ELECTRICAL ARCHITECTURE OF AN ELECTRIC CAR

A PROJECT REPORT

Submitted by;

NAVANEETH VISOKAN

SCM16AU030

In partial fulfillment for the award of the degree
Of

BACHELOR OF TECHNOLOGY

In

AUTOMOBILE ENGINEERING

SCMS SCHOOL OF ENGINEERING AND TECHNOLOGY

VIDYA NAGAR, KARUKUTTY, ERNAKULAM – 683576

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BONAFIDE CERTIFICATE

This is to certify that the Project titled "ELECTRICAL ARCHITECTURE OF ELECTRIC VEHICLE" was prepared and presented by "NAVANEETH VISOKAN" with register no. "SCM16AU030" of eight semester Automobile Engineering in partial fulfillment for the award of the degree of Bachelor of Technology in Automobile Engineering under the APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY during the year 2020.

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NAVANEETH VISOKAN

ABSTRACT

The world is now running towards efficiency along with a care to our mother nature. In case of automobile it is evident that era of polluting IC engines is about to end in next few decades. The future is going to be “Electric mobility”. We can’t just bring in electric mobility just overnight, and technologies haven’t had much technological revolution in field of EV yet and haven’t become accessible yet.

It is very important to an automobile engineer to focus on EV field to ensure a promising future. India is one of the biggest automobile markets in the world. But EV giant like TESLA hasn’t even hit Indian market yet. Also, it’s an upper hand for anyone who came up with a better technology in EV. So, most of existing company’s in India didn’t reveal their works or allow public to access their data. So be a part of their work either as an intern or as an employee is a hectic task.

So we have decided to take an existing EV and explore its mechanisms. Knowledge from own experience always stays and enable us to grasp more information easily. As a part of our plan we purchased **MAHINDRA REVA-i** vehicle. As a team we had divided into various sub groups and concentrated on specific sections of the vehicle. My team had chosen **ELECTRICALS SECTION** as our field and had done efforts to make it as a cut- section model so as to make it useful for others too. Our works and Inferences are followed in this report.

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CHAPTER 1

INTRODUCTION

An electric car is one that operates on an electric motor, instead of an internal-combustion engine that generates power by burning a mix of fuel and gases. Therefore, such as vehicle is seen as a possible replacement for current-generation automobile, in order to address the issue of rising pollution, global warming, depleting natural resources, etc. Though the concept of electric vehicles has been around for a long time, it has drawn a considerable amount of interest in the past decade amid a rising carbon footprint and other environmental impacts of fuel-based vehicles.

Electric motive power started in 1827, when Hungarian priest Anyos Jedlik built the first crude but viable electric motor, provided with stator, rotor and commutator, and the year after he used it to power a tiny car. A few years later, in 1835, professor Sibrandus Stratingh of the University of Groningen, the Netherlands, built a small-scale electric car, and between 1832 and 1839 (the exact year is uncertain). Robert Anderson of Scotland invented the first crude electric carriage, powered by non-rechargeable primary cells. Around the same period, early experimental electrical cars were moving on rails, too. American blacksmith and inventor Thomas Davenport built a toy electric locomotive, powered by a primitive electric motor, in 1835. In 1838, a Scotsman named Robert Davidson built an electric locomotive that attained a speed of four miles per hour (6 km/h). In England a patent was granted in 1840 for the use of rails as conductors of electric current, and similar American patents were issued to Lilley and Colten in 1847.

The first mass-produced electric vehicles appeared in America in the early 1900s. In 1902, "Studebaker Automobile Company" entered the automotive business with electric vehicles, though it also entered the gasoline vehicles market in 1904. However, with the advent of cheap assembly line cars by Ford, electric cars fell to the wayside

Due to the limitations of storage batteries at that time, electric cars did not gain much popularity, however electric trains gained immense popularity due to their economies and fast speeds achievable. By the 20th century, electric rail transport became commonplace due to advances in the development of electric locomotives. Over time their general-purpose commercial use reduced to specialist roles, as platform trucks, forklift trucks, ambulances, tow tractors and urban delivery vehicles, such as the iconic British milk float; for most of the 20th century, the UK was the world's largest user of electric road vehicles.

During the last few decades, environmental impact of the petroleum-based transportation infrastructure, along with the fear of peak oil, has led to renewed interest in an electric transportation infrastructure. EVs differ from fossil fuel-powered vehicles in that the electricity they consume can be generated from a wide range of sources, including fossil fuels, nuclear power, and renewable sources such as tidal power, solar power, hydropower, and wind power or any combination of those. The carbon footprint and other emissions of electric vehicles varies depending on the fuel and technology used for electricity generation. The electricity may then be stored on board the vehicle using a battery, flywheel, or supercapacitors. Vehicles making use of engines working on the principle of combustion can usually only derive their energy from a single or a few sources, usually non-renewable fossil fuels. A key advantage of hybrid or plug-in electric vehicles is regenerative braking, which recovers kinetic energy, typically lost during friction braking as heat, as electricity restored to the on-board battery.

1.1 Need for an Electric car

Plug-in electric vehicles (also known as electric cars or EVs) are connected, fun, and practical. They can reduce emissions and even save money.

Fuelling with electricity offers some advantages not available in conventional internal combustion engine vehicles. Because electric motors react quickly, EVs are very responsive and have very good torque. EVs are often more digitally connected than conventional vehicles, with many EV charging stations providing the option to control charging from a smartphone app.

Just like a smartphone, you can plug in your EV when you get home and have it ready for you to use the next morning. Since the electric grid is available almost anywhere, there are a variety of options for charging: at home, at work or on the road. By charging often, you may never need to go to a gas station again!

But EVs provide more than just individual benefits. EVs can help the United States have a greater diversity of fuel choices available for transportation. The U.S. used nearly nine billion barrels of petroleum last year, two-thirds of which went towards transportation. Our reliance on petroleum makes us vulnerable to price spikes and supply disruptions. EVs help reduce this threat because almost all U.S. electricity is produced from domestic sources, including coal, nuclear, natural gas, and renewable sources.

EVs can also reduce the emissions that contribute to climate change and smog, improving public health and reducing ecological damage. Charging your EV on renewable energy such as solar or wind minimizes these emissions even more. See the difference in emissions between a conventional vehicle and an EV using the calculator on the right. Learn more about how EV’s reduce pollution and there lifecycle emissions.

There are two general categories of vehicle emissions: **direct** and **life cycle**.

Direct emissions are emitted through the tailpipe, through evaporation from the fuel system, and during the fuelling process. Direct emissions include smog-forming pollutants (such as nitrogen oxides), other pollutants harmful to human health, and greenhouse gases (GHGs), primarily carbon dioxide. All-electric vehicles produce zero direct emissions, which specifically helps improve air quality in urban areas. Plug-in hybrid electric vehicles (PHEVs), which have a gasoline engine in addition to an electric motor, produce evaporative emissions from the fuel system as well as tailpipe emissions when operating on gasoline. However, because most PHEVs are more efficient than comparable conventional vehicles, they still produce fewer tailpipe emissions even when relying on gasoline.

1.2 Primary components of an electric vehicle

An electric powered car has three primary components. These are the electric engine, motor controller, and battery.

1.2.1 Battery

The battery of an electric car can be charged through the use of ordinary grid electricity at a specialized power station. But aside from the conventional lithium-ion battery technologies, there are also other major battery technologies which can be used for electric cars.

- Lithium-Ion Batteries: This battery technology gives extra performance and range. However, it also carries the highest price tag. Lithium-ion batteries are lighter than Lead acid and Nickel metal. These are also the batteries used in digital cameras and smartphones.

- Lead Acid Batteries: This battery technology is the most popular. It is also the cheapest among the battery technologies. What's good about it is it's 97% recyclable.
- Nickel Metal Hydride Batteries: This battery technology provides higher output and better performance but it costs much more than lead-acid batteries.

1.2.2 Motor Controller

The motor controller of an electric car administers its complete operation and the distribution of its power at any given moment. It acts as a floodgate between the motor and batteries. It helps monitor and regulates all key performance indications such as the vehicle's operator, motor, battery, and accelerator pedal. It has a microprocessor which can limit or redirect current. It is used to either improve the mechanical performance of the car or suit the operator's driving style. There are also more refined controllers which are capable of greater accuracy and thus, higher efficiency.

1.2.3 Electric Engine

Unlike a gasoline engine with lots of moving parts, an electric engine or motor only has one moving part. This makes it a very reliable source of motive power. Choosing an electric engine depends on your car's system voltage. They can be structured to use either AC or DC current. AC motors are less expensive and lighter compared to DC engines. They are also more common and they tend to suffer from less mechanical wear and tear. However, AC technology requires a more refined or sophisticated motor controller.

1.3 India is going electric

Electric vehicles promise zero tailpipe emissions and a reduction in air pollution in cities. The Indian government has created momentum through its Faster

Adoption and Manufacturing of (Hybrid &) Electric Vehicles schemes that encourage, and in some segments mandates the adoption of electric vehicles (EV), with a goal of reaching 30% EV penetration by 2030. The scheme creates demand incentives for EV and urges the deployment of charging technologies and stations in urban centres. If these aims are realised by 2030, they will generate an estimated saving of up to 474 Millions of tonnes of oil equivalent (Mtoe) and 846 million tonnes of net CO2 emissions over their lifetime.

Various fiscal demand incentives have been put in place to spur the production and consumption of EVs and charging infrastructure - such as income tax rebates of up to INR150,000 ($2,100) for customers on interest paid on loans to buy EVs. To scale production of lithium-ion cell batteries, there will be an exemption from customs duties to bring down their cost.

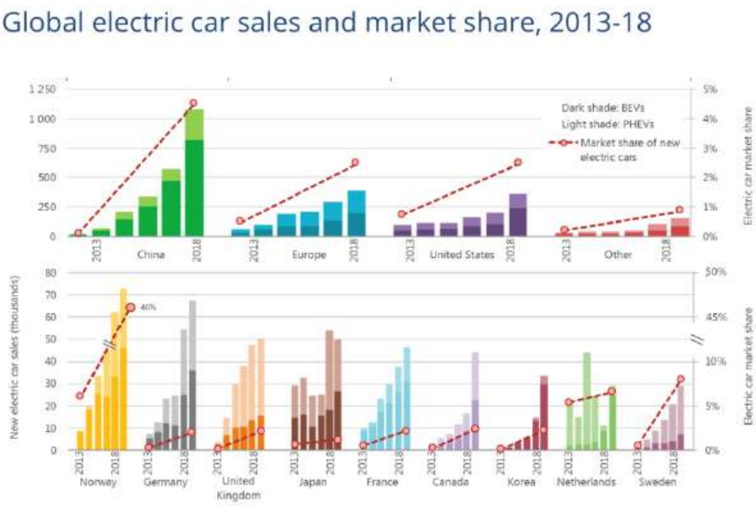


Figure 1: sales of electric vehicles

Assuming the appropriate infrastructure is in place, 90% car owners in India are willing to switch to EVs, according to a survey by the Economic Times in May 2019. At present, however, EV market penetration is only 1% of total vehicle sales in India, and of that, 95% of sales are electric two-wheelers.

The automotive industry players and charging infrastructure, batteries and mobility service providers have taken various actions to ramp up industry action. Companies are designing and testing products suitable for the Indian market with a key focus on two-wheelers and three-wheelers. Ola, an Indian taxi company, has launched “Mission: Electric” to integrate 10,000 e-rickshaws and electric auto-rickshaws into its fleet. Car manufacturer Mahindra and Mahindra is investing INR18 billion over the next three years into EV production to ramp up its four-wheeler production. Other manufacturers are forging partnerships with states to augment their public transport systems. Some of the lightweight motor vehicles manufacturers such as Hero Motorcorporation.

CHAPTER 2

ELECTRIC VS GASOLINE

A gas powered car has a fuel tank, which supplies gasoline to the engine. The engine then turns a transmission, which turns the wheels and an electric car on the other hand has a set of batteries that provides electricity to an electric motor. The motor turns a transmission, and the transmission turns the wheels.

To be useful to you or me, a car must meet certain minimum requirements. The car should be able to:

- Drive at least 300 miles (482 km) before re-fuelling
- Be refuelled quickly and easily
- Keep up with the other traffic on the road

A gasoline car meets these requirements but produces a relatively large amount of pollution and generally gets poor gas mileage. An electric car, however, produces almost no pollution, but it can only go 50 to 100 miles (80 to 161 km) between charges. And the problem has been that the electric car is very slow and inconvenient to recharge.

	Electric car (e2o plus)	Petrol car
Mileage	120km	620km (approx.)
Energy Consumption	12 units	40L
Energy Usage	0.10 unit	3.125L /day
Cost	Rs 7.30 per unit for 400 to 800 units	Rs 72.25 /L
Cost per km	0.73 paisa	Rs 5.140
One day expenditure (50 km average travel)	Rs 36.50	Rs 257.03
Monthly expenditure (25 days travel)	Rs 912.5	Rs 6425

2.1 Internal Combustion Cars

- More bang: Petrochemicals are controlled explosions that deliver a large force for a small amount of fuel and subsequently less weight in comparison to current batteries. There is less inertia to overcome when accelerating.
- Wasted energy: There is no way to apply the vehicle’s latent momentum back into a force that can be reutilized to further accelerate without adding significant weight to the vehicle defeating the advantages of that regeneration.
- Mass distribution and wasted weight: Two large mass centres: the fuel tank and engine. A heavy drive train and chassis are required to support these mass structures.
- Air pollution: ICVs exhaust a mixture of gases and ions that cause harm to the environment and in sufficient concentrations harm to humans directly.
- Refuelling: Refuelling can be achieved quickly as we have constructed an industry around providing fuel to these vehicles at various places of convenience.
- Hazardous chemical risk: Petrol stations are an environmental risk and a safety hazard requiring bulk storage of explosive toxic fuels.
- Range: Petrol fuelled vehicles have a range of 400 – 600km.

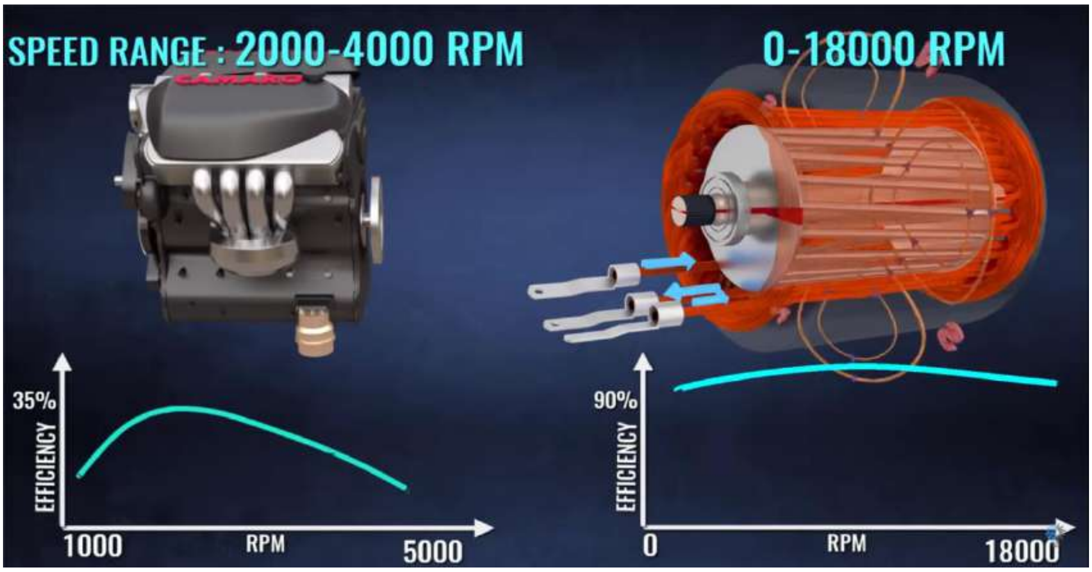


Figure 2: Efficiency of ICE vs EV

2.2 Battery Electric Cars

- Mass distribution: Wheels can be driven directly with a motor at each wheel or the wheel can be the motor. The advantages of smaller masses at motor locations, where maximum force is required, allow for more freedom of design, lower centres of gravity and better handling opportunities. Flexibility in weight distribution also allows for more safety features to be built into the overall design.
- Energy conservation: Power can be regenerated using the vehicle's latent momentum during braking.
- Refuelling depots: Refuelling depots can be set up almost anywhere at low cost and can be easily utilized without the need for monitoring.
- Induction recharging: Vehicles can simply be parked over induction pads or even recharged on the move. No hazardous chemical storage required.
- Car mass: Most of the weight will be in the battery with better more efficient batteries currently being developed.
- More space in the interior: Without the two large masses present in ICVs, different designs can be constructed to utilize the space more effectively.

- Solar panelling: If stranded in remote areas, solar panels mounted in the car body allow for the vehicle to be recharged.
- Vehicle emissions: There are no gas emissions and low noise emissions in a BEV.

Figure 3: Fuel cost of ICE and EV over 50 years

CHAPTER 3

TYPES OF ELECTRIC CAR

The three electric vehicle types are

1. Zero emission 100% electric vehicles
2. Plug in hybrid vehicles
3. Hydrogen fuel cell vehicles

3.1 Zero emission 100% electric vehicles

100% electric vehicles produce zero emissions which means that they do not emit any harmful CO_2 or other greenhouse gasses into the atmosphere while driving. They are the cleanest cars on road and are generally powered entirely by rechargeable electric battery. Owners can charge their 100% electric vehicles either at home using a specially designed car charging unit or at one among the publicly available charging stations throughout the city.

Businesses are also increasingly turning to fully electric vehicles as a cost efficient alternative. They are reliable, easy to run and fun to drive with a wide range of options to suit every type of budget.

3.2 Plug in hybrid vehicles

A plug in hybrid pairs a battery and electric motor with an economical petrol or diesel engine. This gives you around 20 or 30 miles of pure electric driving for the city plus hundreds of miles using the petrol or diesel engine.

3.3 Hydrogen fuel cell vehicles

Hydrogen cell vehicles are one of an advanced EVs that are powered by an electrochemical process which combines hydrogen and oxygen. This process happens in an intelligent fuel stack which fuses highly pressured hydrogen gas with oxygen, thereby creating a reaction that produces the electricity required to power the vehicle’s motor and drive its wheels. This process means the only exhaust it produces is water.Because hydrogen fuel cell cars are powered by the chemical process that fuses hydrogen and oxygen, they do not need to be recharged and can be driven as long as they are supplied with hydrogen. Filling up the car takes less than 5 minutes and the average range of hydrogen fuel cell cars are around 300 to 350 miles. They can be used similar to the conventional vehicles for shorter and longer journeys.

CHAPTER 4

COMPONENTS OF AN ELECTRIC CAR

All-electric vehicles (EVs) have an electric motor instead of an internal combustion engine. The vehicle uses a large traction battery pack to power the electric motor and must be plugged in to a charging station or wall outlet to charge. Because it runs on electricity, the vehicle emits no exhaust from a tailpipe and does not contain the typical liquid fuel components, such as a fuel pump, fuel line, or fuel tank.

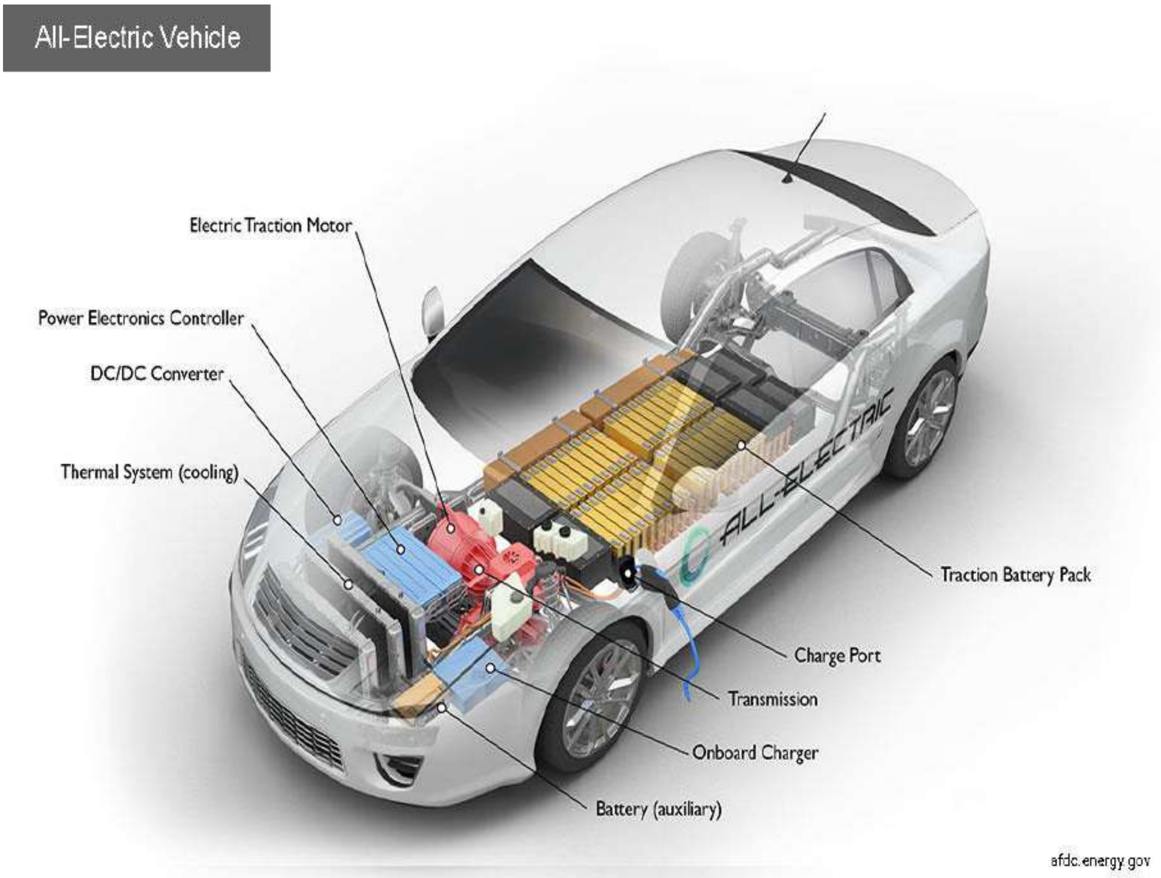


Figure 4: Electric car components

4.1 Key Components

- Battery (all-electric auxiliary): In an electric drive vehicle, the auxiliary battery provides electricity to power vehicle accessories.
- Electric traction motor: Using power from the traction battery pack, this motor drives the vehicle's wheels. Some vehicles use motor generators that perform both the drive and regeneration functions.
- Traction battery pack**:** Stores electricity for use by the electric traction motor.
- DC/DC converter**:** This device converts higher-voltage DC power from the traction battery pack to the lower-voltage DC power needed to run vehicle accessories and recharge the auxiliary battery.
- Power electronics controller**:** This unit manages the flow of electrical energy delivered by the traction battery, controlling the speed of the electric traction motor and the torque it produces.
- On-board charger: Takes the incoming AC electricity supplied via the charge port and converts it to DC power for charging the traction battery. It monitors battery characteristics such as voltage, current, temperature, and state of charge while charging the pack.
- Charge port**:** The charge port allows the vehicle to connect to an external power supply in order to charge the traction battery pack.
- Thermal system (cooling): This system maintains a proper operating temperature range of the engine, electric motor, power electronics, and other components.
- Transmission (electric): The transmission transfers mechanical power from the electric traction motor to drive the wheels.

4.1.1 Battery Pack

An electric-vehicle battery (EVB) in addition to the traction battery specialty systems used for industrial (or recreational) vehicles, are batteries used to power the propulsion system of a battery electric vehicle (BEVs). Vehicle batteries are usually a secondary (rechargeable) battery, and are typically lithium-ion batteries. Traction batteries, specifically designed with a high ampere-hour capacity, are used in forklifts, electric golf carts, riding floor scrubbers, electric motorcycles, electric cars, trucks, vans, and other electric vehicles.

Electric-vehicle batteries differ from starting, lighting, and ignition (SLI) batteries as they are designed to give power over sustained periods of time. Deep-cycle batteries are used instead of SLI batteries for those applications. Batteries for electric vehicles are characterized by their relatively high power-to-weight ratio, specific energy and energy density; smaller, lighter batteries reduce the weight of the vehicle and improve its performance. The most common battery type in modern electric cars is lithium-ion and Lithium polymer battery, because of their high energy density compared to their weight. The amount of electricity (i.e. electric charge) stored in batteries is measured in ampere hours or in coulombs, with the total energy often measured in watt hours.

Lead acid battery

Flooded lead-acid batteries are the cheapest and in past most common traction batteries available. There are two main types of lead-acid batteries: automobile engine starter batteries, and deep cycle batteries. Automobile alternators are designed to provide starter batteries high charge rates for fast charges, while deep cycle batteries used for electric vehicles like forklifts or golf carts, and as the auxiliary house batteries in RV's, require different multi-stage charging.

Traditionally, most electric vehicles have used lead-acid batteries due to their mature technology, high availability, and low cost. Like all batteries, these have an environmental impact through their construction, use, disposal or recycling.Deep-cycle lead batteries are expensive and have a shorter life than the vehicle itself, typically needing replacement every 3 years.Charging and operation of batteries typically results in the emission of hydrogen, oxygen and sulphur, which are naturally occurring and normally harmless if properly vented. Early City car owners discovered that, if not vented properly, unpleasant sulphur smells would leak into the cabin immediately after charging.

Lead-acid batteries powered such early-modern EVs as the original versions of the EV1 and the RAV4 EV.

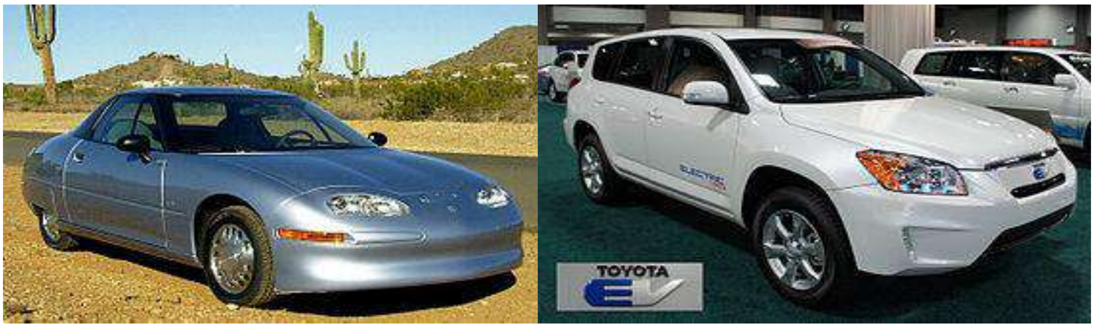


Figure 5: EV's using lead acid battery

Nickel metal hydride

Nickel-metal hydride batteries are now considered a relatively mature technology. While less efficient (60–70%) in charging and discharging than even lead-acid, they have a specific energy of 30–80 Wh/kg, far higher than lead-acid. When used properly, nickel-metal hydride batteries can have exceptionally long lives, as has been demonstrated in their use in hybrid cars and surviving NiMH RAV4 EVs that still operate well after 100,000 miles (160,000 km) and over a decade of service. Downsides include the poor efficiency, high self-discharge, very finicky charge cycles, and poor performance in cold weather.

GM Ovonic produced the NiMH battery used in the second generation EV-1, and Cobasys makes a nearly identical battery (ten 1.2 V 85 Ah NiMH cells in series in contrast with eleven cells for Ovonic battery). This worked very well in the EV-1.

Lithium-ion

Lithium-ion (and the mechanistically similar lithium polymer) batteries, were initially developed and commercialized for use in laptops and consumer electronics. With their high energy density and long cycle life they have become the lead candidate for use in EVs.The downside of traditional lithium-ion batteries includes sensitivity to temperature, low temperature power performance, and performance degradation with age. Due to the volatility of organic electrolytes, the presence of highly oxidized metal oxides, and the thermal instability of the anode SEI layer, traditional lithium-ion batteries pose a fire safety risk if punctured or charged improperly.These early cells did not accept or supply charge when extremely cold, and so heaters can be necessary in some climates to warm them. The maturity of this technology is moderate. The Tesla Roadster (2008) and other cars produced by the company used a modified form of traditional lithium-ion "laptop battery" cells that can be replaced individually as needed.Recent EVs are utilizing new variations on lithium-ion chemistry that sacrifice specific energy and specific power to provide fire resistance, environmental friendliness, rapid charging (as quickly as a few minutes), and longer lifespans. These variants (phosphates, titanates, spinels, etc.) have been shown to have a much longer lifetime, with A123 types using lithium iron phosphate lasting at least 10+ years and 7000+ charge/discharge cycles and LG Chem expecting their lithium-manganese spinel batteries to last up to 40 years.

4.1.2 Traction Motor

The core element of the EV, apart from Electric Vehicle Batteries, which replaces the Internal Combustion engines is an **Electric motor**. The rapid development in the field of Power electronics and control techniques has created a space for various types of electric motors to be used in Electric Vehicles. The electric motors used for automotive applications should have characteristics like high starting torque, high power density, good efficiency, etc.

Various types of Electric Motors used in Electric Vehicles

1. DC Series Motor.
2. Brushless DC Motor.
3. Permanent Magnet Synchronous Motor (PMSM).
4. Three Phase AC Induction Motors.
5. Switched Reluctance Motors (SRM).

DC Series Motor

High starting torque capability of the DC Series motor makes it a suitable option for traction application. It was the most widely used motor for traction application in the early 1900s. The advantages of this motor are easy speed control and it can also withstand a sudden increase in load. All these characteristics make it an ideal traction motor. The main drawback of DC series motor is high maintenance due to brushes and commutators. These motors are used in Indian railways. This motor comes under the category of DC brushed motors.

Brushless DC Motors

It is similar to DC motors with Permanent Magnets. It is called brushless because it does not have the commutator and brush arrangement. The commutation is done electronically in this motor because of this BLDC motors are maintenance free. BLDC motors have traction characteristics like high starting torque, high efficiency around 95-98%, etc. BLDC motors are suitable for high power density design approach. The BLDC motors are the most preferred motors for the electric vehicle application due to its traction characteristics.

BLDC motors further have two types:

- Out-runner type BLDC Motor**:**

  In this type, the rotor of the motor is present outside and the stator is present inside. It is also called as Hub motors because the wheel is directly connected to the exterior rotor. This type of motors does not require external gear system. In a few cases, the motor itself has inbuilt planetary gears. This motor makes the overall vehicle less bulky as it does not require any gear system. It also eliminates the space required for mounting the motor. There is a restriction on the motor dimensions which limits the power output in the in-runner configuration. This motor is widely preferred by electric cycle manufacturers like Hullikal, Tronx, Spero, light speed bicycles, etc. It is also used by two-wheeler manufacturers like 22 Motors, NDS Eco Motors, etc.

Figure 6: BLDC hub motor

- In-runner type BLDC Motor:

  In this type, the rotor of the motor is present inside and the stator is outside like conventional motors. These motors require an external transmission system to transfer the power to the wheels, because of this the out-runner configuration is little bulky when compared to the in-runner configuration. Many three- wheeler manufacturers like Goenka Electric Motors, Speego Vehicles, Kinetic Green, Volta Automotive use BLDC motors. Low and medium performance scooter manufacturers also use BLDC motors for propulsion.

Figure 7: BLDC motor In-runner type

The main drawback is the high cost due to permanent magnets. Overloading the motor beyond a certain limit reduces the life of permanent magnets due to thermal conditions.

Permanent Magnet Synchronous Motor (PMSM)

This motor is also similar to BLDC motor which has permanent magnets on the rotor. Similar to BLDC motors these motors also have traction characteristics like high power density and high efficiency. The difference is that PMSM has sinusoidal back EMF whereas BLDC has trapezoidal back EMF. Permanent Magnet Synchronous motors are available for higher power ratings. PMSM is the best choice for high performance applications like cars, buses. Despite the high cost, PMSM is providing stiff competition to induction motors due to increased efficiency than the latter. PMSM is also costlier than BLDC motors. Most of the automotive manufacturers use PMSM motors for their hybrid and electric vehicles. For example, Toyota Prius, Chevrolet Bolt EV, Ford Focus Electric, zero motorcycles S/SR, Nissan Leaf, Honda Accord, BMW i3, etc use PMSM motor for propulsion.

Figure 8: PMSM used in Toyota Prius

Three Phase AC Induction Motors

The induction motors do not have a high starting toque like DC series motors under fixed voltage and fixed frequency operation. But this characteristic can be altered by using various control techniques like FOC or v/f methods. By using these control methods, the maximum torque is made available at the starting of the motor which is suitable for traction application. Squirrel cage induction motors have a long life due to less maintenance. Induction motors can be designed up to an efficiency of 92-95%. The drawback of an induction motor is that it requires complex inverter circuit and control of the motor is difficult.

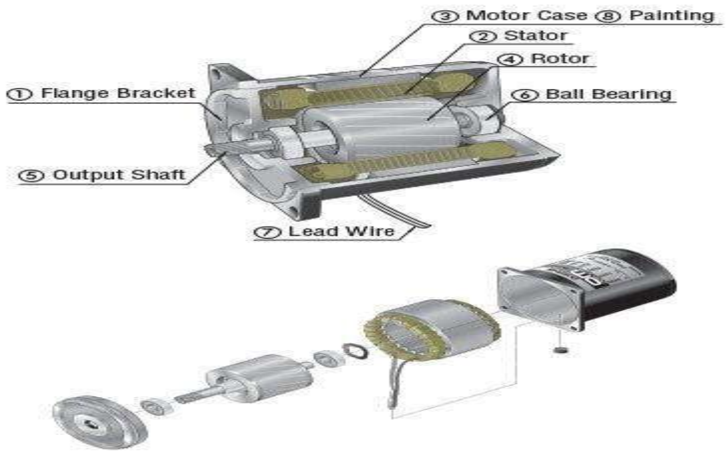


Figure 9: Induction motor

In permanent magnet motors, the magnets contribute to the flux density B. Therefore, adjusting the value of B in induction motors is easy when compared to permanent magnet motors. It is because in Induction motors the value of B can be adjusted by varying the voltage and frequency (V/f) based on torque requirements. This helps in reducing the losses which in turn improves the efficiency.

Tesla Model S is the best example to prove the high-performance capability of induction motors compared to its counterparts. By opting for induction motors, Tesla might have wanted to eliminate the dependency on permanent magnets. Even Mahindra Reva e2o uses a three-phase induction motor for its propulsion. Major automotive manufacturers like TATA motors have planned to use Induction motors in their cars and buses.

Switched Reluctance Motors (SRM)

Switched Reluctance Motors is a category of variable reluctance motor with double saliency. Switched Reluctance motors are simple in construction and robust. The rotor of the SRM is a piece of laminated steel with no windings or permanent magnets on it. This makes the inertia of the rotor less which helps in high acceleration. The robust nature of SRM makes it suitable for the high speed application. SRM also offers high power density which is some required characteristics of Electric Vehicles. Since the heat generated is mostly confined to the stator, it is easier to cool the motor. The biggest drawback of the SRM is the complexity in control and increase in the switching circuit. It also has some noise issues. Once SRM enters the commercial market, it can replace the PMSM and Induction motors in the future.

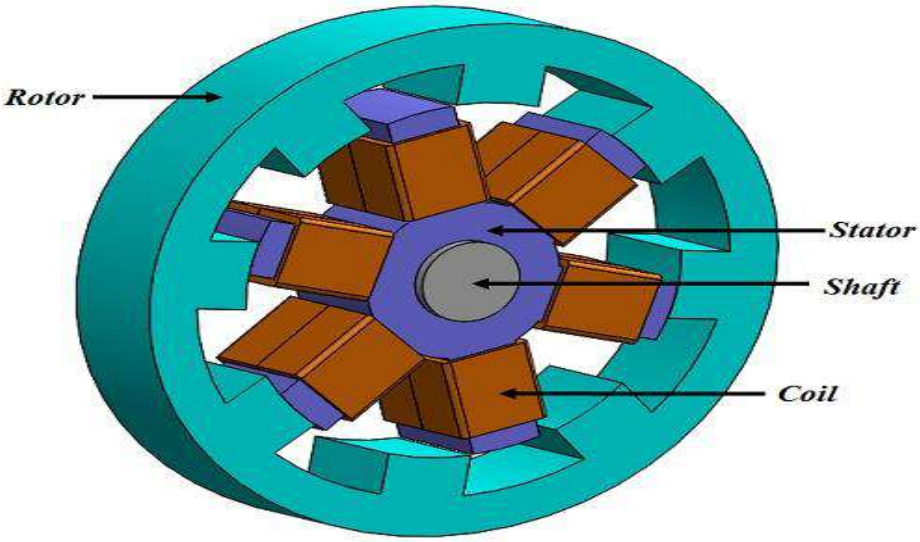


Figure 10: Switched reluctance motor

CHAPTER 5

WORKING OF ELECTRIC CARS

Electric cars get power form the rechargeable batteries installed inside the car. These batteries are not only used to power vehicles but also used for the functioning of wipers and lights. Electric cars look precisely like other normal vehicles outward, but for lack of exhaust system. However, inward they are very different from each other. For instance, you will not find any gas tank, as they do not use fuel for locomotion or propelling the engines.

Consequently, the battery packs are under the vehicle and sometimes in the trunk. It is the same kind of batteries that are commonly used when starting up a gasoline engine. The only difference comes in the fact that in electric vehicles, they have more of them and they also store energy that is used in powering the vehicle. You will also find a regulator on the batteries, which simply ensures energy amount produced and that which is consumed by the car is constant. This ensures there is not battery that burns out.

The controller takes power from the batteries and delivers it to the motor. The accelerator pedal hooks to a pair of potentiometers (variable resistors), and these potentiometers provide the signal that tells the controller how much power it is supposed to deliver. 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.

The controller's job in a DC electric car is easy to understand. Let's assume that the battery pack contains 12 12-volt batteries, wired in series to create 144 volts. The controller takes in 144 volts DC, and delivers it to the motor in a controlled way.

The very simplest DC controller would be a big on/off switch wired to the accelerator pedal. When you push the pedal, it would turn the switch on, and when you take your foot off the pedal, it would turn it off. As the driver, you would have to push and release the accelerator to pulse the motor on and off to maintain a given speed.

Obviously, that sort of on/off approach would work but it would be a pain to drive, so the controller does the pulsing for you. The controller reads the setting of the accelerator pedal from the potentiometers and regulates the power accordingly. Let's say that you have the accelerator pushed halfway down. The controller reads that setting from the potentiometer and rapidly switches the power to the motor on and off so that it is on half the time and off half the time. If you have the accelerator pedal 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.

In an AC controller, the job is a little more complicated, but it is the same idea. The controller creates three pseudo-sine waves. It does this by taking the DC voltage from the batteries and pulsing it on and off. In an AC controller, there is the additional need to reverse the polarity of the voltage 60 times a second. Therefore, you actually need six sets of transistors in an AC controller, while you need only one set in a DC controller. In the AC controller, for each phase you need one set of transistors to pulse the voltage and another set to reverse the polarity. You replicate that three times for the three phases -- six total sets of transistors.

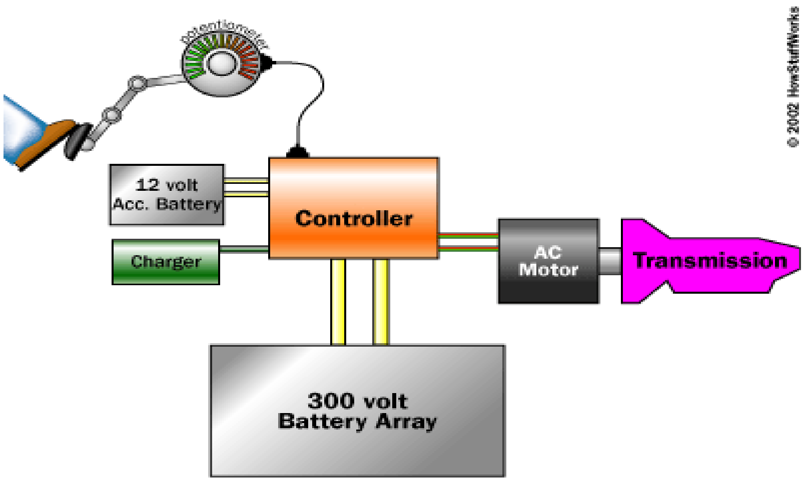


Figure 11: Basic layout of energy flow in electric cars

5.1 Charging of Electric Cars

Charging and electric car is similar to charging an electronic device. A charging cable is used to supply 230V current to the EV through public charging station or home charging station. The electric current flows to the charger which converts the current into a format that can be easily absorbed by the battery. Current then flows to the battery where it gets stored to be retrieved later. Depending on the size and distance to be covered, an EV needs to be charged at appropriate intervals.

Figure 12: Tesla supercharger station

Tesla supercharging stations charge with up to 150 kW of power distributed between two cars with a maximum of 150 kW per car, depending on version. They take about 20 minutes to charge to 50%, 40 minutes to charge to 80%, and 75 minutes to 100% on the original 85 kWh Model S. The charging stations provide high-power direct-current (DC) charging power directly to the battery, bypassing the internal charging power supply. The next version of Supercharging was expected to charge with more than 350 kW.

CHAPTER 6

ADVANTAGES AND DISADVANTAGES OF ELECTRIC CARS

Electric vehicles (EVs) have made huge technological strides since they were first introduced, and they're more popular than ever before. Yet some drivers are still hesitant to make the switch from traditional gas-powered cars, in large part due to misconceptions that EVs still suffer the same shortcomings they did in their earlier years. While electric cars do, indeed, have their downsides, there are also considerable benefits to owning one.

6.1 Advantages

They're easier on the environment

EVs don't even have an exhaust system, meaning they have zero emissions. And since gas-powered vehicles are large contributors to greenhouse-gas build up in the earth's atmosphere, making the switch to an electric car can help contribute to cleaner air and a healthier planet.

Electricity is cheaper than gasoline

Americans pay an average of 15 cents per mile driving gas-powered cars, which really doesn't seem like much — until you compare it to the fact that many EVs run at one-third of that cost, given that electricity is significantly less expensive than gasoline. And since you'll likely charge your electric car in your garage most of the time, installing solar panels on your home can save you even more money on powering both your residence and your EV.

Maintenance is less frequent and less expensive

Since electric cars are, well, electric, they don't run on oil and therefore don't necessitate oil changes (or any other maintenance related to combustion engines, for that matter). Another advantage is that the brakes on an EV typically don’t wear as quickly as those on a conventional car, which means even more savings for you.

They’re very quiet.

Conventional cars are considerably noisy even if they have a small. EVs, on the other hand, are practically silent.

You’ll get tax credits

If you’re the original owner of an electric vehicle, you’ll likely receive a tax credit just for helping to lessen your impact on the environment by driving a zero-emissions car.

6.2 Disadvantages

Most EVs have pretty short ranges

Although EV range is constantly improving, it’s still one of the main pain points for consumers deciding between electric and conventional. On a full charge, most electric models are limited to a range of 60 to 100 miles, but a small minority of models can go between 200 and 300 miles per charge.

Recharging can take a while

Compared to the few minutes it takes to fill up a conventional car at the gas station, recharging your EV is a much more significant time investment. While most electric car takes about four hours to reach a full charge, some take a whopping 15 to 20 hours.

They’re a large initial investment

Initial price of an EV is very high compared to IC engine vehicles. It is mainly due to the high of the battery pack.

Charging station availability is inconsistent

The lack of availability of charging stations is another major grievance for consumers. Since the number of electric cars on the road is considerably less the charging stations are also minimal. This will hopefully change as electric cars become more popular.

CHAPTER 7

PROJECT SPECIMEN: MAHINDRA REVAi

The REVA*i*, known as **G-Wiz** in the United Kingdom, is a small micro electric car, made by the Indian manufacturer Reva Electric Car Company between 2001 and 2012. By late 2013 Reva had sold about 4,600 vehicles worldwide, in 26 countries. Sales in the United Kingdom, its main market, ended by the end of 2011. Production ended in 2012 and was replaced by the Mahindra e2o.The vehicle was originally known as simply the REVA, but was then improved and renamed the REVA*i*.

This is an electric vehicle that is powered by high voltage battery pack. It has two type of battery used for its operation. The car has an 48v motor system and 12v system for all other units like the headlights, wipers, horns etc.
Vehicle requires to be plugged in for charging battery pack once stored energy is discharged in drive. The vehicle has a regenerative braking system that tops up battery pack whenever accelerator is released and /or brake is applied while vehicle is in motion.

Figure 13: REVAi

Vehicle Specification

General	
Type	2 door hatch-back right hand drive
Seating capacity	4 adults [driver(D)+3]
Overall length	3278 mm
Overall width	1575 mm
Overall height	1570 mm
Wheelbase	1958 mm
Ground clearance	172 mm
Kerb weight	942 Kgs.
Gross vehicle weight	1262 Kgs.
Pay load	320Kgs
Turning radius	3850 mm
Steering gear box	Rack & pinion
Frame type	Welded tubular steel space frame

Controls
2 pedal operation (brake and accelerator) 4 operating modes (R,N,F,B)
The RNFB mode selection lever provides reverse / neutral / forward / boost modes of operation.

Tyres	
Tyre (front & rear)	165 / 60 R 14 / 79T, tubeless
Tyre pressure- (Laden): driver(D), D+1 or D+2:	Front: 32psi & rear: 38psi Front & rear : 32psi

Vehicle Identification

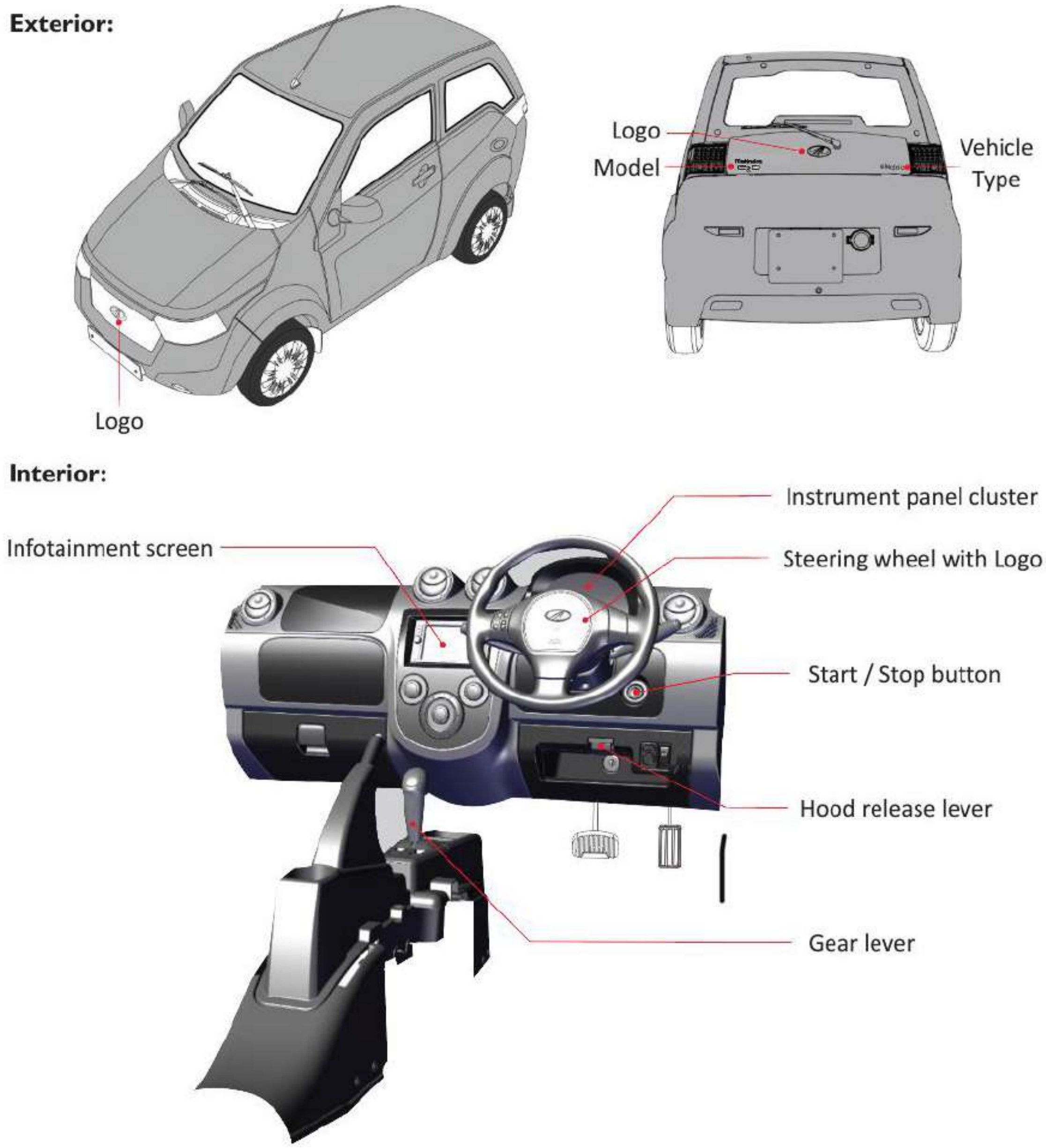


Figure 14: Exterior and Interior

CHAPTER 8

ELECTRICAL LAYOUT OF THEELECTRIC CAR

Figure 15: Electrical layout

- THREE PHASE AC INDUCTION MOTOR
- MOTOR CONTROLLER
- CHARGER AND DC-DC CONVERTER
- CHOKE COIL
- CONTACTOR

Three Phase AC Induction Motors

The induction motors do not have a high starting toque like DC series motors under fixed voltage and fixed frequency operation. But this characteristic can be altered by using various control techniques like FOC or v/f methods. By using these control methods, the maximum torque is made available at the starting of the motor which is suitable for traction application. Squirrel cage induction motors have a long life due to less maintenance. Induction motors can be designed up to an efficiency of 92-95%. The drawback of an induction motor is that it requires complex inverter circuit and control of the motor is difficult.

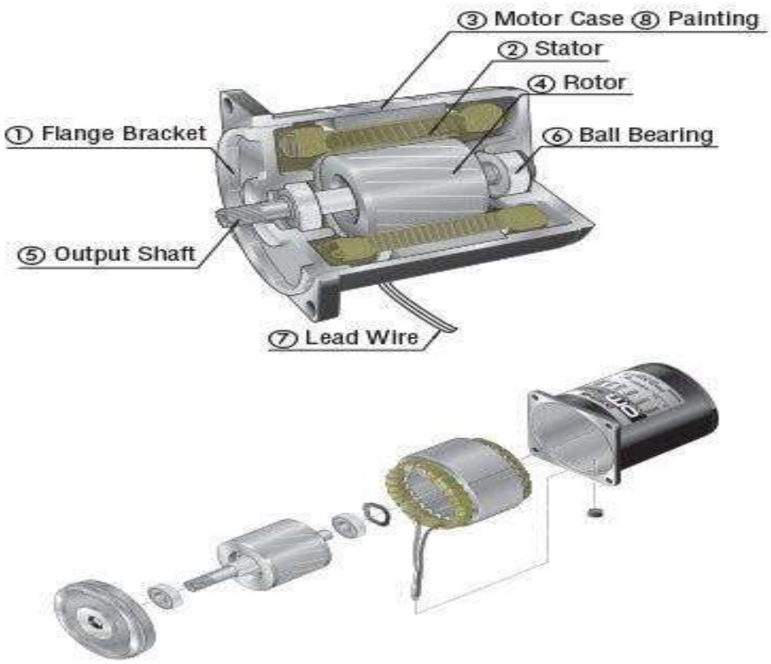


Figure 16: AC induction motor

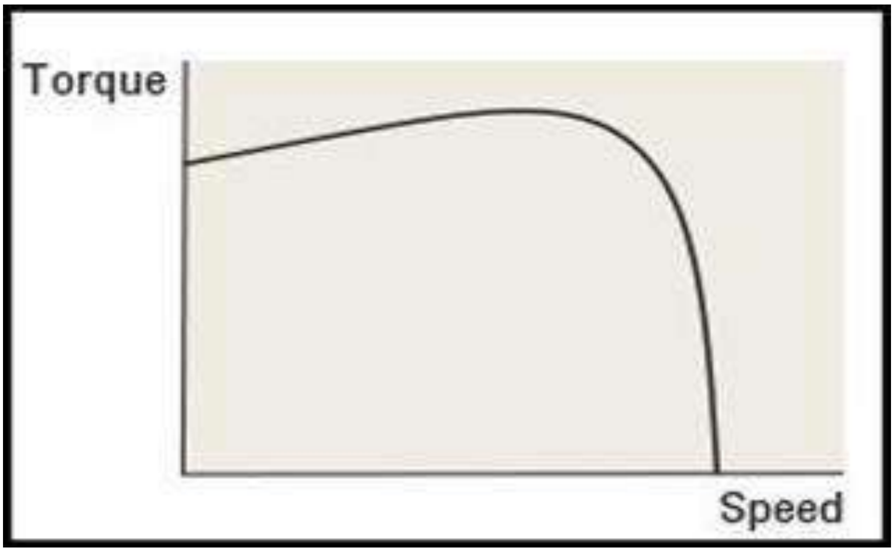


Figure 17:Three phase motor characteristics

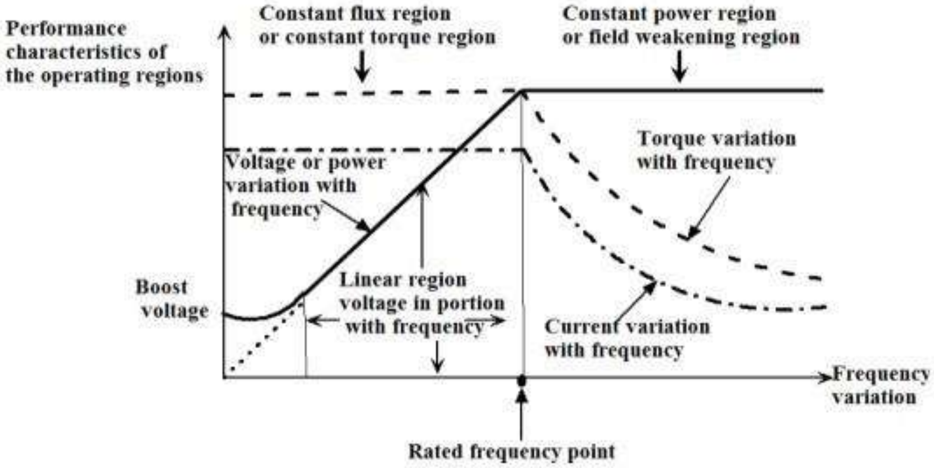


Figure 18: Three phase motor characteristics under flux oriented control

Advantages of the AC induction motor

. simplified design

. Lower cost

. Fewer parts

. Higher reliability

. Less chance of raw material price fluctuations and shortages

Variant	P2
Construction	3 Phase AC Induction Motor
Power	13Kw @ 3500r/min
Torque	70Nm @ 1050 r/min
Controller	350 A

CONTROLLER

Curtis 1238 is AC induction motor controllers deliver smooth power unlike any previous vehicle control system. They provide unprecedented flexibility and power through inclusion of a field-programmable logic controller embedded in a state-of-the-art motor controller. The embedded logic controller runs a fully functional field-oriented AC motor control operating system (OS) that can be user-tailored via parameter modification. The OS also contains logic to execute OEM- developed software, called VCL, that canbe used toenhancethe controller capabilities beyond the basics. VCL (Vehicle Control Language) is an innovative software programming language developed by Curtis. Many electric vehicle functions are uniquely built into the VCL code, and additional functions can be OEM-controlled using VCL code. VCL opens new avenues of customization, product differentiation, and responsiveness to the market. The CAN bus communication in 1238 controller, allow these AC induction motor controllers to be part of an efficient distributed system. Inputs and outputs can be optimally shared throughout the system, minimizing wiring and creating integrated functions that often reduce the cost of the system.

Figure 19:Curtis 1238controller

Features include:

1) High efficiency, field-oriented motor control algorithms
2) Advanced Pulse Width Modulation technology for efficient use of battery voltage, low motor harmonics, low torque ripple, and minimized switching losses
3) Extremely wide torque/speed range including full regeneration capability
4) Smooth low speed control, including zero speed
5) Adaptation of control algorithm to motor temperature variation so optimal performance is maintained under widely varying conditions
6) Real-time battery current, motor torque, and power estimates available
7) Power limiting maps allow performance customization for reduced motor heating and consistent performance over varying battery state-of-charge
8) Powerful operating system allows parallel processing of vehicle control tasks, motor control tasks, and user configurable programmable logic
9) A wide range of I/O can be applied wherever needed, for maximum distributed system control
10) Internal battery-state-of-charge, hourmeter, and maintenance timers
11) Easily programmable through the Curtis 1311 handheld programmer and 1314 PC Programming Station
12) Field-programmable, with flash downloadable main operating code

13) Thermal cutback, warning, and automatic shutdown provide protection

14) Rugged sealed housing and connectors meet IP65 environmental sealing

WIRING

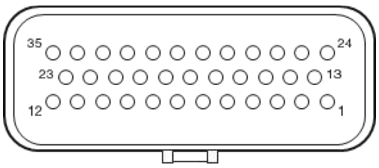
HIGH CURRENT CONNECTIONS

There are five high-current terminals, identified on the controller housing as B+, B-, U, V, and W.

TERMINAL	FUNCTION
B+	Positive battery to controller.
B-	Negative battery to controller.
U	Motor phase U.
V	Motor phase V.
W	Motor phase W.

LOW CURRENT CONNECTIONS

All low power connections are made through a single 35-pin AMPSEAL connector. The mating plug housing is AMP p/n 776164-1 and the contact pins are AMP p/n 770520-3. The connector will accept 20 to 16 AWG wire with a 1.7 to 2.7mm diameter thin-wall insulation.



Motor encoder (Pins 31, 32)

CAN bus (Pins 21, 23, 34, 35)

THROTTLE WIRING

The term throttle is used in two senses: as another name for the drive throttle, and as a generic term covering both the drive throttle and the brake throttle. Wiring is the same, whether the throttle in question is used for braking or for acceleration. Various throttles can be used with the 1238 controller. They are characterized as one of five types in the programming menu of the 1311 programmer.

Type 1	2 wire 5Ω-0 potentiometers
Type 2	Single ended 0 to 5v throttles, current source throttles, 3 wire potentiometers and electronic throttles
Type 3	2 wire 0 to 5Kω potentiometers
Type 4	Wigwag 0-5v throttles and 3 wire potentiometers
Type 5	VCL input

CHOKE COIL

Figure 20:choke coil

When generating and using electrical energy, one speaks more of transformer or choke coils. They almost always have 40 magnetisable cores and have larger manufacturing tolerances. In the case of transformers, the cores are magnetically closed, while in the case of choke coils they have a defined air gap. In filter circuits, a choke coil with a high magnetic resistance and its self-induction dampens alternating voltage components and electrical interference pulses to circuit components connected subsequently. In the widely used switching power supplies, choke coils store magnetic energy in the core material and release it again in the form of electrical energy.

A coil is created when an insulated wire is wound onto a non-conductive carrier body. So far, coils and choke coils are identical. The turns form individual conductor loops connected in series. The main distinction is made between an open-ended solenoid and a closed toroid. Coils made of thick wire and a few turns can also be self-supporting. If the coil carrier is coreless or the core material cannot be magnetized, this is referred to as an air coil. A ferromagnetic core, which is electrically insulated from the coil winding, can also be located in the coil body. A coil can generally be referred to as an inductor.

If electrical current flows through a wire loop or coil, it generates a magnetic field. This special property is effective inside and outside the coil. Cylinder coils and flat coils have a large magnetic field that acts on the outside, while that of ring (core) coils is small. Toroidal core coils are preferably used in order to make maximum use of the magnetic field and to keep the magnetic scatter on adjacent coils and components low.

Magnetizable core material concentrates the magnetic field lines on the core area and thus strengthens the magnetic properties and the associated inductance of the coil with the same size. The 40 magnetisable core should be laminated to keep the eddy current losses and the associated heating up small. If a coil is exposed to a magnetic field that changes over time, it generates an electrical voltage at its connections.

Like any conductor, inductors have an ohmic resistance, which depends on the material as well as on the length and cross section of the conductor. The main characteristic of a coil is its inductance. If electrical current flows through a coil, it builds up a magnetic field. A solenoid connected to DC voltage ultimately acts like a bar magnet. The magnetic force can be increased by an iron core, since the magnetic field lines are concentrated and preferential in it.

If a voltage is applied to an ohmic resistor, the predictable current flows with the help of ohmic law. In the case of a coil, the electromagnetism and its interaction with the inductance cause the current flow to reach its end value only after a delay. During this time, the voltage parallel to the coil decreases and has its lowest value after the magnetic field has completely built up. In the chapter on the electromagnetic coil there are additional descriptions of how the magnetic field is created. Compared to the capacitor, the coil behaves in exactly the opposite direction in terms of DC voltage.

CONTACTOR

Figure 21: contactor

A contactor is an electrically-controlled switch used for switching an electrical power circuit. A contactor is typically controlled by a circuit which has a much lower power level than the switched circuit, such as a 24-volt coil electromagnet controlling a 230-volt motor switch.

Unlike general-purpose relays, contactors are designed to be directly connected to high-current load devices. Relays tend to be of lower capacity and are usually designed for both normally closed and normally open applications. Devices switching more than 15 amperes or in circuits rated more than a few kilowatts are usually called contactors. Apart from optional auxiliary low-current contacts, contactors are almost exclusively fitted with normally open ("form A") contacts. Unlike relays, contactors are designed with features to control and suppress the arc produced when interrupting heavy motor currents.

Contactor come in many forms with varying capacities and features. Unlike a circuit breaker, a contactor is not intended to interrupt a short circuit current. Contactors range from those having a breaking current of several amperes to thousands of amperes and 24 V DC to many kilovolts. The physical size of contactors ranges from a device small enough to pick up with one hand, to large devices approximately a meter (yard) on a side. Contactors are used to control electric motors, lighting, heating, capacitor banks, thermal evaporators, and other electrical loads.

A contactor has three components. The contacts are the current-carrying part of the contactor. This includes power contacts, auxiliary contacts, and contact springs. The electromagnet (or "coil") provides the driving force to close the contacts. The enclosure is a frame housing the contacts and the electromagnet. Enclosures are made of insulating materials such as Bakelite, Nylon 6, and thermosetting plastics to protect and insulate the contacts and to provide some measure of protection against personnel touching the contacts. Open-frame contactors may have a further enclosure to protect against dust, oil, explosion hazards and weather.

Magnetic blowouts use blowout coils to lengthen and move the electric arc. These are especially useful in DC power circuits. AC arcs have periods of low current, during which the arc can be extinguished with relative ease, but DC arcs have continuous high current, so blowing them out requires the arc to be stretched further than an AC arc of the same current. The magnetic blowouts in the pictured Albright contactor (which is designed for DC currents) more than double the current the contactor can break, increasing it from 600 A to 1,500 A.

Sometimes an economizer circuit is also installed to reduce the power required to keep a contactor closed; an auxiliary contact reduces coil current after the contactor closes. A somewhat greater amount of power is required to initially close a contactor than is required to keep it closed. Such a circuit can save a substantial amount of power and allow the energized coil to stay cooler. Economizer circuits are nearly always applied on direct-current contactor coils and on large alternating current contactor coils.

A basic contactor will have a coil input (which may be driven by either an AC or DC supply depending on the contactor design). Universal coils (driven by AC as well as DC) are also available in the market today. The coil may be energized at the same voltage as a motor the contactor is controlling, or may be separately controlled with a lower coil voltage better suited to control by programmable controllers and lower-voltage pilot devices. Certain contactors have series coils connected in the motor circuit; these are used, for example, for automatic acceleration control, where the next stage of resistance is not cut out until the motor current has dropped.

APPLICATIONS

- lighting control
- magnetic starter
- vacuum contactor
- mercury relay

- mercury wetted relay

DC-DC CONVERTER

Figure 22: DC-DC converter

The voltage from the battery pack is stepped down to give power to all the electrical components in the vehicle. According to the vehicle standards all the components work on 12v DC supply. The 48v from battery is directly given to motor, which gives more efficiency to the power train reducing all step-up power loss. The auxiliary units including the headlights, horn, music system, wiper unit, power windows etc. are given power with this converter unit.

The basic working of DC-DC converter is to convert one DC voltage level to another, which may be higher or lower, by storing the input energy temporarily and then releasing that energy to the output at a different voltage. The storage may be in either magnetic field storage component (inductors, transformers) or electric field storage components (capacitors). This conversion method can increase or decrease voltage. Switching conversion is often more power-efficient (typical efficiency is 75% to 98%) than linear voltage regulation, which dissipates unwanted power as heat. Fast semiconductor device rises and fall times are required for efficiency; however, these fast transitions combine with layout parasitic effects to make circuit design challenging. The higher efficiency of a switched-mode converter reduces the heatsinking needed, and increases battery endurance of portable equipment.

ELECTRIC VEHICLE CONVERTERS REQUIREMENTS

- light weight
- high efficiency
- small volume
- low electromagnetic interference
- low current ripple drawn from the fuel cell or the battery
- the step down function of the converter
- control of the DC/DC converter power flow subject to the wide voltage variation on the converter input.

ON-BOARD CHARGER

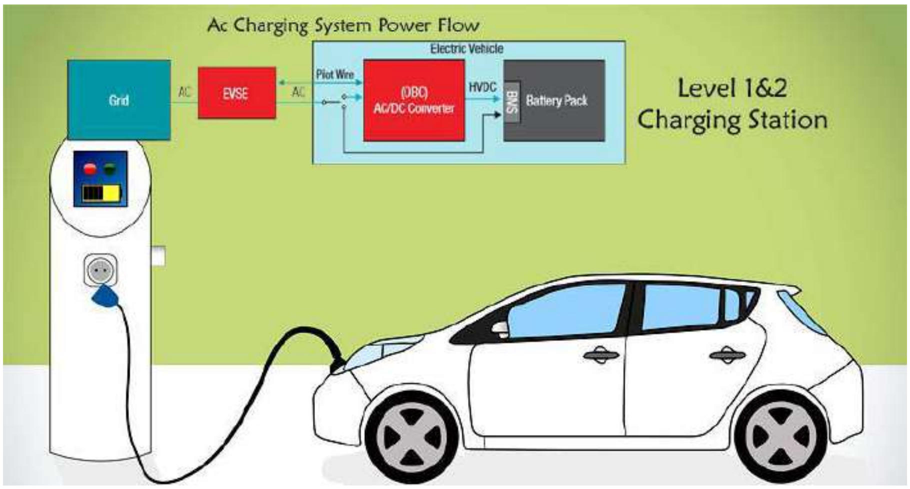


Figure 23:AC SUPPLY ON-BOARD CHARGING

On-board chargers (OBC) allow battery electric vehicles (BEV) to charge anywhere there is AC power, not just at charging stations. AC supply from grid is supplied directly to OBC through EVSE, the OBC then converts it to DC and chargers the battery through the BMS. The Pilot wire is used to sense the type of charger connected to the EV and set the required input current for the OBC. Normally the input voltage is 230v,50hz supply and the output for the electric car is 57v DC. Battery unit is continuously monitored by the charger and battery management system will calculate the time required to full the battery. A notification of charging will be displayed in the vehicle's dash board. The voltage applied to the battery will be always higher than nominal voltage, this is to ensure the current doesn't flow back to the charging circuit.

A stabilizer unit is provided so that feeds constant voltage to a load during over and under voltage conditions. This device detects these voltage conditions and correspondingly brings the voltage to desired range.

Charging Connectors

Figure 24: charger connector

Electric vehicles have different types of charging connectors based on the country it is manufactured form. This has led to confusion among electric vehicle manufacturers as they cannot be made universal easily for all EVs. The main classifications of Connectors for AC chargers and DC chargers is given.

Plug have multiple connections, the three broad pins are for Phase, Neutral and Ground. The input port is plugged into standard 230v,15Amps power plug, and the other side is plugged into the port in car. Always connections are made first, then only the power supply is turned ON, to prevent any short circuit and sparks. A fuse is fitted in the main AC power plug, which is for safety application.

CHAPTER 9

WORK PLAN

ACTIVITIES	INPUTS	TIME FRAME	RESPONSIBLE MEMBERS	OUTPUT
Selection of vehicle	Information from google, olx	22/01/20 – 04/02/20	ERICSSON MAJU, NAVANEETH VISOKAN	Vehicle found in Bangalore
Travelled to Bangalore and selected the vehicle	Data collected from various sources like google maps, Facebook	05/02/20 – 08/02/20	DEEPAK CHERIYAN, UDAY SANKAR	Vehicle delivery to college
Dismantled the vehicle, painted and made into cut section	Utilised college workshop and tools.	10/02/20 – 15/03/20	DEEPAK CHERIYAN, ERICSSON MAJU, NAVANEETH VISOKAN, UDAY SANKAR	Electric vehicle cut section for college
Testing of power unit and report preparation	Utilised automobile lab and library. Information from google	15/03/20 – 20/03/20	DEEPAK CHERIYAN, ERICSSON MAJU, NAVANEETH VISOKAN, UDAY SANKAR	Performance analysis and project report

CHAPTER 10

COST ESTIMATION

EXPENSE	AMOUNT
CAR	25000
MOVERS	19500
TRAVELING	15000
MISCALLANEOUS	500

TOTAL: 60000/-

CHAPTER 11

CONCLUSION

It is clear that an EV has major obstacles to overcome in terms of energy storage, battery lifetime and charging infrastructure. Nevertheless, progress is being done in all areas.Battery technology is also developing at a sustained pace. The volumetric energy density for Lithium-ion battery cells improved from 190 Wh/l, in 1991, to 580 Wh/l, in 2005. Current production lithium-ion cells have around 676 Wh/l or more.Currently, marketed EV have a high purchasing price mainly due to the high voltage battery price. However, the price is estimated to decrease year by year and will go below 300 – 200 USD per kWh by 2022. When battery prices will become competitive and the overall price of an electric vehicle will be similar with an ICE powered vehicle, the market will shift towards EV.Charging infrastructure is currently an issue for the battery electric vehicles. There is a clear need for more charging points which should accommodate the increasing number of electric vehicles. Also, the distribution of the charging point must be carefully planned, taking into account traffic management data. For a certain country there should be electric vehicle charging point (EVCP) hubs in and around major cities. The charging hubs should allow an electric vehicle to travel across the country, whereas the maximum distance between two charging shouldn't be bigger than 80 km (which is below the range of current electric vehicle on the market.

The vehicle model which we approached is a bit older version which is used lead acid battery instead of Li-ion batteries. The battery management system, dc-dc converters and charger unit are having less efficiency compared to the latest version(Mahindra e20), in turn reducing the vehicle performance. The battery needs 8-10 hrs of charging time. We were able to understand the basic concept of EV electrical and electronic components.

CHAPTER 12

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