, G. Cost and carbon footprint reduction of electric vehicle lithium-ion batteries through efficient thermal management. Appl. Energy 2021, 289, 116737. [Google Scholar] [CrossRef]

Ahmad, A.; Khan, Z.A.; Alam, M.S.; Khateeb, S. A Review of the Electric Vehicle Charging Techniques, Standards, Progression and Evolution of EV Technologies in Germany. Smart Sci. 2017, 6, 36–53. [Google Scholar] [CrossRef]

Liu, Y.; Gao, J.; Qin, D.; Zhang, Y.; Lei, Z. Rule-corrected energy management strategy for hybrid electric vehicles based on operation-mode prediction. J. Clean. Prod. 2018, 188, 796–806. [Google Scholar] [CrossRef]

Amjad, M., Ahmad, A., Rehmani, H. and Umer, M.T. (2018) 'A review of EVs charging: from the perspective of energy optimization, optimization approaches, and charging techniques', Transportation Research Part D: Transport and Environment, Elsevier, Vol. 62, pp.386–417, doi: 10.1016/j. trd.2018.03.006

Andersson, S.L., Elofsson, A.K., Galus, M.D., Göransson, L., Karlsson, S., Johnsson, F. and Andersson, G. (2010) 'Plug-in hybrid electric vehicles as regulating power providers: case studies of Sweden and Germany, Energy Policy, Vol. 38, No. 6, pp.2751–2762, doi: 10.1016/j.enpol.2010.01.006.