COCHIN UNIVERSITY OF SCIENCE AND TECHNOLOGY

COCHIN UNIVERSITY COLLEGE OF ENGINEERING KUTTANAD, PULINCUNNU

INDUSTRIAL TRAINING REPORT

SUBMITTED BY

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COCHIN UNIVERSITY OF SCIENCE AND TECHNOLOGY

COCHIN UNIVERSITY COLLEGE OF ENGINEERING KUTTANAD, PULINCUNNU

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CERTIFICATE

Certified that this is a bonafide report of the industrial training titled **ELECTRIC VEHICLE INTERNSHIP** submitted by **PRAFUL RAJ** with Register number: **20318525** under the Division of **Electronics and Communication Engineering**, Cochin University College of Engineering Kuttanad, Pulincunnu, Alappuzha in partial fulfilment of the award of the degree of Bachelor of Technology in Electronics and Communication Engineering.

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ACKNOWLEDGEMENT

First I would like to thank **Mr Mayank Arora**, HR, Head, of Skill India (Elite Techno Groups) for giving me the opportunity to do an internship within the organization.

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ABSTRACT

Electric Vehicle first came into existence in the mid-19th century, when electricity was among the preferred methods for motor vehicle propulsion, providing a level of comfort and ease of operation that could not be achieved by the gasoline cars of the time. Internal combustion engines were the dominant propulsion method for cars and trucks for about 100 years, but electric power remained commonplace in other vehicle types, such as trains and smaller vehicles of all types. In the 21st century, EVs have seen a resurgence due to technological developments, and an increased focus on renewable energy and the potential reduction of transportation's impact on climate change and other environmental issues. Project Drawdown describes electric vehicles as one of the 100 best contemporary solutions for addressing climate change. An electric-vehicle battery is a battery used to power the electric motors of a battery electric vehicle (BEV) or hybrid electric vehicle (HEV). These batteries are usually rechargeable batteries, and are typically lithium-ion batteries. These batteries are specifically designed for a high ampere-hour (or kilowatt-hour) capacity. Electric-vehicle batteries differ from starting, lighting, and ignition (SLI) batteries as they are designed to give power over sustained periods of time and are deep-cycle batteries. Batteries for electric vehicles are characterized by their relatively high power-to-weight ratio, specific energy and energy density; smaller, lighter batteries are desirable because they reduce the weight of the vehicle and therefore improve its performance. Compared to liquid fuels, most current battery technologies have much lower specific energy, and this often impacts the maximum all-electric range of the vehicles.

Elite Techno Group is a fast-growing global training and mentoring organization taking students by hand to become industry-ready with project-based learning Internship/ Courses Course Categories. ETG had organized a Skill India Internship aimed to help 5000 engineers by providing free one month internship. Internship covered the technical needs of upcoming Industry Revolution 4.0 – Mechanical Design Internship, Electric Vehicle internship, FEA/CFD Internship, Python for AI/ML Internship. Electric Vehicle Internship focused on cell chemistry, cell selection procedure, electric vehicle architecture and model.

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1. INTRODUCTION

The 1960s and 1970s saw a need for alternative fuelled vehicles to reduce the problems of exhaust emissions from internal combustion engines and to reduce the dependency on imported foreign crude oil. During the years from 1960 to the present, many attempts to produce practical electric vehicles occurred and continue to occur. The purpose of this report is to describe the technology used to produce an electric vehicle and explain why the electric engine is better than the internal combustion engine. It includes reasons why the electric vehicle grew rapidly and the reason it is a necessity to better the world today. The report describes the most important parts in an electric vehicle and hybrid vehicle. It compares the electric to the hybrid and internal combustion engine vehicle. It also includes the future of the electric vehicle. The overall impact of the electric vehicle ultimately benefits the people. Compared to gasoline powered vehicles, electric vehicles are considered to be ninety-seven percent cleaner, producing no tailpipe emissions that can place particulate matter into the air. Particulate matter, carcinogens released into the atmosphere by gas-powered vehicles, “can increase asthma conditions, as well as irritate respiratory systems”. The paper begins with a history of the electric vehicle, specifically the lows and highs of production and the reasons for the change. The next section provides a technical description of an electric vehicle, including the parts, their functions, and the theory of operation. The following section describes the hybrid car, including parts, their functions and the theory of operation.

Figure 1. Hybrid Electric Car Market Annual Sales

Based on this understanding, I then compare the internal combustion engine, the hybrid engine, and the electrical engine in terms of efficiency, speed, acceleration, maintenance, mileage, and cost. The paper concludes with sections on the advantages and disadvantages of the electric vehicle and its future.

“The market for electric cars is sputtering, but the price of the technology is falling”, says Michael Law, an analyst at Needham & Co. Electric vehicles’ annual sales statistics who also supports this prediction.

Fully electric and electric hybrid vehicles potentially introduce new types of post-crash hazards. This paper reviews those potential hazards and provides advice for minimising risks. It is stressed, however, that experience with electric vehicles is limited and that this advice will need to be reviewed as more information becomes available. It is also acknowledged that vehicles manufacturers have put considerable resources into developing safe and reliable electrical systems for the current generation of electric vehicles. A serious incident involving a lithium-ion car battery is considered to be highly unlikely but it is important that crash test organisations and rescue organisations understand and are prepared for the potential hazards.

2. ELECTRIC VEHICLE TECHNOLOGY

Electrically-propelled automobiles have been in use for more than a century: “Stored electricity finds its greatest usefulness in propelling cars and road vehicles, and it has been for this application, primarily, that the Edison storage battery has been developed. Mr Edison saw that there are two viewpoints: that of the electrical man with his instruments, his rules of efficient operation and reasonable life of the battery, his absolute knowledge that the same care should be given a vehicle battery that is given a valued horse or even a railroad locomotive; and that of the automobile driver, who simply wishes to go somewhere with his car, and who, when he arrives somewhere, wishes to go back. And in the long-promised storage battery the highly practical nature of Edison’s work is once more exemplified in that he has held uncompromisingly to the SAFETY PRECAUTIONS AND ASSESSMENTS FOR CRASHES INVOLVING ELECTRIC VEHICLES Michael Paine David Paine Australasian NCAP, Australia James Elway Euro NCAP, Belgium Craig Newland Australian Automobile Association, Australia Stuart Worden New Zealand Land Transport, New Zealand Paper Number 11-0107 Paine, Page 2 auto mobilist’s point of view.” (Scientific American, January 1911) However the popularity of electric vehicles soon declined when electric batteries could not match the price and energy density of petroleum-fuelled vehicles.

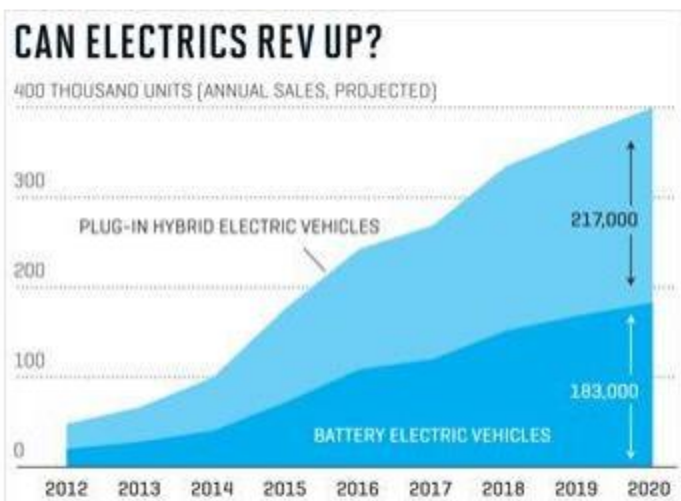


Figure 2. ‘Can Electrics Rev up?’

Electric hybrid vehicles were developed in response to environmental concerns and the desire to reduce fuel consumption for many modes of driving. Most current hybrid models have had Nickel-Metal Hydride (NiMH) storage batteries. Several of these models have been crash-tested by NCAP organisations and no problems associated with the electrical systems have been encountered. Furthermore, rescue organisations have developed procedures for dealing with crashes involving vehicles with NiMH batteries.

Some procedures are model-specific and have been developed in consultation with vehicle manufacturers. More recently lithium-ion (Li-ion) batteries have been increasingly used for electrical storage – particularly in all-electric vehicles. Li-ion batteries are commonly used in laptop computers and they received somewhat negative reputation due to some fires associated with aircraft travel in the late 1990sThe main body may be divided into sections and subsections, appropriately with section numbers.

2.1 Climate Change and Automotive Industry

Climate change and energy security concerns are in our view the primary drivers in the current discussions on CO2 reduction in the automotive industry. Even though it has not been finally proven by scientists, it is widely assumed that global warming is caused by anthropogenic greenhouse gases (GHGs), with CO2 playing the most prominent role. Recent weather phenomena, natural catastrophes and changes in nature are attributed to global warming and thus indirectly to CO2 emissions. In 1997, a variety of countries passed the Kyoto Protocol, setting targets for their CO2 reduction. Even though some countries never ratified the Kyoto Protocol, it is widely accepted as the underlying global standard for expressing a commitment to reduce CO2. Recent studies concluded that the economic impact of climate change in Germany would amount to costs in the region of 800 billion euros by 2050. The need for a global response seems to be the order of the day for both politicians and regulators, thus putting further pressure on the industry. With particular reference to the automotive industry, two major challenges arise: fuel saving and emission reduction ñ two different problems, leading to the same challenge ñ how to make vehicles more efficient, while keeping additional costs at an acceptable level so as to make green vehicles attractive to consumers.

2.2 Electric Vehicle (EV) History

The first electric vehicle (EV) was built between 1832 and 1839, the exact year is not known, in Scotland by Robert Anderson, who created the first crude electric carriage. It was not until 1895, after A.L. Ryker built an electric tricycle and William Morrison built a six passenger wagon, that America paid attention to the electric vehicle. In 1902 Wood created the Electric Phaeton, which was more than an electrified horseless carriage and surrey. “The Phaeton had a range of 18 miles, a top speed of 14 mph and cost $2,000” [2]. The decline in use and production of the electric vehicle occurred in the 1920s. Causes of the decline in production include: a better road system, reduced price of gasoline by the discovery of the Texas crude oil, invention of the electric starter, and the mass production of the internal combustion engine vehicles [2]. According to the History of Electric Vehicles, “In 1912, an electric roadster sold for

$1,750, while a gasoline car sold for $650” By 1935, electric vehicles completely disappeared. In the 1960s and 1970s electric vehicles reappeared because internal combustion vehicles were creating an unhealthy environment for the people in America at that time.

2.3 EV in Indian Market

The Indian Electric Vehicle Market was valued at USD 5 billion in 2020, and it is expected to reach USD 47 billion by 2026, registering a CAGR of above 44% during the forecast period (2021-2026). The Indian Electric Vehicle Market has been impacted by the outbreak of the COVID-19 pandemic due to supply chain disruptions and halt of manufacturing units due to continuous lockdowns and travel restrictions across the county. However, the electric vehicle (EV) market is still in its nascent stage in India. It is expected to grow at a much faster rate during the forecast period due to various government initiatives and policies-commerce companies (Amazon, for example) are launching initiatives to use e-Mobility for last-mile deliveries to reduce carbon footprint. India is experimenting with e-Mobility for public transport, and the country has deployed electric inter-city buses across some major cities. In addition, state governments are also playing an active role in the deployment of policies encouraging the usage of EVs. For instance,Kerala aims to put one million EV units on the road by 2022 and 6,000 e-buses in public transport by 2025.Telangana aims to have EV sales targets for 2025 to achieve 80% 2- and 3-wheelers (motorcycles, scooters, auto-rickshaws), 70% commercial cars (ride-hailing companies, such as Ola and Uber), 40% buses, 30% private cars, and 15% electrification of all vehicles. The EV market in India has gained significant momentum after the implementation of the FAME India scheme with its aim of shifting toward e-mobility in the wake of growing international policy commitments and environmental challenges. Moreover, India offers the world’s largest untapped market, especially in the electric two-wheeler segment. As 100% foreign direct investment is allowed in this sector, the automatic route market is expected to gain momentum during the forecast period.

2.4 EV Architecture

The electric vehicle (EV) is propelled by an electric motor, powered by rechargeable battery packs, rather than a gasoline engine. From the outside, the vehicle does not appear to be electric. In most cases, electric cars are created by converting a gasoline-powered car. Often, the only thing that clues the vehicle is electric is the fact that it is nearly silent [5]. Under the hood, the electric car has:

- An electric motor.
- A controller.
- A rechargeable battery.

The electric motor gets its power from a controller and the controller gets its power from a rechargeable battery. The electric vehicle operates on an electric/current principle. It uses a battery pack (batteries) to provide power for the electric motor. The motor then uses the power (voltage) received from the batteries to rotate a transmission and the transmission turns the wheels [3]. Four main parts make up the electric vehicle: the potentiometer, batteries, direct current (DC) controller, and motor. See Figure Below.

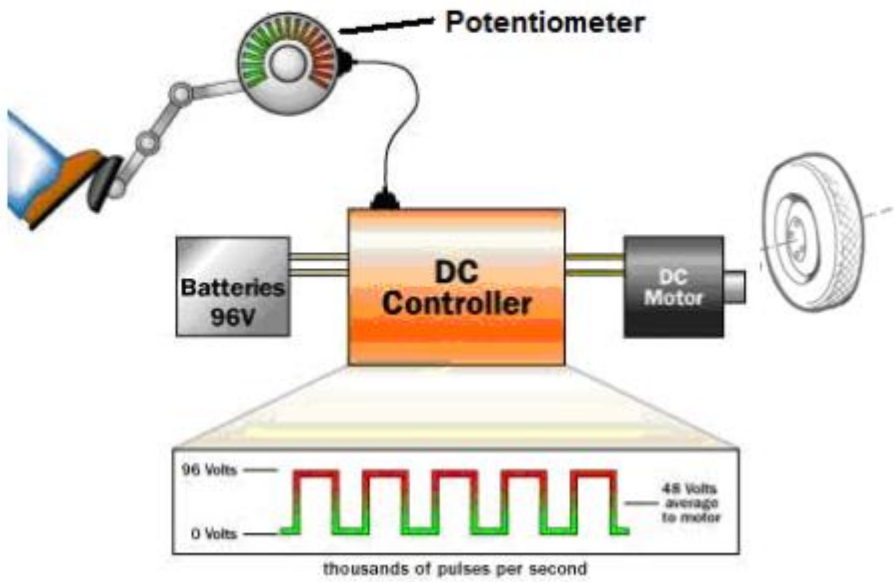


Figure 3. Parts of an electric vehicle

2.4.1 Description of Parts and their Functions

Potentiometer: It is circular in shape and it is hooked to the accelerator pedal. The potentiometer, also called the variable resistor, provides the signal that tells the controller how much power is it supposed to deliver.

Batteries: The batteries provide power for the controller. Three types of batteries: leadacid, lithium ion, and nickel-metal hydride batteries. Batteries range in voltage (power).

DC Controller: The controller takes power from the batteries and delivers it to the motor. The controller can deliver zero power (when the car is stopped), full power (when the driver floors the accelerator pedal), or any power level in between. If the battery pack contains twelve 12-volt batteries, wired in series to create 144 volts, the controller takes in 144 volts direct current, and delivers it to the motor in a controlled way [3]. The controller reads the setting of the accelerator pedal from the two potentiometers and regulates the power accordingly. If the accelerator pedal is 25 percent of the way down, the controller pulses the power so it is on 25 percent of the time and off 75 percent of the time. If the signals of both potentiometers are not equal, the controller will not operate .

Motor: The motor receives power from the controller and turns a transmission. The transmission then turns the wheels, causing the vehicle to run.

2.5 Introduction to Batteries

The fundamental piece of any electric vehicle (EV) is its battery. The battery must be designed to satisfy the requirements of the motor(s) and charging system that a vehicle utilizes. This includes physical constraints such as efficient packaging within the vehicle's body to maximize capacity. As the main contributor to weight in an EV, designers must also consider the battery's placement within a vehicle as they can affect power efficiency and vehicle handling characteristics (which is typically why you'll often see batteries placed under the floor pan of the vehicle). An electric vehicle battery is often composed of many hundreds of small, individual cells arranged in a series/parallel configuration to achieve the desired voltage and capacity in the final pack. A common pack is composed of blocks of 18-30 parallel cells in series to achieve a desired voltage. For example, a 400V nominal pack will often have around 96 series blocks (as in the Tesla Model 3). Common nominal pack voltages in current vehicles range from 100V-200V for hybrid/plug-in hybrid vehicles and 400V to 800V and higher for electric-only vehicles. The reason for this is higher voltages allow more power to be transferred with less loss over the same diameter (and mass) of copper cable.

2.5.1 Battery Parameters

Life Span: Various factors influence the life cycle of a battery. You could give EV batteries a life cycle of 8 years or 160,000 km. Some factors before picking your pick would be: The purpose of the battery, Operating conditions, The depth of battery discharge, but you can generally estimate EV battery life as 8 years or 160,000 km (100,000 miles).

Safety: Driving an EV takes a lot of power, which is why it must be managed properly. A carefully designed battery management system (BMS) assures safe operation.

Cost: Compared to ICE vehicles this is a disadvantage for EV's. The cost of a small ICE vehicle and an EV battery system is pretty much the same.

2.5.2 Battery Characteristics

1. Voltage of a battery: The terminal EMF provided by a battery is known as it's voltage. the Voltage of a battery depends upon various other characteristics of the batteries like cell-chemistry , internal impedance etc. The average Voltage of a lead acid cell is 2.0 V , but it depends on various other factors like Specific gravity of electrolyte , temperature, time between the measurement and last charge etc. The Voltage or EMF of a cell depends upon the composition and type of electrolyte used in it. For lead acid cells the EMF increases with the increase in specific gravity of the electrolyte. The EMF of a lead acid cell also increases slightly with the increase in temperate.

2. Capacity of a Battery: The capacity of a cell or a battery is essentially the number of atoms or the amount of current or electrical energy that can be obtained from a cell/battery after it is fully charged.

The Capacity of a cell is expressed in Ampere-hour because it is the integration of the current supplied by the cell over time. A rated capacity of 10-AH of a cell means that if a current equal to one ampere is drawn from the battery then it will last for 10 hours before it gets discharged.
The capacity of a cell depends upon various factors among which the important ones are Plate Surface Area, quantity arrangement and porosity of active materials, quality of electrolyte etc.

3. Efficiency of a Battery: Efficiency of a battery is the ratio of the energy provided by the battery/cell or output energy while in use over the energy used by the battery/sell to get charged or input energy expressed in percentage. The efficiency of a battery or cell can be calculated using the following formula:

Efficiency = $\frac{Output Watt - Hours}{Input Watt - Hours} \times 100$

Ratings of a Battery:

Battery ratings are the ratings provided with a battery which defines the characteristics and quality of a battery. Some of the popularly used battery ratings are:

1. Ampere-Hour Capacity Rating:

The Ampere-hour rating of a battery is determined from a test in which a battery is continuously discharged at a constant current rate for 20 hours at 27 degree Celsius of temperature. For example if a battery was able to continuously provide 5 A of current for 20 hours then the battery is rated 100 AH. The more the Ampere-Hour rating of a battery is; the more power it can accumulate and provide.

2. Reserve Capacity:

The reserve capacity of a battery is usually indicated in terms of minutes. It is the number of minutes a battery is capable of providing a large current of 25 A , without dropping it's EMF to 1.75 V per cell. The higher Reserve Capacity rating indicates a better battery.

3. Cold Rating:

The Cold rating of a battery is also indicated in term of minutes. It is the number of minutes a battery can deliver a current of 300 Amps at -18 degree Celsius temperature.

4. Cold Cranking Power Rating:

The rating is applicable to all 12 volts batteries irrespective of their size. It is expressed in terms of the ampere. It is the maximum current a battery is able to supply for 30 seconds after continuously discharging it at -18 degree Celsius till it's EMF drops to 7.2 Volts.

2.5.3 Types of EV Batteries

Electric car batteries are different from SLI batteries (starting, lightning and ignition). SLI batteries are batteries that are usually installed in gasoline or diesel cars. This type of electric cars battery is designed as an energy storage system, capable of delivering power for long and sustainable periods.

There are 5 types of electric vehicle batteries to be discussed in this article:

- Lithium-Ion (Li-On)
- Nickel-Metal Hybrid (NiMH)
- Lead Acid (SLA)
- Ultracapacitor
- ZEBRA (Zero Emissions Batteries Research Activity)

2.5.4 Lithium-Ion Vehicle Batteries

Li-ion vehicle batteries are much more sophisticated than laptop computer batteries. There are numerous levels of automatically isolating stored electrical energy and they have inbuilt cooling systems to prevent heat build-up under most foreseeable circumstances. Severe testing of Li-ion car batteries has been conducted: Sandia National Laboratories' Battery Abuse Testing Laboratory, which has become the de facto automotive battery-testing shop in the U.S. The lab heats, shocks, punctures and crushes batteries to see how safe they would be in crashes and extreme operating conditions. When lithium-ion cells first came to the laptop market, "the active materials were very energetic. There were some significant field failures," notes Chris Orndorff, the battery lab's team leader. The usual cause was thermal runaway, a chemical reaction that could start from excessive overheating, then potentially cause a cell to catch fire or explode. Although even extreme driving conditions are unlikely to trigger those problems, a crash could, and so could a sudden overcharge - for example, if lightning struck a charging port while a car was being recharged.

2.5.5 Modelling in Simulink for Battery Parameters

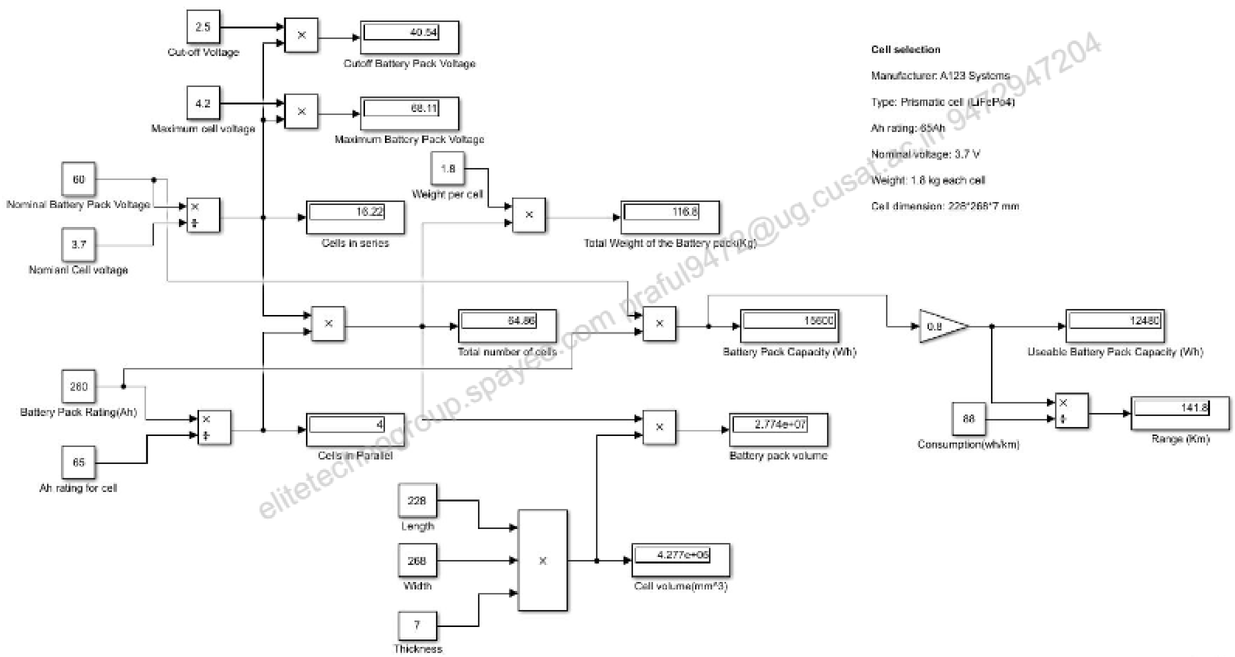
Battery models have become an indispensable tool for the design of battery-powered systems. Their uses include battery characterization, state-of-charge (SOC) and state-of-health (SOH) estimation, algorithm development, system-level optimization, and real-time simulation for battery management system design.

Battery models based on equivalent circuits are preferred for system-level development and controls applications due to their relative simplicity. Engineers use equivalent circuits to model the thermo-electric behavior of batteries, parameterizing their nonlinear elements with correlation techniques that combine models and experimental measurements via optimization

Problem Statement:

Simulate Mahindra's Electric Vehicle E2o Plus(P2 variant).Power =19KW@3500 RPM(Nominal Power=14kW).It uses 3 phase AC induction motor (60 Volt system).88 Wh/km energy consumption.

Simulation



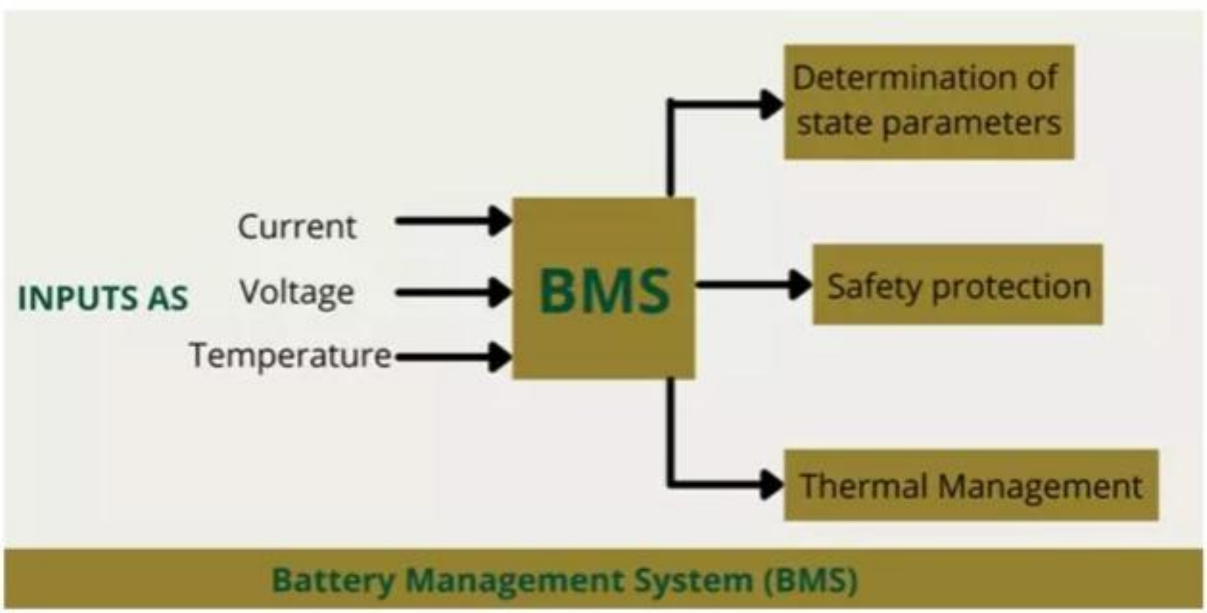
Comparing the Results

	Mahindra E2O (P2 Variant)	Values from Model
Cells In series	16	16.22~ 16
Cells in parallel	4	4
Total N.o of cells	64	64
Battery Pack Rating	280 Ah	260 Ah
Pack Capacity	15 Kwh	15.6 kwh
Weight	112 kg	116 kg
Range	140 km	141.8 km

2.5.6 Battery pack Monitoring

Rechargeable batteries are used to deliver power to the auxiliary systems and motors in electric vehicle applications. Among all rechargeable batteries, Lithium-Ion Batteries will give high efficiency for electric mobility because Li-Ion batteries have a low self-discharge rate, wide operating range, maximum energy density, and high life cycle. To improve the quality of battery and safe operation, a Battery Management System (BMS) is employed and it plays a vital role in the application of Electric Mobility. To prevent battery failure and mitigate potential hazardous situations, there is a need for a supervising system that ensures that batteries function properly in the final application. This supervising system is referred to as a Battery Management System (BMS). For the management of the batteries during electric vehicle operation, to achieve the best performance and prolong battery life, it is necessary to monitor various states inside the battery depending on the battery management system (BMS) in real-time. These states include state of health (SoH), state-of-charge (SoC), state-of-function (SoF), charge acceptance (CA), etc. While there is no unique definition of a BMS, it should be designed with a minimal set of requirements Such as-

- It must measure individual cell voltages
- The BMS must measure temperatures at different points as close as possible to the battery
- It must measure currents flowing through it
- The BMS should communicate information to control units and undertake action to ensure the battery will be operated within safety limits
- The BMS should balance battery cells passively or actively
- And, the BMS should provide thermal management



Battery State Parameters

2.5.7 Crashes that might challenge Battery Integrity

ANCAP and Euro NCAP have conducted 64km/h offset crash tests of the Mitsubishi i-MiEV electric car. No problems with the battery or high-voltage electrical system were encountered in either crash test and the automatic safety systems operated as designed. In the ANCAP tests (conducted at JARI in Japan) the peak vehicle body deceleration was 38g, measured at the base of the driver-side B-pillar. This deceleration is typical for a small car in this type of crash test (Paine 2009). Euro NCAP also conducted a 29km/h pole test of the iMiEV. Again no problems with the battery or high voltage electrical system were encountered. However, Figure 7 illustrates that the vehicle body deformation came close to the exterior of the battery pack, which is mounted under the rear floor.

2.6 Theory of Operation for EV

When the driver steps on the pedal the potentiometer activates and provides the signal that tells the controller how much power it is supposed to deliver. There are two potentiometers for safety. The controller reads the setting of the accelerator pedal from the potentiometers, regulates the power accordingly, takes the power from the batteries and delivers it to the motor. The motor receives the power (voltage) from the controller and uses this power to rotate the transmission. The transmission then turns the wheels and causes the car to move forward or backward.

If the driver floors the accelerator pedal, the controller delivers the full battery voltage to the motor. If the driver takes his/her foot off the accelerator, the controller delivers zero volts to the motor. For any setting in between, the controller chops the battery voltage, thousands of times per second to create an average voltage somewhere between 0 and full battery pack voltage.

2.7 Description of a Hybrid Vehicle

The hybrid vehicle (HV) is powered by both a gasoline engine and electric motor. The HV runs using power from an internal combustion engine and electric motor. The engine provides most of the vehicle’s power, and the electric motor provides additional power when needed, such as accelerating and passing. The hybrid vehicle operates on a gasoline and electric energy principle. A hybrid car features a small fuel-efficient gas engine combined with an electric motor that assists the engine when accelerating. The electric motor is powered by batteries that recharge automatically while you drive. Five main parts make up the hybrid vehicle: the battery, internal combustion engine (ICE), generator, power split device, and electric motor. See Figure 3.

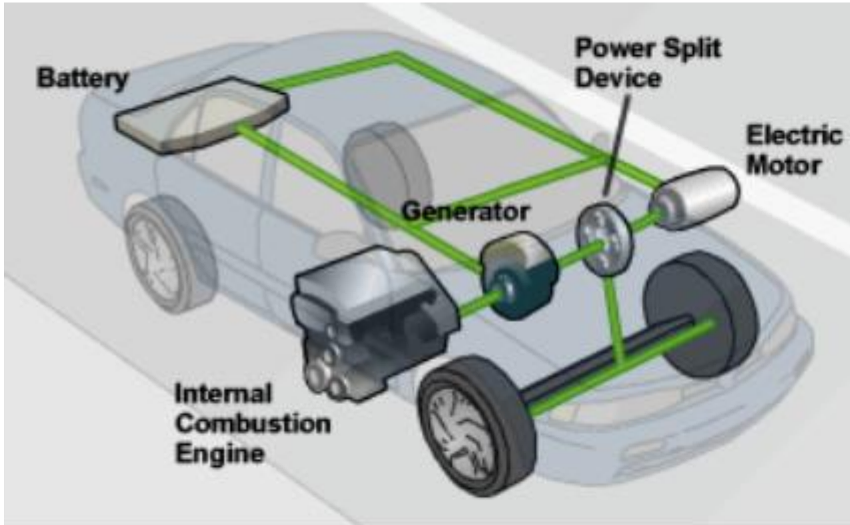


Figure 4. Parts of a hybrid vehicle

2.7.1 Description of Parts and their Functions

Battery: The batteries in a hybrid car are the energy storage device for the electric motor. Unlike the gasoline in the fuel tank, which can only power the gasoline engine, the electric motor on a hybrid car can put energy into the batteries as well as draw energy from them.

Internal Combustion Engine (ICE): The hybrid car has an ICE, also known as a gasoline engine, much like the ones found on most cars. However, the engine on a hybrid is smaller and uses advanced technologies to reduce emissions and increase efficiency. Receives its energy from the fuel tank where the gasoline is stored.

Generator: The generator is similar to an electric motor, but it acts only to produce electrical power for the battery.

Power Split Device: The power-split-device resides between the two motors and together with the two motors creates a type of continuously variable transmission.

Electric Motor: The electric motor on a hybrid car acts as a motor as well as a generator. For example, when needed, it takes energy from the batteries to accelerate the car. But acting as a generator, it slows the car down and returns energy to the batteries.

2.7.2 Theory of Operation for Hybrid

When the driver steps on the pedal the generator converts energy from the engine into electricity and stores it in the battery. The battery then provides power to the electric motor. The internal combustion engine and electric motor work simultaneously and each provide power to the power split device. The power split device combines both powers and uses it to turn the transmission. The transmission then turns the wheels and propels the vehicle.

The energy used when braking is converted into electricity and stored in the battery. When braking, the electric motor is reversed so that, instead of using electricity to turn the wheels, the rotating wheels turn the motor and create electricity. Using energy from the wheels to turn the motor slows the vehicle down. When the vehicle is stopped, the gasoline engine and electric motor shut off automatically so that energy is not wasted in idling. The battery continues to power auxiliary systems, such as the air conditioning and dashboard displays.

2.8 Comparison of Combustion Engine, Hybrid and Electric

Now that there is an established concept of how the internal combustion engine, hybrid, and electric vehicle function, their efficiency, speed, acceleration, maintenance, mileage and cost are compared in Table 1. The following abbreviations are used: ICE (internal combustion engine), HV (hybrid vehicle), and EV (electric vehicle).

	ICE	HV	EV
Efficiency	Converts 20% of the energy stored in gasoline to power the vehicle.	Converts 40%, of the energy stored in gasoline to power the vehicle.	Converts 75% of the chemical energy from the batteries to power the wheels [5].
Speed (average top speed)	124 miles per hour (mph)	110 mph	30-95 mph [6]

Acceleration (on average)	0-60 mph in 8.4 seconds	0-60 mph in 6-7 seconds	0-60 mph in 4-6 seconds [6]
Maintenance	• Wheels/tires • Engine • Fuel/gas • Bodywork/paint • Electrical • Lights • Dash/instrument warning lights	Same as ICE.	Does not require as much maintenance because it does not use a gasoline engine. No requirements to take it to the Department of Environmental Quality for an emissions inspection [1].
Mileage	Can go over 300 miles before refueling. Typically get 19.8 miles per gallon (mpg).	Typically get 48 to 60 mpg.	Can only go about 100 to 200 miles before recharging [5].
Cost (on average)	$14,000 to $17,000.	$19,000 to $25,000.	Extensive range, $6,000 to $100,000 [6].

Table 1: Comparison between the ICE, HV, and EV

2.9 Advantages and Disadvantages of the EV

The greatest challenge EVs face deal with the rechargeable battery. Most EVs can only go about 100–200 miles before recharging; fully recharging the battery pack can take four to eight hours. Battery packs are heavy, expensive, may need to be replaced, and take up considerable vehicle space. Overall, the electric vehicle has more advantages than disadvantages. Advantages include no tailpipe emissions, which leads to a reduction in global warming and unhealthy people. Table summarizes the advantages and disadvantages of the EV.

Advantages	Disadvantages
Fuel can be harnessed from any source of electricity, which is available in most homes and businesses.	Limited in the distance that can be driven before the complete failure of the battery.
It reduces hydrocarbon and carbon monoxide, responsible for many environmental problems, by 98%.	Accessories, such as air conditioning and radios drain the battery.
Also reduces pollution.	Heavier car due to the electric motors, batteries, chargers, and controllers.

Does not produce emissions. Important in urban cities, where cleaner air is much needed.	More expensive because of cost of the parts.

TABLE 2: Advantages and Disadvantages of the EV

Emissions

Compared to gasoline powered vehicles, electric vehicles are considered to be ninety-seven percent cleaner, producing no tailpipe emissions that can place particulate matter into the air.

Global Warming: Ozone Layer

The process of carbon dioxide emitted into the atmosphere, also known as global warming, diminishes the Earth's ozone layer, which is what occurs at this time. A factor that makes electric vehicles clean is their ability to use half the number of parts a gasoline powered vehicle does, including gasoline and oil.

2.10 Future of the EV

Future electric cars will most likely carry lithium-ion phosphate (LiFePO4) batteries that are now becoming popular in other countries. The LiFePO4 batteries are rechargeable and powerful and are being used in electric bikes and scooters. Electric cars will most likely adopt this technology in the future.

Another technology that is likely for future electric cars is the increased use of supercapacitors and ultracapacitors for storing and delivering electrical charge. Many of these batteries are currently being used in conjunction with hybrid car prototypes, so these are expected in the electric car future markets as well.

If the developers of future electric cars can create vehicles with a range of 300 miles per charge, a charging time of five to ten minutes, and safety in operating the vehicles, the market is wide open for them. Researchers are working on improved battery technologies to increase driving range and decrease recharging time, weight, and cost. These factors will ultimately determine the future of EVs.

3. CONCLUSION

As part of this Electric Vehicle internship, a research-based project on EV market survey and a simulation based project had been done successfully which helped to gain more knowledge regarding the EV field . As seen in this report, the electric vehicle has many advantages and benefits over the internal combustion engine and hybrid vehicle. It is cleaner and much more efficient; however, it also has disadvantages. It is heavier, limited to the distance it can travel before recharge, and costs more. The future of the EV relies on its battery. If researchers can produce or find the “super battery”, the EV’s future is promising. As of today, each vehicle has its own characteristic that makes it better than the other. Only time and technological improvements will tell which vehicle will excel in the future. Automakers are preparing to phase out cars powered solely by internal combustion engines (ICEs) as governments look to tackle fuel emissions. The growth in electric vehicles (EVs) and hybrid electric vehicles (HEVs) is climbing and by 2025, EVs and HEVs will account for an estimated 30% of all vehicle sales. Comparatively, in 2016 just under 1 million vehicles or 1% of global auto sales came from plug-in electric vehicles (PEVs).By 2025, J.P. Morgan estimates this will rise close to 8.4 million vehicles or a 7.7% market share. While this jump is significant, it doesn’t compare to the kind of growth expected in HEVs - cars that combine a fuel engine with electric elements. This sector is forecast to swell from just 3% of global market share to more than 25 million vehicles or 23% of global sales over the same period.[1] This leaves pure-ICE vehicles with around 70% of the market share in 2025, with this falling to around 40% by 2030, predominantly in emerging markets.

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