THE STUDY OF THE CURRENT SCENARIO OF ELECTRIC VEHICLES

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Abstract- **The transportation sector plays a significant role in contributing to greenhouse gas emissions, making it essential to transition towards electric vehicles (EVs) to mitigate environmental impacts. This paper offers a comprehensive overview of EVs, categorizing them into three main types: Hybrid Electric Vehicles (HEVs), Plug-In Hybrid Electric Vehicles (PHEVs), and Battery Electric Vehicles (BEVs). It delves into the various configurations available for BEVs, highlighting the flexibility in motor placement and power transmission. The study assesses different battery and motor technologies to identify the most optimal configuration for BEVs, with Lithium-ion batteries emerging as the leading choice due to their exceptional performance. The paper also addresses the challenges in the adoption of EVs, including issues related to charging infrastructure, driving habits, and cost, and presents existing solutions to these challenges. Moreover, it underscores the potential of permanent magnet motors and lithium sulphur batteries to shape the future of electric vehicles, offering enhanced performance and efficiency. Overall, this research provides valuable insights into the present state and future prospects of EV technology, contributing to sustainable transportation and the reduction of greenhouse gas emissions. It represents a significant step towards promoting environmentally friendly and efficient mobility solutions.**

Keywords: **Electric Vehicles, Battery, electric motor, ICE, BEVs, Types of EVs.**

INTRODUCTION

The transportation sector is recognized as a major contributor, responsible for approximately 25% of greenhouse gas (GHG) emissions [1]. The powertrains in land vehicles have been continuously evolving to reduce emissions and enhance performance. This evolution includes improvements in conventional internal combustion engines (ICE), such as advancements in fuel injection combustion [2] [3], the use of biofuels, and the implementation of technologies like turbocharging and downsizing [4].

In response to the need to reduce GHG emissions, electric vehicles (EVs) have emerged as a commercially viable and technologically mature solution. Consequently, government authorities are making efforts to transition cars and bikes from fossil fuel-powered vehicles to battery-powered electric vehicles (BEVs) while considering bans on conventional Internal Combustion Engines (ICEs). EVs are particularly well-suited for urban environments for several reasons:

1. EVs do not store liquid, flammable fuels and do not produce emissions.
2. EVs generate maximum torque from the moment they start.
3. EVs are capable of frequent start-stop driving.
4. EVs eliminate the need for traditional gas stations.

The operation of an electric vehicle (EV) relies on a combination of various subsystems, each of which plays a crucial role in the overall functioning, as depicted in Figure 1. Some of these components function independently with minimal interaction, while others require extensive cooperation. Electric vehicles can be configured in various ways: some rely solely on stored electrical power, others generate energy from an internal combustion engine (ICE), and certain EVs use both an ICE and electric motors for propulsion. This diversity in configurations allows for flexibility and adaptation to different driving needs and preferences.

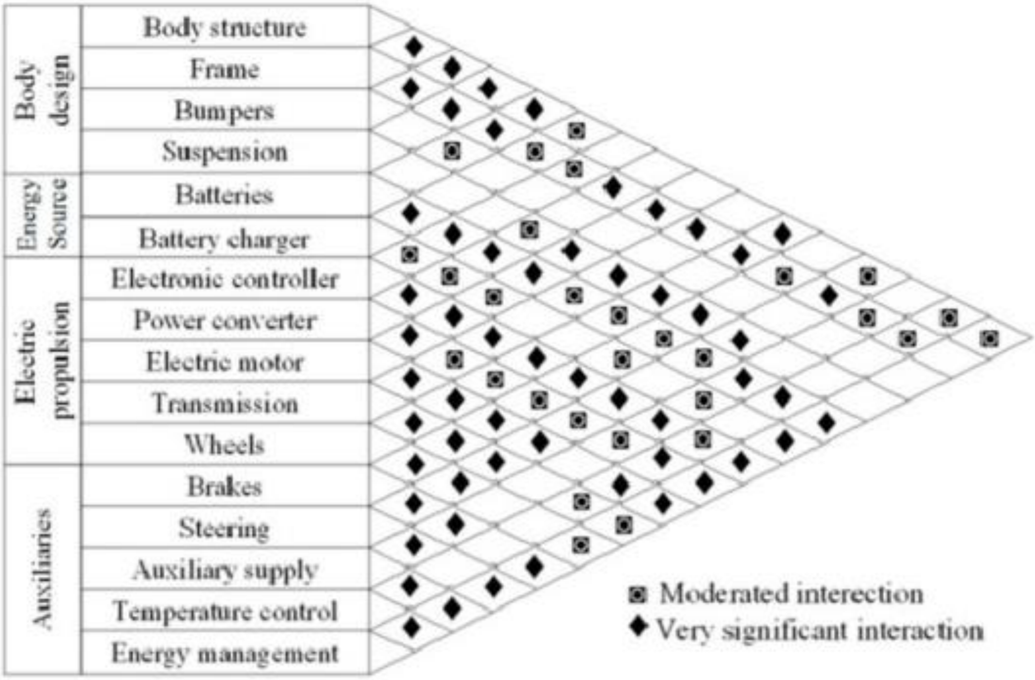

Figure 1: Major subsystem and its interaction [5]

TYPES OF EVs

Electric vehicles (EVs) have the flexibility to operate either purely on electric power or in conjunction with an internal combustion engine (ICE). In the fundamental powertrain of EVs, batteries serve as the exclusive energy source. However, more advanced powertrains can incorporate various modes of energy sources, giving rise to what we refer to as Hybrid Electric Vehicles (HEVs). According to the guidelines set forth by the International Electrotechnical Commission, vehicles that make use of two or more types of energy storage, sources, or converters can be categorized as HEVs, as long as they generate electrical energy [6].

Hybrid Electric Vehicle

In Hybrid Electric Vehicles (HEVs), the internal combustion engine (ICE) comes into play when higher speeds are demanded, allowing for a simultaneous operation of both electric and ICE drivetrains to enhance the vehicle's overall performance. Hybrid power systems are commonly adopted to eliminate turbo lag, which is especially notable in turbocharged vehicles like the Acura NSX. The electric powertrain can enhance performance by delivering extra speed when necessary and bridging gaps during gear shifts. Additionally, regenerative braking enables HEVs to recover energy. Compared to conventional internal combustion engine (ICE) vehicles that solely rely on an electrical drivetrain without energy storage, HEVs offer superior fuel efficiency and enhanced performance.

In Figure 2, you can observe the fundamental elements governing the power flow within a Hybrid Electric Vehicle (HEV) throughout different phases of a typical driving cycle. When a vehicle begins from a complete standstill, the internal combustion engine (ICE) can serve as a generator to produce power, which is then stored in the battery. When overtaking is necessary and requires a speed boost, both the electric motor and the ICE work in tandem to drive the powertrain. During the braking process, the battery is replenished with energy through regenerative braking, and the ICE has the capability to function as a generator. While cruising, the vehicle is propelled by the ICE, and this also serves to recharge the battery. When the vehicle comes to a halt, the power flow ceases as well. The energy management systems employed in HEVs are responsible for the distribution of power between the electric motor and the ICE. To achieve maximum fuel efficiency, it's crucial to take into account factors such as the driver's input, vehicle speed, the state of charge (SOC) of the battery, and the motor speed [7].

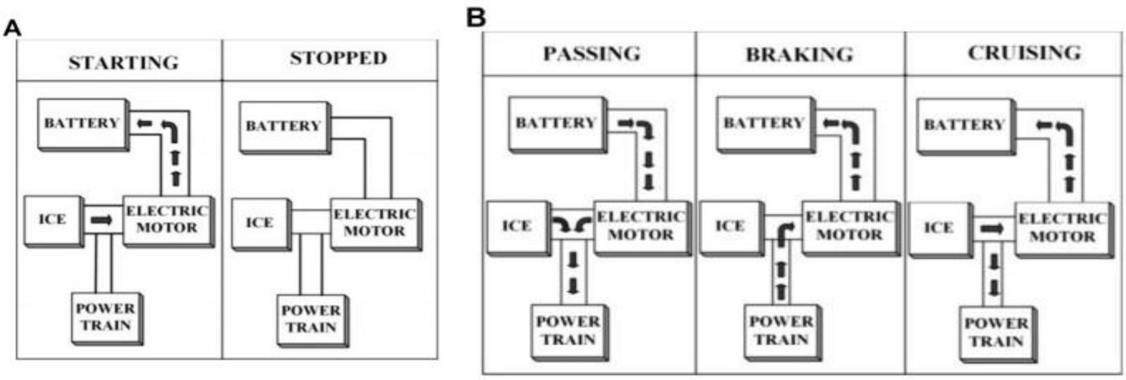

Figure 2: Power Flow in different conditions of HEVs [8]

Plug-In Hybrid Electric Vehicle

The concept was introduced to increase the range of all-electric HEVs. PHEVs use both electrical motor and ICE (similar to HEV). The only difference between HEV and PHEV is that in PHEV, electric propulsion serves as the main driving force. This leads to a bigger battery capacity requirement in PHEVs [9][10].

Plug-in Hybrid Electric Vehicles (PHEVs) are designed to function in an "all-electric" mode, utilizing their batteries for propulsion. When the battery charge becomes low, the internal combustion engine (ICE) is engaged to either recharge the battery or provide additional power to the electric motor. The primary role of the ICE in PHEVs is to extend the vehicle's driving range. PHEVs have the advantage of being able to directly charge from the electrical grid, making it possible to reduce their carbon footprint. These vehicles are known for their reduced fuel consumption and their ability to harness regenerative braking to enhance efficiency.

Battery Electric Vehicle

BEVs use only batteries to drive. The range of BEVs depends heavily on their battery capacity as they rely solely on the stored energy in their battery packs. A typical single charge has a range of 100–250 km [11]. Battery Electric Vehicles (BEVs) are characterized by their simplicity in operation, manufacturing, and maintenance. They are known for producing neither noise nor greenhouse gas emissions (GHG). Additionally, BEVs have the capability to generate high torque instantly, even at low speeds. These advantages, in combination with their limited driving range, make them an ideal choice for urban environments. In contrast, at lower rpm, higher torque, which is common in situations involving frequent start-stop driving, typical of a traffic-congested urban setting.

Different configurations of BEV

In contrast to an Internal Combustion Engine (ICE) vehicle, a Battery Electric Vehicle (BEV) offers greater flexibility in its configuration. This flexibility arises from the absence of intricate mechanical systems. In a BEV, the electric motor stands as the sole moving component. Various techniques and control arrangements can be employed to manage the motor's operation. The power source is derived from an array of batteries, and these battery arrays, along with the electric motor, can be placed at various locations within the vehicle. As long as there is an electrical connection between them, the vehicle can function. This inherent flexibility allows for a wide range of configuration possibilities.

Figure 3a illustrates how an electric motor can replace the Internal Combustion Engine (ICE) in a front-engine front-wheel drive vehicle. In this setup, a clutch and gearbox work together to provide low torque at high speeds and high torque at low speeds. This configuration allows the wheels to rotate at different speeds.

In Figure 3b, the clutch is removed from the system, and the gearbox is replaced with a fixed gear, eliminating the variability in gear ratios.

Figure 3c depicts a setup with a fixed gearbox, a motor, and a differential as a single unit that drives both wheels. Typically, an electric motor powers the front axle, a configuration found in vehicles like the Nissan Leaf and Chevrolet Spark.

Figure 3d shows a configuration with two motors, one for each wheel, allowing for differential action. This setup enhances control and traction by managing each wheel independently.

In Figure 3e, motors are placed inside the wheels, forming an "in-wheel" drive. This design reduces mechanical interaction and offers unique advantages.

For high-speed reduction ratios, inline arrangements of input and output shafts often use planetary gear systems, as demonstrated in this configuration.

Finally, in Figure 3f, the mechanical gear system is completely eliminated. Instead, a low-speed motor with an outer rotor configuration on the wheel rim is employed to control wheel and vehicle speed directly through motor speed.

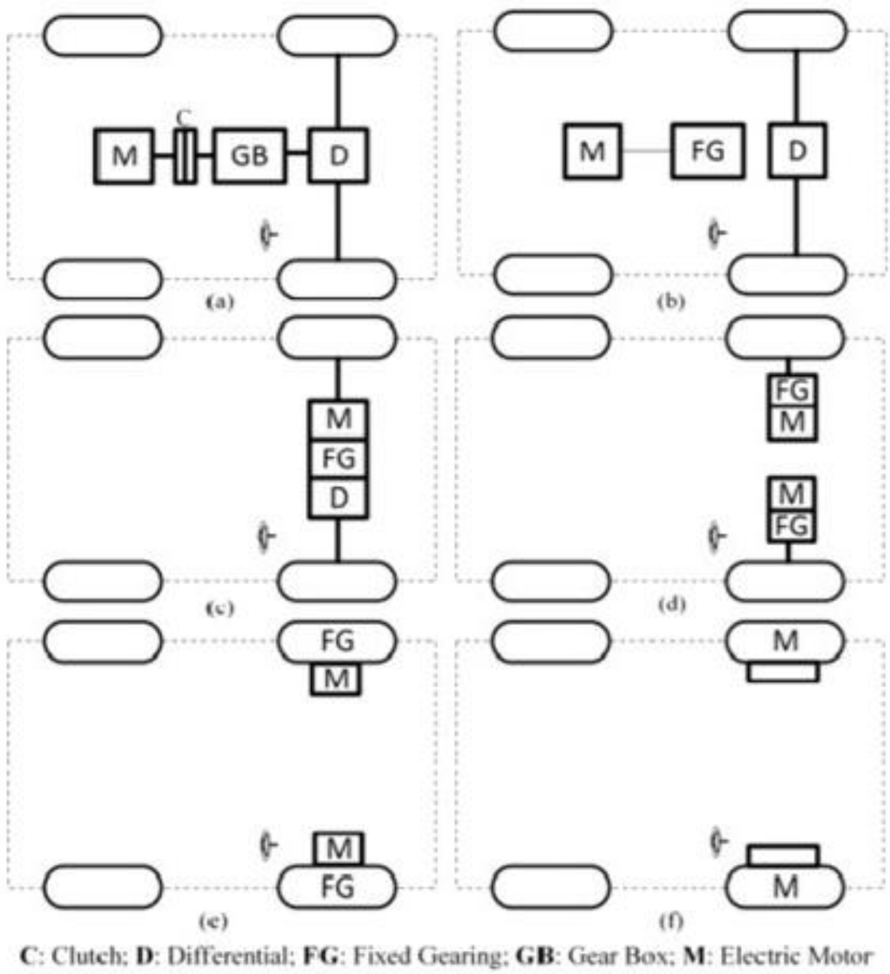

Figure 3: Power Flow in different conditions of HEVs [12].

Limitation of EV Technology

Even though electric vehicles offer promising results for the future, they are still not widely adopted. Some of the reasons are quite serious as well. It takes some time for society to accept new and immature technology, along with its consequences. Driving an EV means

1) a Change of re-fuelling habits;
2) Preparedness to find an alternative mode of transportation in case the battery is low; and
3) a Change of driving patterns [13][14].
4) Lack of Technological infrastructure for battery repairs and recyclation process.
5) Lack of skilled workers to make repairs in time and cost-effectively.

While there has been a significant increase in the quantity of charging stations, there is still a pressing need for more. The extended duration required for charging remains a significant impediment to the widespread adoption of electric vehicles. Furthermore, not all public charging stations are universally compatible with all car models, making it challenging to locate a suitable charging point when needed. There's also the concern of charging stations being occupied. To address these challenges, manufacturers such as Nissan and Tesla are taking steps to expand their charging infrastructure networks.

The range of EVs is dictated by the capacity of batteries. Additionally, the range depends on 1) the driving behaviour;
2)the speed of the vehicle;
3) the terrain;
4) the carried cargo on the vehicle; and
5) the energy consumed by services running in the car (for example: air conditioning, heating, electronics).

The "range anxiety" is amplified by the limited number of appropriate charging stations. Surveys have shown that most drivers are willing to spend up to £ 50 to acquire one more extra mile of range [15].

Electric vehicles (EVs) are considerably more expensive than internal combustion engine (ICE) vehicles primarily because of the elevated costs associated with their batteries[16]. To mitigate this challenge, governments offer financial incentives. A reduction in battery prices will ensue as a consequence of widespread technological advancements and increased production.

Methodology

Lithium-sulphur, lithium-ion, and nickel-cadmium batteries were examined in the study due to their known high specific energy and specific power density characteristics. The evaluation also involved the testing of Permanent Magnet Synchronous Motors (PMSM) and Induction Motors (IM) because of their capacity to generate substantial torque and power. Various combinations of these motors and batteries were assessed in order to determine the most optimal configuration for a Battery Electric Vehicle (BEV). The findings were assessed based on two key factors: torque production and power consumption. Subsequently, a comprehensive review of the results was conducted, considering techno-economic criteria to determine the most cost-effective and technically sound configuration.

A PMSM relies on permanent magnets integrated into the rotor to establish a consistent magnetic field. The stator is equipped with windings connected to an AC power supply to generate a rotating magnetic field. These motors typically use neodymium magnets, which enhance performance but also add to the cost. Neodymium magnets contribute to reducing the size of PMSMs.

On the other hand, an IM incorporates permanent magnets within the stator to create a steady magnetic field. The rotor is equipped with windings connected to an AC power supply to produce a rotating magnetic field. IMs employ brushes, which can have a detrimental effect on their performance. Nevertheless, the use of permanent magnets on the stator makes IMs a more cost-effective option, as they don't require expensive magnet materials like neodymium.

Battery Electric Vehicles (BEVs) are reliant on their batteries, which serve as the primary energy storage component. Several battery chemistries are presently available in the market and recommended for use in electric vehicles. These include Lead-acid, Nickel-metal-hydride (NiMH), Sodium Sulphur (NaS), and Lithium-ion (Li-ion) batteries.

In this study, the focus was specifically on nickel-cadmium (NiCd), Lithium-ion (Li-ion), and lithium-sulphur (Li-S) batteries. It's important to note that lithium sulphur batteries, despite their attractive attributes such as high specific energy and power densities, have not yet been employed in any vehicles currently available in the market. This suggests that Li-S batteries hold potential but are yet to see widespread adoption in the automotive industry.

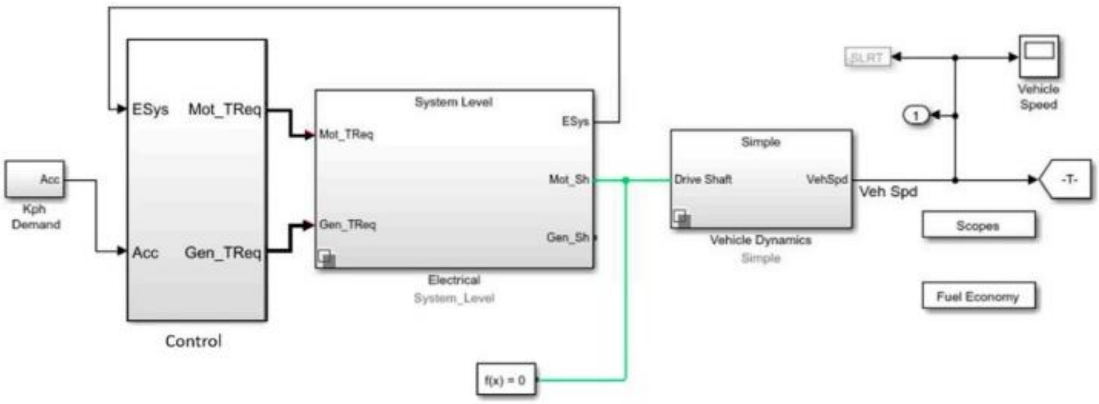

Figure 4: Block diagram of working BEV [17].

Figure 4 illustrates the fundamental components of a medium-sized Battery Electric Vehicle (BEV). These components are the control system, the electrical system, and the vehicle dynamics. The design of these blocks draws inspiration from the original Hybrid Electric Vehicle Series—Parallel configurations.

The controller serves as the central hub, receiving inputs from the electrical system and taking into account the driver's speed demands. Additionally, there's a battery charger controller, which oversees the flow of current in and out of the battery pack. To prevent potential overheating issues, this controller regulates the current, thereby ensuring the safety and longevity of the battery. Furthermore, the controller also plays a role in extending the overall lifespan of the battery. Another critical component is the motor controller, which is responsible for the precise management of the electric motor. The motor controller records data regarding the motor's speed and current, enabling the calculation of the optimal torque value to be delivered.

Table 1: Results of different types of battery

Battery Type	Max Battey Power (kWh)	Max Voltage (V)	SoC (%) After cycle
Lithium Ion (Li-ion)	40	335	70
Nickel Metal Hydride (Ni-MH)	33	300	55
Li-Sulphur	42	540	78
Nickel Cadmium (Ni-Cd)	40	310	67
Lead Acid	30	320	59

Table 1 presents the performance data for various battery types, including Lead Acid, NiCd, Li-ion, Li-Sulphur, and Ni-MH batteries. At the conclusion of the 500-second simulation period, the Lithium-ion battery demonstrated the most impressive results. It provided a maximum battery power of 40 kW while maintaining a state of charge percentage (SoC) of 70%. These values outperformed the other simulated battery types, with the exception of Li-Sulphur, which, however, is known to have the drawback of a limited number of recharge cycles before failure. The exceptional performance of the Lithium-ion battery can be attributed to its high energy density and remarkable charge retention capabilities, as evident in Figure 5. These attributes make it a standout choice in terms of power and longevity among the simulated battery options.

Lithium-ion batteries are presently regarded as the primary battery choice for Battery Electric Vehicles (BEVs), despite their relatively high cost [19]. The simulation results from the four different battery types evaluated in this study (Lead Acid, NiCd, Li-ion, and Ni-MH) clearly demonstrate that Lithium-ion batteries stand out as the most advantageous option for a compact BEV. It's worth noting that within the category of Lithium-ion batteries, there are various subtypes with similar performance characteristics, offering a range of choices for BEV applications.

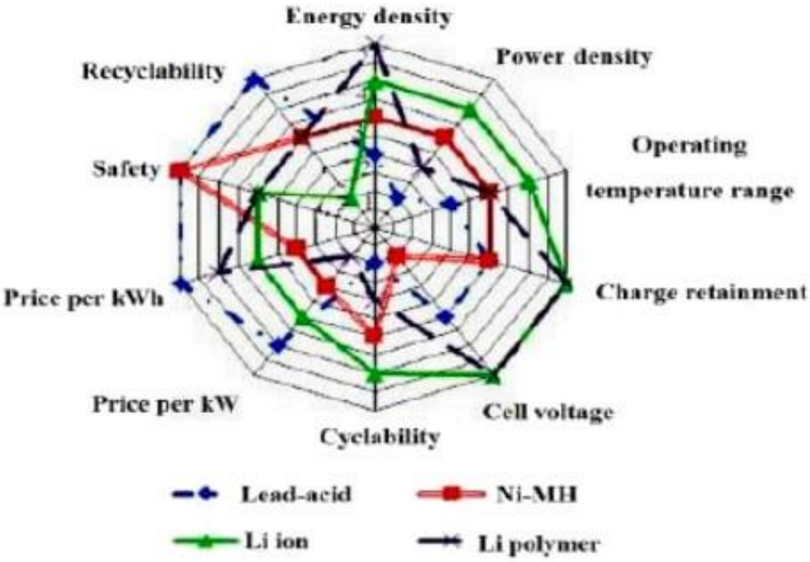

Figure 5: different batteries performance comparison [18]

In Table 2, these different Li-ion battery technologies are compared, outlining their respective advantages and disadvantages. Generally, Li-ion battery technology offers a host of advantages when compared to other established types of batteries. However, one notable drawback of Li-ion batteries is their tendency to overheat, which, in extreme cases, could lead to safety concerns such as vehicle powertrain fires.

To address this issue, manufacturers such as Tesla and Nissan are making substantial investments in research and development to mitigate the overheating problem and enhance the safety of Battery Electric Vehicles (BEVs). This ongoing research aims to make Li-ion batteries even more reliable and secure for widespread use in the automotive industry.

Table 2: Advantages and disadvantages of different types of batteries [19]

Technology	Advantages	Disadvantages
Lithium-ion phosphate (LiFePO4)	Safe	Energy Density
Lithium Cobalt Oxide (LiCoO2)	Energy density and power.	safety
Lithium Polymer (LiMnO4)	Power density.	Life
Nickel Cobalt and Aluminium (NCA)	Energy and power density, overall lifetime.	Safety

A permanent magnet motor is generally considered to be a more suitable choice for a Battery Electric Vehicle (BEV) when compared to an induction motor. However, an important factor to consider is the performance of the Li-ion battery used in conjunction with the motor. Interestingly, when assessing Li-ion battery performance, it's observed that the induction motor exhibits lower power consumption than that of the permanent magnet motor. This is significant because the life cycle of a battery is closely tied to its power consumption. In essence, the more power a battery consumes, the shorter its overall life cycle. High power consumption can lead to reduced efficiency over time and have a detrimental impact on the long-term performance of the vehicle. Therefore, the choice between a permanent magnet motor and an induction motor needs to be made while considering the specific Li-ion battery performance and overall efficiency goals for the BEV.

Figure 6 presents a comparison of the advantages and disadvantages of different battery technologies. Li-S batteries have a higher capacity compared to other battery technologies. However, Li-S batteries have a shorter life cycle, due primarily to the charging cycle in this type of battery causing a build-up of chemical deposits that degrade the cell and shorten its lifespan.

Electric motors		
Motor Type	**Advantages**	**Limitations**
Induction Motor	Mature motor drive system Field orientation control is applicable to allow separate operation of excited DC motor	Less efficient than PMSM system
Permanent Magnet Brushless DC Motor	No rotor copper loss More efficiency than induction motors More torque density More specific power Lighter and smaller Good heat dissipation	Short constant power range Increasing speed will reduce torque
Permanent Magnet Synchronous Motor	Does not require gear systems to go different speed ranges High torque at low speed Compact and efficient Suitable for in-wheel application	Huge iron loss at high speed during in-wheel operation
Batteries Technologies		
Battery Type	**Advantages**	**Limitations**
Ni-Cd (Nickel- Cadmium)	Long lifetime Able to discharge fully without being damaged Cadmium can cause pollution if disposed wrongly	High cost
Li-Ion (Lithium-Ion)	Energy density twice than that Ni-Cd Good performance at high temp High specific power High specific energy Long life cycle (around 1,000)	Require time for charging purpose, but still better than some of the batteries High cost
Li-S (Lithium- Sulfur)	High specific energy High specific energy Low cost Improved safety Improved environmental impact	Short life cycle Cost

Figure 6: Advantages and disadvantages of different types of battery and motor [20][21][22]

The implementation of a permanent magnet motor in Battery Electric Vehicles (BEVs) has shown the potential to deliver higher performance characteristics. However, considering the stability and reliability factors, an induction motor is often preferred. This preference explains why nearly all the BEVs currently available in the market utilize induction motors as their propulsion system. Nonetheless, it's important to note that with some minor technological advancements to address stability issues, permanent magnet motors are expected to become a more dominant force in the future BEV market. This shift is likely to be accompanied by the increasing adoption of Lithium-Sulphur batteries, which are known for their high specific energy and power density, further enhancing the performance and range of BEVs. This suggests a promising future for permanent magnet motors and Lithium-Sulphur batteries in the evolution of electric vehicles.

CONCLUSION

With increasing environmental concerns and a decrease in fossil fuel, EV technology seems to be a favourable shift. HEVs, PHEVs, and BEVs were made to penetrate the consumer market as an economically viable option. Different types of BEVs are discussed in this paper along with different available options for battery and motor and their different combinations. It was concluded that there is still much development that needs to be done in different stages of the life of EVs before making the shift to EVs mandatory. Areas that need further studies are the energy source of electricity, the cost-effectiveness of the battery, uniformity infrastructure for easy and hassle-free working, repairability and recyclability of EVs, and economical factors from the consumer's point of view.

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