Battery Electric Vehicles (BEVs)

Chapter *in* Green Energy and Technology · January 2021

DOI: 10.1007/978-981-15-9251-5_8

T. Saravanan
GITAM University, Bengaluru Campus

Battery Electric Vehicles (BEVs)

Ahmad Faraz, A. Ambikapathy, Saravanan Thangavel, K. Logavani, and G. Arun Prasad

1 Introduction

1.1 A Brief Introduction of Battery Electric Vehicles (BEVs)

A battery electric vehicle (BEV) is basically an electric vehicle (EV) that solitary consumes compound energy to run which is put away in rechargeable battery packs, with no other source (e.g., hydrogen energy component, an internal combustion engine, and so forth). BEVs utilize electric engine and system instead of an internal combustion engine (ICEs) for propulsion. They get all force from battery packs and use it to run the engine which further aides in driving the wheels. They are otherwise called unadulterated electric vehicles or just electric vehicles or all-electric vehicle. Battery electric vehicles (BEVs) incorporate different sorts of vehicles, for example, cruisers, bikes, skateboards, railcars, watercraft, forklifts, transports, trucks, and other vehicles.

Battery electric vehicles (BEVs) are basic and simple to work when contrasted with an exemplary internal combustion engine (ICE) vehicles. The engineering of

A. Faraz · A. Ambikapathy (✉) · S. Thangavel · G. Arun Prasad
Galgotias College of Engineering and Technology, Greater Noida, UP, India
e-mail: ami_ty21@yahoo.com

A. Faraz
e-mail: theahmadfaraz@gmail.com

S. Thangavel
e-mail: tsaravcse@gmail.com

G. Arun Prasad
e-mail: arun.prasad@galgotiacollege.edu

K. Logavani
Government College of Engineering—Salem, Salem, Tamil Nadu, India
e-mail: Vani.tulips@gmail.com

N. Patel et al. (eds.), *Electric Vehicles*, Green Energy and Technology,
https://doi.org/10.1007/978-981-15-9251-5_8

Fig. 1 Nissan Leaf and Tesla Model S [1]. *Source* Wikipedia

the battery electric vehicle comprises of high-voltage battery, an electric engine with the power electronics controller and a solitary speed gearbox. Battery electric vehicles are expanding their piece of the overall industry since they are the most practical route towards a perfect and effective vehicle framework. Contrasted to ICE vehicles, the most significant preferences of a BEV are the general high effectiveness, dependability, and the moderately minimal effort of the electric engine.

In 2016, there were 210 million electric bicycles overall utilized day by day. The general deals of battery electric vehicles that are skilled to run on parkway were seen as one million unit till September 2016. Before the finish of 2019, world's top selling makers Nissan and Tesla have done the worldwide offer of 450,000 units of Nissan Leaf and 448,634 units of Tesla Model S separately [1] (Fig. 1).

1.2 Features

The idea of battery electric vehicles was to utilize charged batteries on board vehicles for propulsion. Battery electric vehicles are turning out to be increasingly more alluring with the expansion on fuel costs and headway of new battery innovation (lithium-ion). They have a higher force and energy capacity which gives huge range and more prominent conceivable speeding up when contrasted with more established battery types, for example, lead–acid batteries. For instance, lithium-ion batteries have an energy capacity of 0.8–2.5 MJ/L while lead–acid batteries had an energy capacity of 0.4 MJ/L, which is higher. There is as yet far to go if contrasting it with oil-based energizers and biofuels.

BEVs limit the energy wastage by halting the vehicle when it is stopped and by charging the battery when the brakes are applied ("regenerative braking") like other electric vehicle and hybrid electric vehicles. Electric motors are in like manner more energy compelling than gas or diesel engines.

Battery electric vehicles have the extra favorable position of home stimulating. A 240-V supply is adequate for the vehicle to charge the whole battery in a period of time. Completely energized battery electric vehicles have a driving constraint of 80–100 miles or to a most outrageous extent of 270 miles. Electric motors produce high torque or turning-power, while the torque of ICE vehicle increases with the engine's speed (RPM). This suggests that BEVs have amazingly snappy speeding up appeared differently in relation to standard vehicles [1].

2 History and Evolution of BEV

2.1 Idea of the Electric Car

In the early eighteenth century, the prerequisite needed, apart from the discovery of an electricity, to manufacture electric-driven cars was a battery which can be recharged. In 1828, a Hungarian inventor, Anyos Jedlik made an electric driven motor which consumes electricity as a means of a transportation with the help of a small car model which could be run using his motor.

Later, Thomas Davenport, a Vermont Blacksmith developed an electric vehicle model in 1834 which used to move on a path which is circular. But all those models manufactured were lacking self-mounted power source. The solution to this major problem came out in the year 1859, when French Physicist Guston Plante made the lead–acid battery. In 1881, Camille Alphonse Faure expanded the limit of the battery which prompted the creation of batteries on a large scale. With this, battery-powered energy source creators began exploring different avenues regarding power and velocity [2] (Fig. 2).

Fig. 2 Thomas Parker's EV [3]. *Source* Wikimedia Commons

Fig. 3 GM's The Electrovair [4]. *Source* My Car Quest

2.2 Invention of an EV

In the year 1884, a British Inventor, Thomas Parker delivered the main electric car. It was controlled by his uniquely structured high-limit battery. Be that as it may, Henry G. Morris, a Mechanical Engineer and a Chemist Pedra G. Salom in 1894 in Philadelphia, Pennsylvania, created the principal effective electric vehicle, The Electrobat. It had steel tires to help its substantial edge and huge lead battery.

Later on, in the US William Morrison of Des Moines developed a six-passenger electric car (wagon) which was capable of reaching a speed of 23 km/h. By the time, different creators and architects created numerous models [2].

2.3 First BEV by General Motors

In the mid-1960s, GM's first concept electric vehicle was the Electrovair which was controlled by utilizing a silver-zinc battery pack that could convey upto 532 V. In any case, this idea neglected to make large-scale manufacturing. Their first present-day age electric vehicle to be mass delivered was created in the mid-1990s, named General Motors EV1. California enlivened its planning and fabrication which stated a command that it is necessary for producers to create zero-emanation vehicles [2] (Fig. 3).

2.4 First BEV by Tesla

In 2008, Tesla Motors made their outright first battery electric vehicle (BEV), called as The Roadster. The car was a revolution in the propelled age electric vehicle as it

Fig. 4 Tesla's The Roadster [5]. *Source* Getty Images

used some pattern setting developments, for instance, cutting edge battery advancement and electrically operated powertrain. The main Roadster is a battery electric vehicle, and it was the primary lawful sequential creation of all-electric vehicle which had ever used a lithium-ion battery as a force source. It is likewise first BEV which is fit for traveling in excess of 320 km for every charge. It can likewise arrive at a mind blowing top speed of 200 km/h. During its creation years (2008–2012), about 2500 Roadsters were bought in more than 25 nations around the globe [2] (Fig. 4).

3 Comparison Between BEVs and Other EVs

3.1 BEV

B = Battery, E = Electric, V = Vehicle.

Battery electric vehicles are the vehicles which totally runs on the power. They do not utilize some other fuel (petroleum or diesel) to run. They are 100% all-electric vehicle. The power is put away in the batteries introduced in vehicles (Fig. 5).

They are condition neighborly as they do not discharge any sort of unsafe outflows in nature or we can say that they are zero-emanation vehicle. The charging of the battery electric vehicle is simple as it is very well-finished with the typical home unit supply, or at the charging outlet if accessible. A portion of the instances of battery electric vehicles are Tesla Model 3, Peugeot e-208, MG ZS EV, Nissan Leaf, Renault Zoe, Hyundai Kona Electric, Kia e-Niro, Jaguar I-Pace, and so on [6].

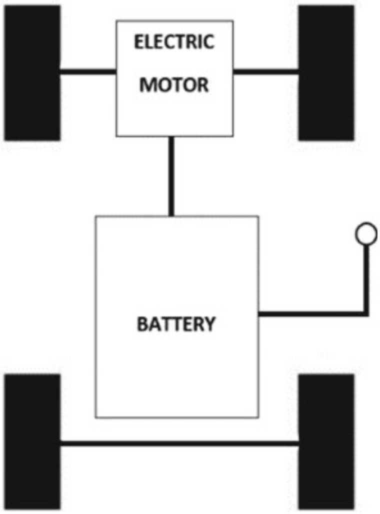


Fig. 5 BEV

3.2 HEV

H = Hybrid, E = Electric, V = Vehicle.

These vehicles are the vehicles which are controlled through the internal combustion engine with the assistance of fuel, for example, petroleum or diesel. They additionally have a battery which supplies the ability to run the electric engine. Be that as it may, the downside is, this battery cannot be legitimately charged by the external charger or supply. The battery is charged uniquely with the regenerative slowing down which implies when we apply the brakes to stop the vehicle then the engine turn over filling in as a generator and consequently helps in charging the battery (Fig. 6).

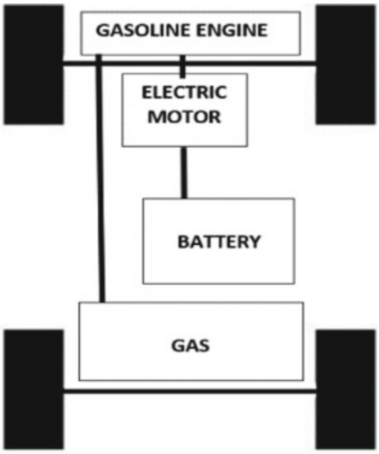
Such kind of vehicle frequently runs on a battery at low speeds, and when the vehicle needs to go quicker, they switch on to the internal combustion engine and turn over running on fuel. A portion of the instances of hybrid electric vehicles are Toyota Corolla Hybrid, Toyota Yaris Hybrid, Lexus RX450h, Ford Mondeo Hybrid, Honda NSX, and so on [6].

3.3 PHEV

P = Plug-in, H = Hybrid, E = Electric, V = Vehicle.

These electric vehicles are the vehicles like the half breed vehicles, yet the distinction here is we can charge our vehicle by connecting the charger remotely dissimilar to the hybrid electric vehicles where the battery is charged just regenerative slowing

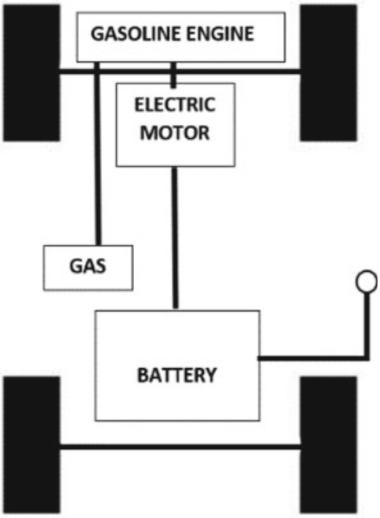
Fig. 6 HEV



down. As such type of vehicles has both internal combustion engines just as batteries along these lines so that they can be run on both the modes (Fig. 7).

The plug-in hybrid electric vehicles can run upto 30 miles on battery on a solitary charge, after that the vehicle begins running on a fuel. A portion of the instances of the plug-in hybrid electric vehicles is Mitsubishi Outlander, Volvo XC60 Twin Engine, BMW 225xe, Volkswagen Golf GTE, Toyota Prius Plug-in, Mercedes-Benz E350 e SE, and so forth [6].

Fig. 7 PHEV



4 Construction of BEV

4.1 Key Components

The parts labeled in Fig. 8 are the major key components of any battery electric vehicles.

The auxiliary battery plays a major role in an electrically driven vehicle which offers capacity to control vehicle decorations. There is a charging port which allows the vehicle to communicate with an external power supply so that the battery of the vehicle can be charged. These types of vehicles contain a type of converter which are capable of converting DC supply to DC supply. They basically convert high DC voltage into low DC voltage because low DC voltage helps in operating the parts of the vehicle and also to provide energy to the battery. Another major component of such vehicle is the traction motor which uses power from the battery and helps in moving the wheels so that the vehicle can drive. Such type of motors can be used as both to drive and to recover. For the charging of the batteries, we need a charger which is known as the on board charger. The role of this charger is to extract the AC power supply from the household or any other power source which is generally 240 V. Now this AC power supply is then converted into a DC supply to charge the battery. It also checks the voltage, current, temperature, and various other factors of the battery. There is another device called as the power electronics controller which helps in the conveying of the power supply from the battery and the speed and torque control of the vehicle. The system which handles or manages the temperature of certain parts of the vehicle is also installed along with the other components, and this system is known as the thermal system. This system maintains the temperature of

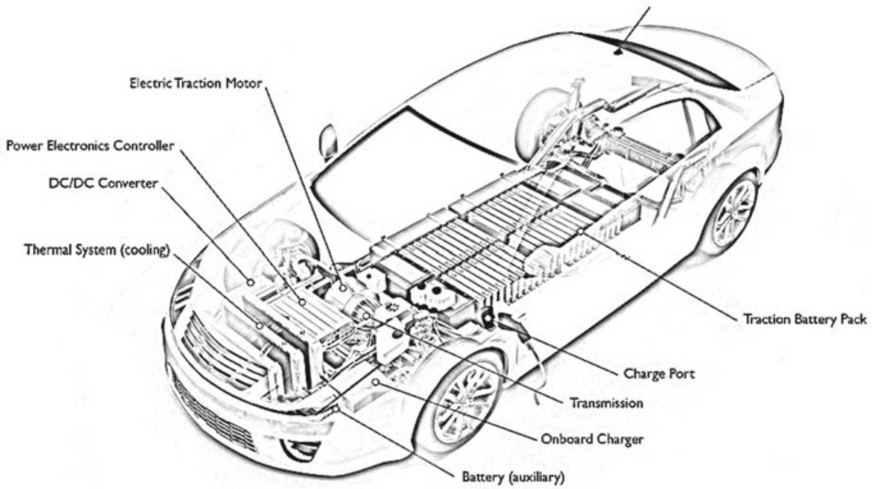


Fig. 8 Construction of BEV

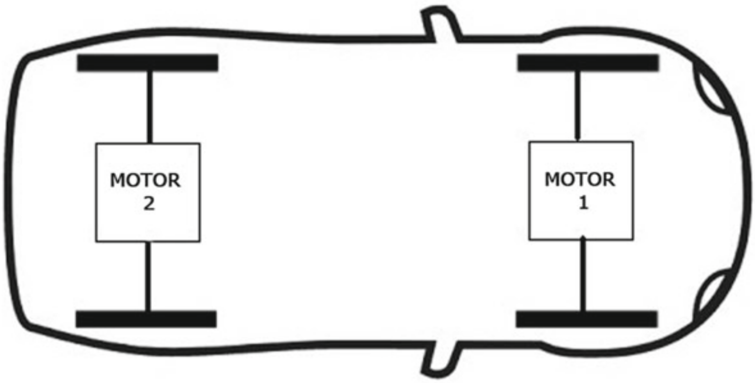


Fig. 9 Anatomy of Tesla Model S

motor, engines, etc. There is a traction battery pack which is another key components of the vehicle. It is used to store power which is further used in the engine of the electric vehicle. And lastly, there is a component of transmission. The role of this component is to transmit the mechanical force from the motor to the wheels so as to move the vehicle [7, 8].

4.2 Anatomy of Tesla Model S

The Tesla Model S is one of the superior battery electric vehicles. It has two electric engine for traction, one for the front pivot and the other one on the back hub independently. Additionally, both the motors have their own individual power electronics controller. This double engine design for both the axles is the bit of leeway for the vehicle as it gives all-wheel drive (AWD) abilities and furthermore a decent exhibition as far as increasing speed and driving elements [9] (Fig. 9).

4.3 Anatomy of Rimac Concept One

Another exceptionally elite BEV is Rimac Concept One. This is the principal battery electric hypercar. It has a significant level of execution and the driving elements. The powertrain of this vehicle comprises of four separate motors, one for each wheel. Every one of these motors has their own apparatus box, the single speed gear box in the front and the two-speed gearboxes with carbon fiber grips in the back. The high-voltage battery is uprooted in a “T” shape, between the front and the back axles as appeared in Fig. 10 [9].

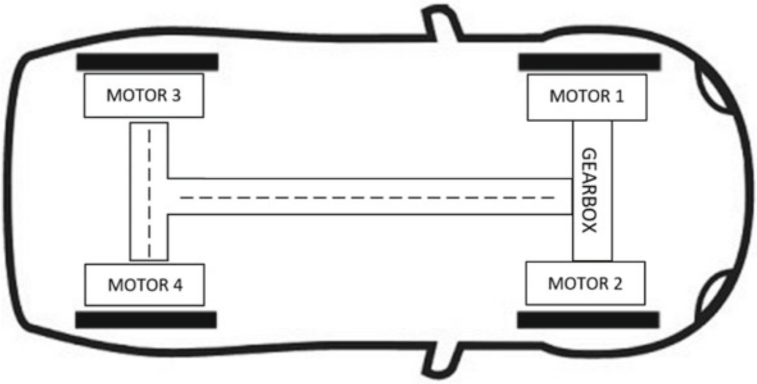


Fig. 10 Anatomy of Rimac Concept One

5 Working of BEVs

5.1 Working Principle

Since we realize that an electric vehicle utilizes electrically driven engine unlike an internal combustion engine. The electric vehicle uses the force put away in the huge battery pack which supplies energy to the electric engine. Each electric vehicle has own port of charging, which allows the vehicle to communicate to an external power supply which helps in the charging of the battery. Charging station or the charging outlet gives charging of the large battery packs. The principle capacity of this battery is to give power to the embellishments in an electric vehicle (Fig. 11).

All the vehicle need a low voltage DC power for working, with the goal that a DC/DC converter is introduced in it. The electric motor which is associated with the

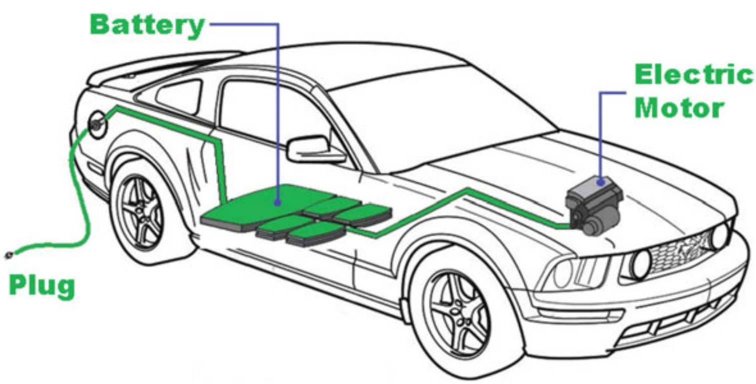


Fig. 11 Internal architecture of BEV [10]. *Source* Circuit Digest

wheels of the vehicle utilizes the energy of the batteries which helps to run the motor or engine so as to move the vehicle. The speed and the torque of the motor created in it are constrained through the power electronics controller, and it moreover manages the movement of electrical energy passed on by the battery. This is the fundamental working guideline of the battery electric vehicles (BEVs).

It has anon board charger, which changes over AC power to DC power to charge the batteries of the vehicle. The characteristics of the standard battery, for instance, voltage, temperature, current, and state of charge are obliged through it while charging the battery pack. The working temperature extent of the electric motor, power contraptions and various parts are kept up with the help of the cooling system [11].

5.2 *Modes of Operation*

5.2.1 Electrical Driving

This method of driving is the fundamental driving mode, wherein the vehicle is in the running condition. The power electronics of the vehicle are given power with the help of the high-voltage battery. The converter changes over the direct voltage into an alternating voltage which helps in driving the electric engine and subsequently the vehicle moves. Then again when the motor runs as an alternator the rotating voltage is changed over into the immediate voltage and afterward took care of to the battery which prompted the charging of the battery [12].

5.2.2 Regenerative Braking

In the event that the electric vehicle is moving with no assistance of the driving torque from the electric engine then a piece of a dynamic energy is taken care of into the high-voltage battery with the help of the electric engine which works as an alternator. Fundamentally, regenerative braking is the change of the vehicle's kinetic energy into energy which is put away in the battery, where it is very well-utilized to drive the vehicle later. It is regenerative in light of the fact that the energy is recovered to the battery where it tends to be utilized once more.

The kinetic energy put away in a moving vehicle is identified with the mass and speed of the vehicle through the condition $E = 1/2mv^2$. All else being equivalent, if the vehicle is twice as heavy it has double the kinetic energy and in the event that it is moving twice as quick it has multiple times the kinetic energy. Whenever the vehicle hinders the active energy put away in the vehicle must be recoupled with the assistance of an engine as engine changes over the formed torque into the fitting voltage and current waveforms to deliver the instructed torque in the engine in the most effective way. The torque order can be negative or positive. At the point when the torque serves to slow the vehicle, then energy is stored back to the battery, and henceforth, this is called regenerative braking [12].

5.2.3 Climate Control While Vehicle Is Stationary

In the event that the electric vehicle is remaining in a car influx, no yield is required from the electric engine or generator. The solace necessities of the inhabitants are met with a high-voltage warming framework and climate control system blower. There is no utilization of energy when the vehicle isn't moving or fixed. An atmosphere control gadget for a fixed control of the atmosphere in an engine vehicle has a heatpump circuit. There are two heat exchanger, one heat exchanger for taking up heat, and another heat exchanger for releasing heat into the vehicle interior. There is an electrically or precisely drivable blower which is situated in the stream heading of the heat siphon circuit between the first and the second heat exchanger, and a supporter set for delivering mechanical and electrical force. The electrical and mechanical force is being utilized in any event to some degree to drive the blower. Also, there is a third heat exchanger by which the fume heat of the sponsor set is moved to the heatpump circuit. Along these lines, great proficiency is guaranteed for the atmosphere control gadget in the warming activity while the vehicle is not moving [12].

6 About Batteries in BEVs

The fundamental and the most significant piece of any battery electric vehicle is the high-voltage battery. Different parts and the components of the vehicle are altogether affected through the parameters of the battery, for example, greater traction motor torque, most extreme recovery brake torque, vehicle run, weight of vehicle, vehicle cost, and so on.

6.1 Types of Batteries

A battery comprises of at least two electrochemical cells combined. The battery changes over the chemical energy to electric energy. A solitary battery cell is made of a positive cathode and a negative anode, both are associated with an electrolyte. The compound response between the electrolyte and terminals produces power. Battery-powered batteries can turn around the substance response by switching the current. Along these lines, the battery can be energized. The material and their types utilized for the cathodes and electrolyte decides the battery particulars. Various batteries accessible are appropriate for EVs. These batteries are depicted here.

6.1.1 Lead/Acid

These batteries are one of the most established class of a battery utilized in battery electric vehicles. The positive terminal of the battery is lead oxide, and the negative terminal of the battery is lead. Both the terminals of the battery are drenched in an electrolyte of sulfuric acid. During the release procedure, the lead on the negative terminal and the lead oxide on the positive terminal respond to sulfuric acid. Because of the response lead sulfate is shaped and the electrolyte transforms into water, energy is discharged during the chemical reaction and when energy is involved the reaction will be reversed.

The cost of the particular energy of the lead/acid batteries is low when contrasted with the other battery innovations. A common lead/acid battery has a particular energy of about 40 Wh/kg and a particular intensity of about 240 W/kg [13].

6.1.2 Nickel Metal Hydride

These types of batteries, on the positive terminal of the battery, use nickel. These are of four sorts: nickel zinc (Ni–Zn), nickel iron (Ni–Fe), nickel metal hydride (Ni–MH), and nickel cadmium (Ni–Ca). Due to their minimum life and less explicit force, the Ni–Zn and Ni–Fe types of batteries are not viewed as a possibility for EVs. The best invention was the cadmium-based Ni-Ca batteries. These batteries are in contrast with the Ni-MH batteries. The Ni-MH battery reaction is such that the metal hydride reacts with the nickel oxyhydroxide and gives nickel hydroxide and metal separately.

They have high explicit force upto 2000 W/kg and have explicit energy between the scope of 45 and 70 Wh/kg [13].

6.1.3 Lithium-Ion

These type of batteries are the most dependable and prevailing innovation in the field of batteries for BEVs just as different EVs. The development of the lithium-ion batteries has been expanding from the last few years. Maximum BEVs in the future are going to be outfitted with lithium-ion batteries. Examples of vehicles which use such type of batteries are the Tesla Roadster and the Mitsubishi i-Miev. These batteries are really reasonable for superior EV batteries as a result of the principle characteristics of this metal which is high expected potential. This means they have high potential energy (in Wh/kg), all things considered. Lithium is additionally light in weight among all the accessible metallic materials.

The particular energy of the lithium-ion battery ranges from 60 to 250 Wh/kg while the force capacity can be as high as 2000 W/kg [13].

6.1.4 Metal Air

The metal air batteries are not as easy to work as different batteries referenced on the grounds that the greater part of them cannot be revived by turning around the current rather we need to supplant the anodes with different materials. These batteries are precisely rechargeable and are practically identical in energy units. The significant favorable position of such batteries is that it has only one reactant and other reactant is supposed to be due to which the weight of the battery is reduced. Among all the metal air batteries, the zinc air battery is the most popular while other batteries are in progress to develop. The enormous energy capacity of the battery is valuable in little gadgets requiring a dependable battery.

They have a high explicit energy of about 220 Wh/kg, yet they have a generally low explicit intensity of about 110 W/kg [13].

6.1.5 Ultra Capacitors

Ultra capacitors are totally not quite the same as batteries, as they store their energy genuinely though the batteries store their energy artificially. The two plates of the capacitors are known as collectors which are separated in an electrolyte. The role of capacitors is to store the energy on high surface materials. Ultra capacitors can be charged and released a lot quicker than batteries and are truly reasonable for putting away the energy from regenerative slowing down. The ultra capacitor has high explicit intensity to 5000 W/kg yet a low energy capacity of 5 Wh/kg [13] (Fig. 12).

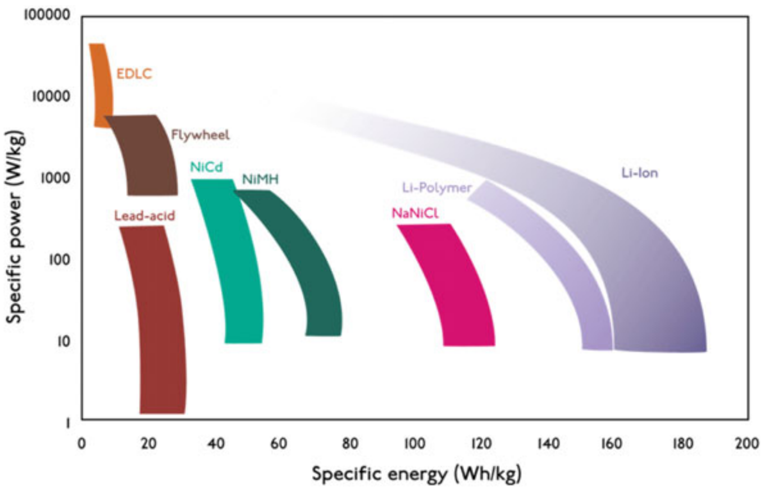


Fig. 12 Power and energy of different batteries [9]. *Source* x-engineer.org

6.2 Battery Pack Architectures

A battery pack of high-voltage battery is the mix of a number of battery cells organized in strings and modules. The battery cell is considered as the smallest unit of the battery pack. When the individual battery cells are gathered together or arranged together, they are called as modules. Further, when these modules are joined together and orchestrated in the arrangement or pattern, they structure battery packs. Depending upon the battery parameters, there might be a few degrees of measured quality.

The quantity of cells orchestrated in arrangement decide the all out battery pack voltage. Consider the model demonstrated as follows shows the series connection of the cells.

So as to build the present limit of the battery, the blend of strings has to be associated equally. Think about the model as demonstrated as follows: The limit and the current ability of the battery will be multiple times when the series of cells are associated equally. From Figs. 13 and 14, the series and the parallel combinations of batteries and their representation can be understood [9].

6.2.1 Mitsubishi i-MIEV Battery Pack

The high-voltage battery pack of Mitsubishi i-MIEV has 22 modules which contains 88 cells which are associated in arrangement. These modules contain 4 cells each. The voltage of each cell is 3.7 V, and the absolute voltage of the battery pack is 330 V which can be seen from Fig. 15 [9].

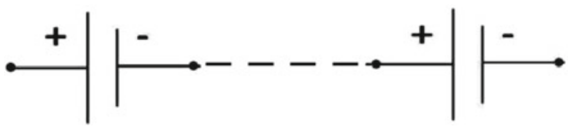


Fig. 13 Battery cells in series

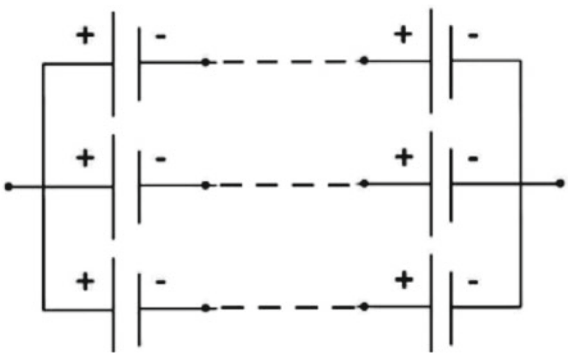


Fig. 14 Battery cells in parallel

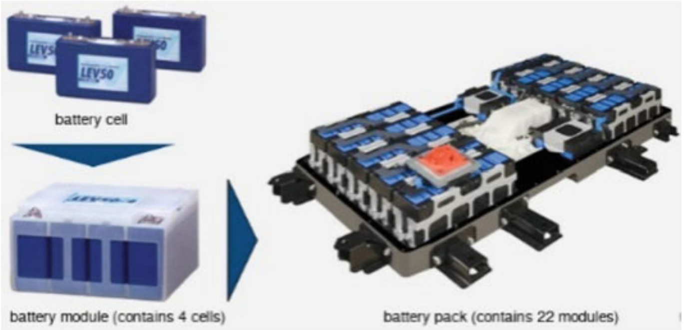


Fig. 15 Battery pack of Mitsubishi [14]. *Source* Mitsubishi

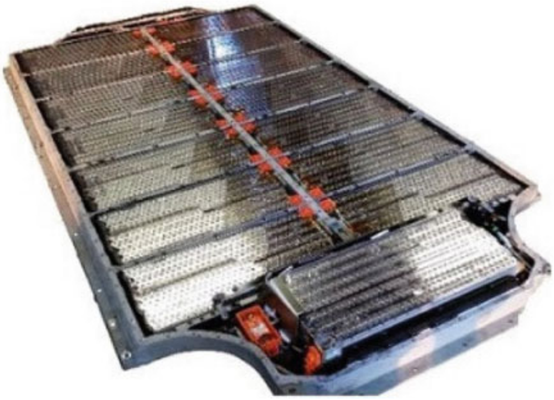


Fig. 16 Battery pack of Tesla Model S [14]. *Source* Tesla

6.2.2 Tesla Model S Battery Pack

The high-voltage battery pack of Tesla Model S has 16 modules involved 6 gatherings each. Each gathering present in every module is a mix of 74 cells; in this manner, all out number of cells present in the battery pack are 7104. This can be seen in Fig. 16 [9].

6.3 Battery Pricing

Battery estimating is the most significant detail of the battery electric vehicle (BEVs). Today the NiMH battery is as yet less expensive than lithium-ion batteries; however, lithium-ion batteries will in the long run be more affordable than the NiMH battery when being mass delivered.

The Pb/A battery won't decline in value in the future as the innovation is practically developed. NiMH battery costs are additionally cannot be predicted significantly may be as more as the cost of nickel which make up the vast majority of the battery cost. The first delivered lithium-ion pack is about 1600 €/kWh and at a creation stock of one lakh packs per year the manufacturing cost will be as minimum as 150 €/kWh.

The advancement proportion determined can give a sign of how the innovation will create in coming years when one lakh battery packs are delivered. An advancement proportion for lithium-ion batteries for purchaser items was determined and evaluated as of 83% somewhere in the range of 1993 and 2003. An other report assessed an advancement report of 92.5% somewhere in the range of 2010 and 2030. Similarly, as with different advancements the cost will diminish more in the beginning time of improvement [9].

7 Classification of Charging

The charging of the battery electric vehicle is arranged into three levels: level one, level two and level three or DC fast charging.

7.1 Level One Charging

From Fig. 17, this level utilizes a similar 120-V supply found in home unit outlets, and this charging can be done by using the normal cable of charging which other

Fig. 17 Level one charging [11]. *Source* New Car Kids

electrically driven vehicle use. Making this sort of charging accessible is as straightforward as introducing devoted 120 V outlets in the parking area, home or work environment. The charging of about 10 h is sufficient to travel roughly 70–80 miles [15].

Advantages

No establishment cost if an outlet is accessible close to where the vehicle is left.

This has a low effect on electric utility.

Disadvantages

Slow charging, commonly in one-hour of charge it can travel 5–6 miles.

7.2 Level Two Charging

From Fig. 18, this type of charging requires a specific station which gives power at 240 V. This sort of charging needs installation of charging station unit and electrical wiring fit for dealing with higher voltage power. Such type of charging is beneficial for daily work commute. It takes nearly 4–5 h to completely charge a battery so that the vehicle can travel around 70–80 mile [15].

Advantages

Faster charge time normally 10–20 miles per every hour of charge.

Energy effective, about 3% gain in proficiency.

Assortment of EV charging makers gives separated items which can plan charging, track use, and gather expenses.

Fig. 18 Level two charging [16]. *Source* Arthur D. Little

Disadvantages

More costly than level one.

It has possibly higher effect on top kilowatt request charges for organizations.

7.3 Level Three Charging or DC Fast Charging

From Fig. 19, DC quick charging of 480 V gives good vehicles a 80% charge in 30 min to 1 h by changing over AC capacity to DC power capacity in EV batteries. For DC quick charging, there are three attachment types utilized by various automakers: the CHAdeMO, Society of Automotive Engineers (SAE) consolidated charging framework (Combo/CSS). Tesla's Supercharger hardware is just good with Tesla vehicles, inspite of the fact that they offer a connector which permits Tesla proprietors to utilize CHAdeMO gear [15].

Advantages

Charge time is decreased radically, and it is almost as quick as refueling a fuel vehicle.

Disadvantages

Altogether costlier than the other two levels of charging.

Conceivably expanded charges for business areas.

Diverse fitting sorts are confounding to potential EV purchasers and charging station administrators.

The contingent upon the vehicle and charging gear, quick charging can be eased back during chilly climate.

Fig. 19 Level three charging [16]. *Source* Arthur D. Little

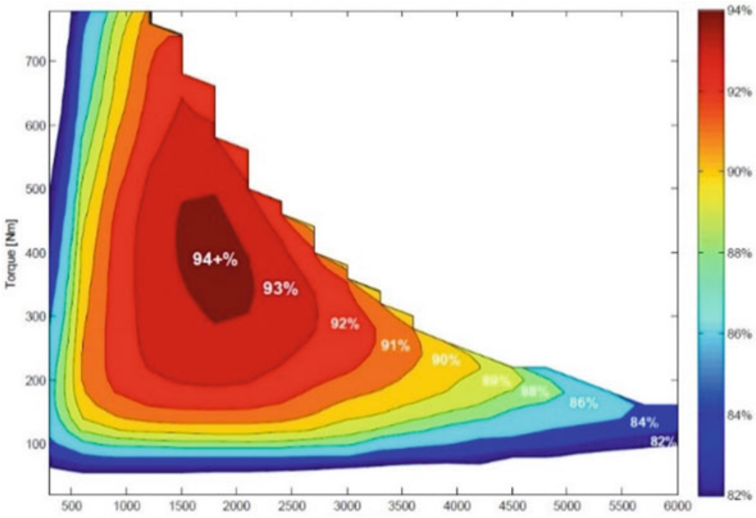


Fig. 20 Efficiency map [9]. *Source* x-engineer.org

8 Advantages of BEVs Over Other EVs and Ice Vehicles

8.1 Efficiency

In battery electric vehicles, the substituting flow (AC) electric engine which has permanent magnet or induction rotors offer high generally efficiency. The engine utilized for the vehicle is permanent magnet electric engine which has a base productivity of around 65–80% and a limit of 90–97%, though the efficiency of an ICE is a lot of lower around 10–40%.

An electric engine can be handily worked at a normal productivity of 80–90% on a driving cycle; however, the normal efficiency of an ICE vehicle is 20–30% which implies that the effectiveness of BEVs is multiple times higher than the internal combustion engines [9] (Fig. 20).

8.2 Dynamic Performance

Figure 21 gives information regarding torque and power characteristics. The engine of the battery electric vehicle has a perfect traction trademark. The electric engine can convey the most extreme torque at a zero speed, which gives an excellent beginning to the vehicle. An electric engine is equipped for giving a peak torque to a constrained measure of time in the beginning and a ceaseless torque as long as there is an inventory given to the vehicle. For a top torque in the beginning, the engine requires a very

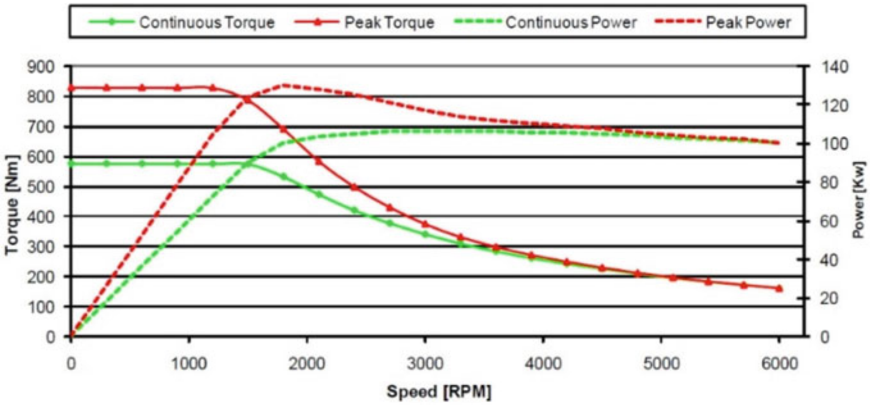


Fig. 21 Torque and power characteristics [9]. *Source* x-engineer.org

measure of current from the battery which creates a high temperature in the force hardware and engine. To shield the parts from higher temperature, the peak torque is constrained in time yet the torque is accessible enough to help the speeding up execution of the vehicle [9].

8.3 Reliability

The battery electric vehicles have not many prospects of disappointments when contrasted with the internal combustion engine vehicles in light of the fact that BEVs have less moving parts. Likewise because of high torque and fast qualities of the electric engine, there is no requirement for a multistage gearbox which implies a solitary advance mechanical gearbox is sufficient for traction prerequisites. Though ICE vehicles have many moving parts and furthermore extra framework, for example, a fuel framework, a weariness framework, and so on which can prompt disappointments and an extra wellspring of disappointments is a multi-stage gearbox. In this way, BEVs are more dependable than other vehicles [9].

8.4 Torque Vectoring

For an all-wheel drive (AWD) battery electric vehicle, the soundness during the cornering is significant. This stability during cornering can be improved with the assistance of controlling the torque of the wheels. An electric engine of a battery electric vehicle has quicker torque reaction and is equipped for creating negative torque additionally, which then again, internal combustion engine vehicle cannot do.

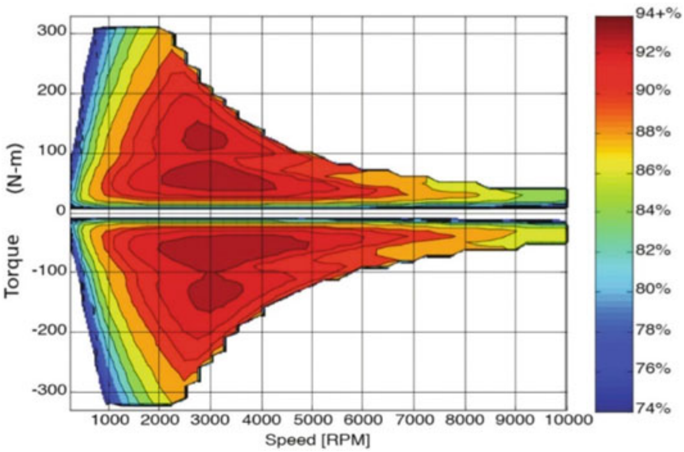


Fig. 22 Positive and negative torque map [9]. *Source* x-engineer.org

Rather than ICE vehicles, they have constrained commitment to the vehicle solidness and they lessen the measure of torque conveyed [9].

8.5 Energy Recuperation and Brake Regeneration

The utilization of an electric machine in the battery electric vehicles is one of the unmistakable favorable position of BEVs over different vehicles. The electric machines are reversible which implies that they can deliver torque in the event that they are provided through the electrical energy, and they can likewise create electrical energy when they have an input torque because of the latency of the vehicle. At the point when the electric machine is creating torque, then it is in engine mode and when the electric machine is delivering electrical energy, then it is in generator mode. Figure 22 shows that the negative torque can be as high as the positive torque which implies the electric machine can create a lot of the slowing down torque [9].

8.6 Cost and Maintenance

The battery electric vehicles have a bit of leeway of much lower running expense when contrasted with different EVs just as the regular internal combustion engine vehicles. The expense of power required to charge a battery electric vehicle is 33% as much per kilometer as the expense of purchasing petroleum for other customary vehicles. Additionally having less moving parts and segments, a battery electric vehicle is simpler and less expensive to keep up.

8.7 *Better for an Environment*

Less Pollution: The battery electric vehicles help in lessening the destructive air contamination from exhaust emanations as the BEVs have zero fume discharges [17].

Renewable Energy: By utilizing the sustainable power source to energize the battery electric vehicle, the green house gas outflows can likewise be decreased. Utilizing solar PV to revive the vehicle is a bit of leeway as it requires typical household supply to energize its battery which should be possible by solar powered PV framework or some other sustainable power source. Also, renewable energy such as wind energy can be used to produce power which can be further utilized to charge the vehicle [18–20].

Eco-friendly Materials: In the cutting edge age, there are manufacturers who are using eco-friendly materials for the development of vehicles, for instance, recycled plastic materials, bio-based materials, or recycled household waste materials. In this way, the manufacturers are concerned to build the vehicles with an eco-friendly materials.

9 Conclusion

From the invention of the electric vehicles in the early eighteenth century to the modern age world of today, there have been many evolutions and developments in the electric vehicles. After years of growth and development in this field, battery electric vehicles demand is finally increasing. A number of factors such as better performance, cutting edge technologies, connectivity, environment friendly, quieter ride, and low running cost are combining to focus the attention on the adoption of battery electric vehicles.

Despite having so many features, there are a few concerns as well before adoption such as driving range, initial cost, lack of charging infrastructure, and time required to charge the vehicle. The average driving range of the battery electric vehicles is 150–200 miles which are quite less than that of ICE vehicles. But it is better for the people who have a daily commute of 70–100 km s. Similarly, the initial cost of BEVs is more in contrast with the ICE vehicles, whereas the maintenance cost and the running cost of BEV are much less than that of ICE vehicles, and therefore, BEVs are better for long run. One of the major concerns about BEVs is the lack of charging infrastructure. For the vehicles used for the daily commute, the home or workplace charging is more than sufficient. But for the long-range drive of BEVs, there is a need of charging stations at various places just like the fuel stations for the ICE vehicles. With the help of charging stations, batteries of the vehicles can be recharged and they can travel over the longer distance. Addition to this, time taken to charge the vehicle is another concern about BEVs. On an average, a typical battery electric vehicle takes near about 8 h to charge a 60 kWh battery from empty-to-full which can cover up to 200 miles of distance. This charging time can be reduced to minimum of 30 min with the help of fast-charging stations. Also, benefiting from the battery technology improvements, the time required to charge at fast-charging stations can be reduced further.

Considering all these factors and the technological advancements, the market of the battery electric vehicles will be at the tipping point in the coming few years.

References

1. Z. Shahan, *1 Million Pure EVs Worldwide: EV Revolution Begins* (Clean Technica, 2016)
2. J. Fuller, What is the history of electric cars? How Stuff Works, 14 July 2009
3. *World's First Electric Car Built by Victorian Inventor in 1884* (The Daily Telegraph, London, 2009)
4. E. Rishavy, W. W. Bond, T. Zechin, Electrovair—A Battery Electric Car, SAE Technical Paper 670175, 1967
5. G. Berdichevsky, K. Kelty, J.B. Straubel, E. Toomre, *The Tesla Roadster Battery System* (Tesla Motors, 2006)
6. D.B. Sandalow, *Plug-in Electric Vehicles: What Role for Washington?* (The Brookings Institute, 2009). ISBN 978-0-8157-0305-1
7. A. Anand et al., Optimal selection of electric motor for E-rickshaw application using MCDM tools, *Cognitive Informatics and Soft Computing* (Springer, Singapore, 2020), pp. 501–509
8. K.C. Manjunatha, A.K. Bhoi, K.S. Sherpa, Design and development of buck-boost regulator for DC motor used in electric vehicle for the application of renewable energy, *Advances in Smart Grid and Renewable Energy* (Springer, Singapore, 2018), pp. 33–37
9. T.R. Crompton, *Battery Reference Books*, 3rd edn. (Newnes, 2000). ISBN 978-0080499956. Retrieved 18 Mar 2016
10. How Exactly Do Electric Cars Work? Green Car Future, 11 November 2018. Retrieved 22 Nov 2018
11. Components and Systems for Electric Vehicles (HEVs/EVs), Hitachi Review. Retrieved 18 Mar 2016
12. *Seminar on Electric Vehicles* (Automative Research Association of India, 2017)
13. D. Bakker, *Battery Electric Vehicles Performance, CO_2Emissions, Lifecycle Costs and Advanced Battery Technology Development Emissions, Lifecycle Costs and Advanced Battery Technology Development* (Utrecht University, Netherland, 2010)
14. The Battery Pack of Mitsubishi i-MIEV, Green Car Congress Energy, Technologies, Issues and Policies for Sustainable Mobility, 14 May 2008
15. *Electric Vehicle Charging Types, Time, Cost and Savings* (Union of Concerned Scientists, 2018)
16. J.W. Brennan, T.E. Barder, Battery electric vehicles vs internal combustion engine vehicles, *A United States-Based Comprehensive Assessment* (Arthur D Little, Strategy and Organization, Boston)
17. N. Priyadarshi et al., A closed-loop control of fixed pattern rectifier for renewable energy applications, *Advances in Greener Energy Technologies* (Springer, Singapore, 2020), pp. 451–461
18. N. Priyadarshi, F. Azam, A.K. Bhoi, A.K. Sharma, A multilevel inverter-controlled photovoltaic generation, in *Advances in Greener Energy Technologies* (Springer, Singapore, 2020), pp. 149–155
19. A. Sahu et al., Design of permanent magnet synchronous generator for wind energy conversion system, *Advances in Smart Grid and Renewable Energy* (Springer, Singapore, 2018), pp. 23–32
20. S. SenGupta, A.F. Zobaa, K.S. Sherpa, A.K. Bhoi, *Advances in Smart Grid and Renewable Energy* (2018)