Electric Vehicles over Contemporary Combustion Engines

Abhishek Upadhyay 1, Mihir Dalal 1, Naman Sanghvi 1, Vaibhav Singh1,
Sheeja Nair1, Ionut Cristian Scurtu2, Cristian Dragan 3
1 Dwarkadas J Sanghvi College of engineering, Mumbai, Maharashtra, India
2 Mircea cel Batran Naval Academy, Constanta, Romania
3 Constanta Maritime University, Constanta, Romania

Abstract. IC engine or internal combustion engine have been dominating the automotive since its inception. Although it seems quite skeptical but the first electric vehicle was developed around 1890 by William Morrison. During early 1900s around 40% of cars were electric, 38% on steam and mere 22% on gasoline. Due to range, capacity and also power produced by electric vehicles made them obsolete. The research paper focuses on how electric vehicles are not only comparable but better than internal combustion engine in many ways. Various studies and Simulink proves that electric vehicle is going to be the future of transportation.

Keywords: Electric vehicles, transportation.

1. Introduction

Due to the massive growing rate of global warming due to the carbon emissions from the vehicles, the introduction of electric vehicles on the road is something that can bring a major change and help us in the fight against air pollution. To curb this situation the solution is the development of electric vehicles with zero pollution motor which don’t run on fossil fuels but electricity stored in the batteries of the vehicle. The other major highlight is that, electric vehicles ask for a very low running and maintenance cost. Apart from that, they can have frequent starts and stops with a smooth acceleration without the overall system getting overloaded.

![Figure 1. Introduction to electric vehicle](image_url)
The specifications have been discussed in a much more detailed manner ahead in the report, but to sum up the introduction, EVs are the future as we cannot expect IC engines on a later stage when there is going to be a major fuel crisis [1]. Basic model of electric vehicle contains motor, battery and charging port/dock (as referenced from figure 1- Introduction to Electric Vehicle). EVs are growing rapidly since there are multiple renewable sources to provide power to them such as: Solar, Wind, Hydro, bio fuel and so on.

1.1. Classification of batteries used in electric vehicles:

Batteries are used as a system for storage of energy in electric cars. Battery type can vary depending upon the type of electric vehicle i.e. an all-electric vehicle or plug in hybrid vehicle. Batteries now are built to be long-lasting they typically last for about 10000 miles or 8 years. Judging by referencing figure. 2- Types of batteries and their advantages it is obvious that lithium ion has to be the ideal choice for primary battery in EV vehicle.

1.2. Types of batteries used electric car

1) Lithium-ion batteries:

These are the most used type of batteries in electric vehicles. They can also be seen in many electronic day-to-day devices such as phones and laptops. They have high power to weight ratio, high energy efficiency, and good temperature performance. These lithium-ion batteries are recyclable. These batteries are used in AEV and PHEV. Li-ion batteries are now being used widely by electric vehicles of the new generation. After studying the dangers of the instability of the battery it was reported that LiFePO4 type is preferable due to its chemically stable nature. Also, the LiFePO4 type is inherently safe. Li-ion such as LiCoO2, LiMn2O4, and Li (Ni1/3n1/3Co1/3) O2 [2] may have thermal and overcharge concerns. But Lead-acid battery is still used in a major part of the market due to its low cost.
2) Nickel-metal hydride batteries:

Hybrid electric vehicles mostly use this battery. It is one of the mature battery technology. Nickel metal hydride batteries have longer life span than lithium-ion and lead-acid batteries. Hybrid electric vehicles do not derive power from an external plug-in source and instead rely on fuel to recharge the battery which excludes them from the definition of an electric car.

Nickel-metal hydride batteries have a longer life-cycle than lithium-ion or lead-acid batteries. They are also safe and tolerant to abuse. They have high durability. They are very expensive, their self-discharge rate is high and also have low power density which is the biggest drawback, and the fact that they generate significant heat at high temperatures. These issues make these batteries less effective for rechargeable electric vehicles therefore, they are not ideal for AEV.

3) Lead-acid batteries:

Lead-acid batteries are also a mature technology. They have high performance. They are significantly cheaper when compared to other batteries. They are secure and dependable but have a short lifespan. Their performance in cold temperature is also very poor. due to their low power density, they cannot be used in electric vehicles as a primary energy storage system but are wide as supplement storage in commercial vehicles.

4) Ultra-Capacitors:

Ultra-Capacitors are not batteries in the traditional sense. Instead, they store polarized liquid between an electrode and an electrolyte. As the liquid’s surface area increases, the capacity for energy storage also increases. An ultra-capacitor is very high capacity capacitance and lower voltage limits than other types of capacitors they lie between electrolytic capacitors and rechargeable batteries they can be charged very fast (from Table 1- Super Capacitor Characteristics). They have a lifespan of almost 10000 to 1 million cycles. They have very wide operating temperatures -40F to 150F. The discharge rate of ultra-capacitors is very higher than the lithium-ion battery. In addition, Ultra-Capacitors can provide electric vehicles with extra power during acceleration and regenerative braking.

Table 1. Super Capacitor Characteristics

| Storage characteristics | Device | Super Capacitor | Capacitors | Battery |
|-------------------------|--------|----------------|-----------|---------|
| Charging time           | 1-30 s | 10²<t<10⁶ S    | 1<t<5h    | T>0.3h  |
| Discharging time        | 1-30 s | 10²<t<10⁶ S    |           |         |
| Energy Density (Wh/kg)  | 1-10   | <0.1           | 10-100    |         |
| Life time (Cycle number)| 10⁶    | 10⁶            | 1000      |         |
| Power density(W/kg)     | 10,000 | >1,000,000     | <1000     |         |
| Charge/Discharge efficiency | 0.85-0.98 | >0.95          | 0.7-0.85  |         |
2. Conventional battery

The invention of conventional battery (lead acid battery) was done by French scientist Gaston Planté in 1859. The lead acid battery has the ability to supply high surge currents which means that the cells have very high power to weight ratio despite having a very low energy to volume ratio and a very low energy to weight ratio. These batteries are used in motor vehicles because of their low cost and their ability to provide the high currents required by tarter motors. Although they are used in electric vehicle they are never used as primary battery in electric vehicle because of:

1) Cost of lithium ion is higher but in terms of cost and range it is a more favorable option (600 Wh/L for lithium ion and 90 Wh/L for lead acid) [4]
2) Charging of lead acid battery takes as long as 10 hours while lithium ion just gets charged in 3 hours.

2.1. Working of lead acid battery

The battery which uses sponge lead and lead peroxide to convert chemical energy into electrical energy is known as a lead-acid battery. This is very commonly used as a storage battery or secondary battery used in cars. A material for cathode which is the positive terminal is lead peroxide and for the anode which is the negative terminal of the battery pure lead / spongy lead is used. Dilute sulphuric acid used for the lead-acid battery has a ratio of water is to acid is 3:1.

Construction of simple lead-acid battery contains cathode and anode dipped in an electrolyte which is a dilute sulphuric acid. This simple construction is not used on an industrial level, the plates form a grid to distribute current equally they are made up of antimony and lead. Several positive and negative plate is connected in parallel to increase the surface area. The electrolyte gets splits into ions i.e. into hydrogen (positive) and sulphate (negative). These hydrogen and sulphate ions are quite unstable so hydrogen ion receives an electron from lead peroxide i.e. the cathode. The hydrogen atom newly forms attack lead peroxide plate and form lead oxide and water are formed. Lead oxide form attacks the remaining sulphuric acid atoms to form lead sulphate and water. The negative sulphate ions carry their negative charge towards the anode plate and give their negative to pure lead and form a sulphate radical which is highly unstable [5]. Therefore, it reacts with pure lead and form lead sulphate. This creates inequality of electrons in both the plates, as a consequence, it also results in a potential difference which is normally of 2V. Due to this, there would be a flow of electron through the external load, this is known as discharging of a battery. During charging the concentration of sulphuric acid falls but there is still some sulphuric acid which remains in the electrolyte. This sulphuric acid also remains as positive hydrogen ions and negative sulphate ions in the solution. The positively charged hydrogen ions are attracted to the negatively charged anode. The hydrogen ions take an electron to form a hydrogen atom. This hydrogen atom reacts with lead sulphate and forms pure lead and sulphuric acid. The negative sulphate ions get attracted towards the positive terminal of externally applied potential difference and give its extra electron to it forming sulphate radical. This radical sulphate reacts with lead sulphate of cathode and forms lead peroxide and sulphuric acid. Hence by charging the lead-acid storage battery cell becomes ready for discharge.

2.2. Why Electric Battery instead of an IC Engine?

Internal combustion engines have been ruling the streets for decades now. People get up in the morning,
head for their cars, hit the ignition, and hope the engine comes to life so that they won’t be late for work. But technology is ever-advancing, and with that comes new ground-breaking ideas that have the potential to be revolutionary. Although electric cars have been here for more than a decade, it is only now through advancements in certain technologies that we are witnessing a surge in their production.

Recent developments in engineering have advanced to autonomous or self-driving vehicles which are highly dependent on electronics so it would make much sense to develop a car which would run on electricity. The efficiency of an electric battery is much more than an internal combustion engine. Compared with internal combustion engines cars with an electric battery have less tailpipe emission and are very quiet than internal combustion engines.

Another advantage of electric battery over IC engines is that it has very few moving parts. There is no need of balancing when electric batteries are used. When we use electric battery we have a very good control of speed than that in IC engines. It has high acceleration as compared to IC engines. Also, electric batteries are self-started.

![Figure 3. Block diagram of Hybrid Electric Vehicle](image)

### 3. Working of electric car battery

The principle on which electric car batteries are based on is called electrochemical potential. The tendency of a metal to lose electrons is called electrochemical potential. The first electric cell was built by Alessandro Volta also based on the principle of electrochemical potential. In the electrochemical series, lithium has the highest tendency to lose electrons. In lithium-ion cells, lithium has only one electron in its outer shell and thus has the tendency to lose this electron, due to this reason pure lithium is highly reactive, but lithium, when part of metal oxide, is quite stable. The lithium-ion battery pack consists of many cells connected in series and parallel to form modules. In a cell, the graphite and metal oxide are coated onto copper and aluminium foil and act as a current collector, graphite acts as a negative electrode whereas the lithium metal oxide acts as a positive electrode, an organic salt of lithium acts as the electrolyte and is coated on the separator sheet all these three sheets are wound onto a cylinder around a central steel core making the cell more compact. From figure 3 (Block diagram of Electric Vehicle) ideal position of energy storage system i.e. lithium-ion battery can be seen in hybrid vehicle. When the battery is being charged up that means we have connected a power source across this
arrangement the electrons from the lithium atom of the metal oxide will be attracted to the positive part these electrons will from the external circuit to the graphite layer as they cannot flow through the separator. Then the positively charged lithium ions from the lithium metal oxide (lithium –cobalt oxide or lithium iron phosphate) attracted to the negative part of the power source will move through the electrolyte to the graphite layer and remain there. When all of the lithium ions reach the graphite sheet the cell is fully charged but this unstable condition for lithium-ion so as soon as a load is connected instead of the power source the lithium ions are ready to flow to the metal oxide through the separator electrolyte and electrons through the load due to which we get an electrical current in the load. The graphite does not take part in the chemical reaction it is just a storage medium for lithium ions. If the internal temperature of the cell rises due to some abnormal condition the liquid electrolyte will dry out causing a short circuit between anode and cathode which will lead to fire or explosion to avoid such a situation, an insulating layer called the separator is placed between the electrodes it is permeable to lithium ions because of its micro-porosity. The battery pack consists of electronic controllers that can regulate and also control the way the cells charge and discharge, unlike other batteries. Lithium-ion cell can be seen in figure 4 which shows various parts of lithium-ion cell.

![Figure 4. Lithium Ion Cell](image)

4. Overview of automobile industry, future and changes it brings:

We know about it already because of the boom revolution of electric car battery technology. As per the Auto industry, lithium-ion technology will dominate the EV battery market share on the high reaches by the coming years. These batteries are more powerful and give consistently better performance than ever and cost has come down strikingly over years. Electric vehicles have increased in sales from 0.02 million in 2010 to almost 7.5 million in 2019 although this might now seem much since global vehicle sales are around 60 million cars per year. But it is an increase of 37,500 percent. The major drawback of electric vehicles is mainly its price which is predicted to be equal to conventional petrol/diesel engines in the coming 5 years. Many countries have also electrified their transportation system for example Norway where 46% of the vehicle on road is electric, also adding electric buses year by year. Singapore has also started electric car-sharing services. Tesla which is the biggest brand in electric vehicle business would reach 100 billion dollars in revenue by 2025. It also has an EBITDA margin of 20%. Its valuation exceeds major car manufacturers such as Ford and
GM combined.
Electrification is the most booming thing in major automotive manufacture nowadays. Although they might not develop fully electric vehicles they are developing hybrid vehicles that use both electric as well as the IC engine. For example, Lamborghini which was known for its naturally-aspirated big engines such as V12 and V10 developed its first hybrid vehicle known as Lamborghini SIAN. Not only this Koenigsegg launched its first hybrid vehicle known as Koenigsegg Regera which produced 700 hp (1500 hp combined) only by its three YASA electric motors. This car could achieve a top speed of 403 kmph. Also, big manufacture like Daimler AG (commonly known as Mercedes) has stopped its development of any new combustion engine. The EV market is projected to reach almost 27 million units per year by 2030. Therefore, many major car manufacturers have switched their attention to the EV market to achieve a fair share of the pie.

Indian companies have also come forward in this electrification for a better future. Companies like Ather have developed two products since its inception i.e. 450 and 450x. These electric scooters can give battery capacity of 2.9 kWh which will provide 75 km on a single charge. These scooters will be launched in July 2020. The company bagged an investment of 51 million dollars in its latest round of funding. The company is also expected to grow in other states of India as well after achieving success in Bengaluru.

Global warming is the major cause of this planet right now. The average temperature of our earth has increased by 2 degrees in the last 50 years. In 24 years i.e. from 1993 to 2017, the sea level has risen by an average of 3.0 mm.

We can observe extreme dry or wet events in South East Asia. These things have also resulted in the melting of ice in the arctic region. Levels of dissolved carbon dioxide have also increased in oceans which causes ocean acidification. Also, oxygen is less soluble in warmer water which causes deoxygenation of water. Apart from these, there are various hazardous effects on humans, wildlife, livelihood, industry, etc.

India has pledged to reduce 30-33% of its carbon emission by 2030[c]. This mitigates the problem very much since we are the third-largest emitter of greenhouse gases after China and the USA. According to the study has done carbonbrief.org [6] emissions by transport result in 270.6 MT (from figure 5- Graph of MTCO2e of India) of carbon dioxide emission. This is 7.4% of emissions totaling at 3631 MT of
carbon dioxide yearly.

Figure 5. Graph of MTCO2e of India

The government of India takes this transport sector very seriously since this can be reduced to just 2% therefore, they have launched schemes and incentives to promote electric mobility in our country. This reduces the price of electric scooters approximately by 2,000 INR but this incentive rises to 1.3 lacs INR for electric cars. Apart from these incentives bringing electric mobility in any country is not an easy task. Big companies like TATA Power in conjunction with Fortum is working in this project, the plan is to have a charging every 25 KM on both side of highways in cities with a population of more than 4 million i.e. small cities and megacities by 2022. They plan to start phase 2 of this project after this i.e. covering big cities, state capitals, etc. Anther Energy, an automotive electric vehicle industry of India launched its charging services in Bangalore on May 22, 2018. They are called as Anther Grid.

5. Raw materials in demand use and its extraction sources:

As per the selection of raw materials, there are many battery technologies out there we have to keep the focus on the internals of lithium-ion batteries as they are more in production demand of the total rechargeable battery market by 2025.
The above chart i.e. figure 6 showed us an element selection by percentage, in which Li-ion has 70%, lead acid has 19.2%, with some % of nickel and other elements like Co 6.6% and at last sodium based 3.9% is in use.

Extraction raw materials from other countries in which companies such as Tesla mined most percentage of nickel from North America, which is mined in Canada, also 65 % of graphite is mined from China, with other who are extracting Li-ion there most enrich resources are Argentina, Chile and Bolivia.

6. Recent development practices on ev vehicles

6.1. Wireless Charging:
Perhaps the major drawback of EV vehicle is its range and also the refueling / charging time it may take up to 8 hours to charge it to full and that too with 7kW of charging port which you will only find in charging station. House charging port is generally of 2.5kW which can increase the time up to 17 hours. The development of wireless charging would not just mitigate this drawback but also it would be lifesaving for this industry since it can enable charging anywhere such as in malls, offices, on-road parking, etc.

The wireless charging system is used for transferring voltage from an AC voltage source to the load. Wireless charging works on a principle of magnetic resonance (MR) or inductive power transfer (IPT). Wireless charging can be divided into two parts. First is a transmitter (on a charging pad or inside the parking space) and second a receiver (on a vehicle or phone). The resonance frequency of both transmitter and receiver are set to the same value for high efficiency, a changing magnetic flux is generated by the transmitter, the alternating magnetic field is picked up by the receiver and the current is induced in the receiver [7]. Although this technology looks like it could make drawbacks of EV trivial there is a lot of honing require in this field too. Such as efficiency since the highest efficiency provided by the current industry is just 49% let’s take Tesla Model S for example it uses 7kW of energy for daily commute which is the same power as a small residential home so charging it wirelessly would add 2 small residential home. There has been development in this field such as in OAK RIGDE National Laboratory providing efficiency up-to 90% [8].
6.2. Batteries:
The technology that is in development since the dawn of the electric vehicle is the battery. The major development has reduced the battery price from 1000 dollars/kWh to a mere 150 dollars/kWh. Not only this the longevity of battery has also improved from example Tesla offers 8 years warranty or 160,000 km, for battery degradation to only 70% of its capacity. This is a major development since the provenance of electric vehicle battery would decrease to quite below 80% in the first two years. The developments in this region are to reduce degradation but controlling the formation of SEI (solid electrolyte interface) layer as mentioned above. This layer only permits ions and is impermeable to electrons. This layer is essential for the working of lithium-ion batteries and hence for the battery capacity. This layer can be not formed enough in the frigid climate since the chemical activity is hindered in cold conditions. After regular intervals of charging and discharging give a chance to this layer to form too much in this case it will also hinder some ions. Therefore, the battery degrades after some time.

Ultracapacitors can also be considered as recent developments since capacitor stores charge in the form of ions clinging on to the surface of the electrode. Not like in battery which stores charge in the form of a chemical reaction. A capacitor can be charged and discharged very quickly than a battery. Not only this they also do not degrade like a battery, this makes them ideal things to swap for batteries. Here the drawback is the energy density of the capacitor is far smaller than batteries which is only 7.4 Wh/kg as compared to batteries which are 250 Wh/kg. So ultracapacitors cannot be used alone, they need to use it in conjunction with the battery. Ultracapacitor could be used when high acceleration is required and they can also be charged in braking, this will make them an ideal candidate for the sports car i.e. the Tesla Roadster.

6.3. Differential:
There are two types of differentials available. Electronic differentials and Mechanical differentials. Mechanical differentials are larger in volume and therefore increases weight of the vehicle. Also, it is not suitable for electric vehicles especially for those using separate drives for two rear wheels. Electronic differentials are thus introduced in electric vehicle design to provide passengers with better stability and control.

While taking a turn speeds of the inner and outer wheel are different. The outer wheel has to maintain a larger speed with respect to inner wheel because the outer wheel has to go through a larger radius. Electronic differentials uses commands from the steering wheel and then the motor speed will then signal to control the power to each wheel so that each wheel get the torque that they require.

7. Results

Simulation of simple electric vehicle using MATLAB/SIMULINK performed. Vehicle body mass 1200kg provided. A DC motor with a power output of 50KW and a rated speed of 5000 rpm. H-Bridge with default values. Reference speed from FTP75 graph, 48V battery and a longitudinal driver for driving the vehicle body at reference speed given by the reference graph.
8. Conclusion
The electric vehicle has many advantages and benefits over the internal combustion engine and hybrid vehicle. It is cleaner and much more efficient. Many researchers are working constantly and showing concerns about the automobile as a source of air pollution has been expressed periodically. This technology is now being optimized to reduce the product cost associated with emission controls while improving the in-use durability of the emission control systems. Also, judging from the simulation (i.e. figure- 7 and 8) it can be conclude that even the performance of electric vehicle is improving year by year. It is inevitable that EV is going to be included in daily driving vehicle soon in near future.
9. References

[1] Electric vehicle future aspects. https://digital.hbs.edu/platform-rectom/submission/exxon-mobil-oil-and-gas-giant-or-much-more/

[2] Cheng, K.W.E.. (2009). “Recent development on electric vehicles”. 2009 3rd International Conference on Power Electronics Systems and Applications, PESA 2009. 1 - 5.

[3] TG Gautham1 Prasad et al2 2019 IOP Conf. Ser.: Mater. Sci. Eng. 561 012105

[4] Latest trend. https://www.cummins.com/news/2019/06/17/spot-difference-lithium-ion-versus-lead-acid-battery-electric-technology

[5] Battery storage. https://www.electrical4u.com/working-of-lead-acid-battery-lead-acid-secondary-storage-battery/

[6] Carbon emission. https://www.carbonbrief.org/the-carbon-brief-profile-india

[7] Mohamed1, Naoui & Flah2, Aymen & Moua3, Ben4. (2019). “Wireless Charging System for a Mobile Hybrid Electric Vehicle”. 10.1109/ISAECT.2018.8618829.

[8] Mjaku, M. (2020). Software simulation of residual stresses in high frequency longitudinal welded pipes. Technium: Romanian Journal of Applied Sciences and Technology, 2(4), 87-97. https://doi.org/10.47577/technium.v2i4.882

[9] Purece, C., Vasile Pleșca, & Lilica Corlan. (2020). Technologies for obtaining energy from micro-hydropower resources. Technium: Romanian Journal of Applied Sciences and Technology, 2(4), 124-133. https://doi.org/10.47577/technium.v2i4.837

[10] M.Salih, A., & A. S. Sadiq Mayi, D. (2020). Electrochemical Etching Gold Tips. Technium: Romanian Journal of Applied Sciences and Technology, 2(5), 182-186. https://doi.org/10.47577/technium.v2i5.1316

[11] Wireless charging electric vehicles. https://www.ornl.gov/news/ornl-surges-forward-20-kilowatt-wireless-charging-vehicles