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SUMMER INTERNSHIP REPORT ON

ELECTRIC VEHICLE

BY

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DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING

AY 2025-2026

Department of Electrical and Electronics Engineering

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CERTIFICATE

This is to certify that the “Internship Report” entitled **“E-VEHICLE”** submitted by **RAMAVATH JAGADISH (B200077)** , Department of Elctrical and Electronics Engineering, is a bonafide record of the work and investigations carried out by them under my supervision and guidance and submitted during 2025-2026, in partial fulfillment of the requirement for the degree of **BACHELOR OF TECHNOLOGY** in **ELECTRICAL AND ELECTRONICS ENGINEERING,** at Rajiv Gandhi University of Knowledge Technologies, Basar, Nirmal, Telangana.

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This is to certify that **Mr R . Jagadish S/O R. Shakru Naik** has been Completed **Industrial Internship** of this Company from **16. May . 2025 to 30. June . 2025** . He has been involved in the following areas and his performance has been found to be exemplary.

- Skilled In **Electric Vehicle .**

He is of sterling character and maintains high level of dignity in moving with their superiors and colleagues . His dedication, hard work and timely execution of job assigned to him will stand in good steady at any organization .

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The success and final outcome oflearning E-VEHICLE required a lot ofguidance and assistance from many people and I am extremely privileged to have got this all along the completion ofmy course and few ofthe projects. All that I have done is only due to such supervision and assistance and I would not forget to thank them.

I respect and thank SAMAR TECH TRAINING AND SOFTWARE SOLUTIONS. For providing me an opportunity to do the course and project work and giving me all support and guidance, which made me complete the course duly. I am extremely thankful to the project Manager Mr.SAMAR. I am thankful to and fortunate enough to get constant encouragement, support and guidance from all Teaching staffs of SAMAR TECH TRAINING AND SOFTWARE SOLUTIONS. Which helped us in successfully completing my course and project work.

Thank you all

ABOUT THE COMPANY

Samar Tech Training And Software Solutions is a 1 year 11 months old Proprietorship Firm incorporated on 30-Aug-2022, having its registered office located at 1-8-66/1, Dilsukhnagar, Vidyutnagar, Road No 1 Dwarakapuram, Hyderabad, Telangana.The major activity of Samar Tech Training And Software Solutions is Manufacturing, Sub-classified into Manufacture of fabricated metal products except machinery and equipment and is primarily engaged in the Manufacture of other fabricated metal productsnec .Samar Tech Training And Software Solutions is classified as Micro enterprise in the financial year 2022-23. It has its unit situated at Hyderabad, Telangana

ABSTRACT

This report presents a comprehensive study on Electric Vehicles (EVs), focusing on their working principles, major components, and role in achieving sustainable transportation. EVs use electrical energy stored in rechargeable batteries to power electric motors, offering high efficiency and zero emissions compared to conventional internal combustion engine vehicles. The study explores various types of EVs, including Battery Electric Vehicles (BEVs), Hybrid Electric Vehicles (HEVs), Plug-in Hybrid Electric Vehicles (PHEVs), and Fuel Cell Electric Vehicles (FCEVs). It also highlights essential components such as batteries, motors, converters, inverters, and regenerative braking systems that improve performance and energy recovery. The internship provided both theoretical and practical insights into EV technologies, charging methods, and power electronics. Furthermore, it discusses the environmental and economic benefits of EV adoption, along with challenges like high cost and limited infrastructure. Overall, the study emphasizes that electric vehicles are crucial for a cleaner, energy-efficient, and sustainable future.

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CHAPTER 1 - INTRODUCTION

1.1 INTRODUCTION TO ELECTRIC VEHICLES

Electric Vehicles (EVs) have emerged as one of the most promising solutions for achieving sustainable transportation in the modern world. With the growing concerns over environmental pollution, depletion of fossil fuels, and the need for clean energy alternatives, EVs are rapidly transforming the global automobile industry. Unlike conventional internal combustion engine vehicles, electric vehicles operate using electrical energy stored in batteries, which power electric motors to drive the vehicle efficiently and quietly.

During my internship at Samar Tech Training and Software Solutions, I had the opportunity to gain both theoretical and practical knowledge about EV technology and its components. The training covered essential topics such as electric propulsion systems, battery management systems (BMS), charging methods, power electronics, and regenerative braking. I also learned about the integration of software and control systems used in EVs to enhance performance and energy efficiency.

This internship helped me understand the fundamental working principles of electric vehicles, their advantages over traditional vehicles, and the challenges faced in large-scale adoption. It also provided valuable exposure to simulation tools, design principles, and real-world applications, thereby strengthening my technical foundation and interest in the field of electric mobility.

1.2 HISTORY OF EV'S

Electric motive power began in 1827 when Hungarian priest Ányos Jedlik built the first functional electric motor, which he later used to power a small model car. In 1835, Professor Sibrandus Stratingh in the Netherlands created a miniature electric vehicle, and between 1832 and 1839, Robert Anderson of Scotland invented the first crude electric carriage powered by non-rechargeable batteries. In the same period, American inventor Thomas Davenport built a toy electric locomotive, and in 1838, Robert Davidson built an electric locomotive reaching speeds of 6 km/h.

In 1840, England granted a patent for using rails as conductors of electric current, and similar patents were issued in the U.S. by Lilley and Colten in 1847. The first mass-produced electric vehicles appeared in America in the early 1900s. Studebaker entered the electric car market in 1902, although the rise of affordable gasoline cars from Ford led to a decline in electric car popularity.

Fig1.1:Thomas Edison and George Meister in a Studebaker electric runabout ,1909

Early EVs were successful in urban settings and specialized roles such as delivery vehicles, ambulances, and milk floats. In the U.S., 28 percent of cars in 1900 were electric, and even President Woodrow Wilson used an electric car. However, limitations in battery technology, lack of electricity infrastructure, improved roads requiring longer range, abundant cheap gasoline, and easier operation of gasoline cars led to the decline of electric vehicles.

Fig1.2:A charging station in Seattle shows an AMC Gremlin, modified to take electric power; it had a range of about 50 miles (80 km) on one charge, 1973

By the 1930s, many electric tram networks in the U.S. were dismantled and replaced with buses. Despite setbacks, interest in electric vehicles revived in the 21st century due to climate change concerns and advancements in battery technology. Recently, electric off-road motorcycles and recreational vehicles have gained popularity.

In recent years, technological advancements in lithium-ion batteries, regenerative braking systems, and electric drivetrains have greatly improved the performance and efficiency of electric vehicles. Governments worldwide are promoting EV adoption through subsidies, tax incentives, and infrastructure development, such as public charging stations. This has led to a growing market for electric cars, buses, and trucks

1.3 BLOCK DIAGRAM OF EV

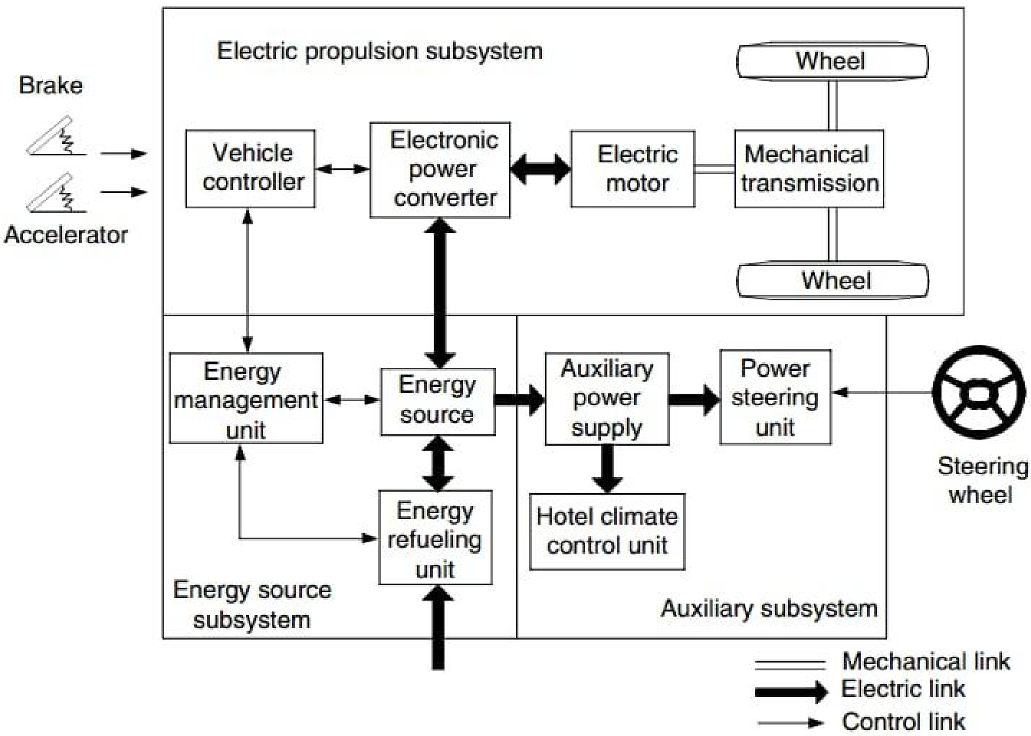

Fig1.3: Block Diagram of EV

CHAPTER 2 - CLASSIFICATION&WORKING PRINCIPE OF EVs

Electric Vehicles (EVs) can be classified based on their power source and method of energy storage. The main categories include Battery Electric Vehicles (BEVs), Hybrid Electric Vehicles (HEVs), Plug-in Hybrid Electric Vehicles (PHEVs), and Fuel Cell Electric Vehicles (FCEVs). Each type differs in its energy source, range, charging method, and level of electrification.

The classification is important to understand how different EV architectures contribute to energy efficiency, performance, and sustainability in modern transportation systems

1. Battery Electric Vehicles (BEVs)
2. Hybrid Electric Vehicles (HEVs)
3. Plug-in Hybrid Electric Vehicles (PHEVs)
4. Fuel Cell Electric Vehicles (FCEVs)

2.1 Battery Electric Vehicles (BEVs)

A Battery Electric Vehicle (BEV), sometimes known as an All-Electric Vehicle (AEV), is a vehicle that is driven by a battery and an electric drive train. These EVs do not have an IC Engine.

Electricity is stored in a huge battery pack, which is charged by connecting to the power grid. In turn, the battery pack powers one or more electric motors that power the electric vehicle.

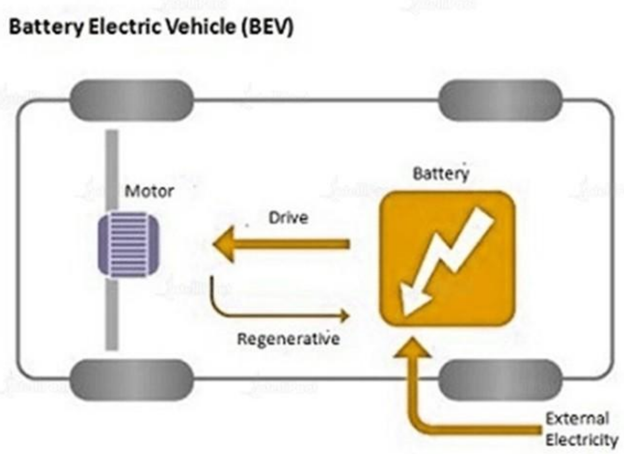

Fig 2.1: Configuration of Battery electric Vehicle(BEV)

>In an electric motor, power is transformed from the DC battery to the AC.

>The accelerator pedal of such a vehicle is responsible for sending a signal to the controller, which alters the frequency of the AC flowing from the inverter to the motor to control the speed.

>The motor rotates the wheels through a gear.

>When the brakes are applied, the motor transforms into an alternator and generates electricity, which is supplied to the battery.

2.2 Hybrid Electric Vehicles (HEVs)

A hybrid vehicle, also known as a parallel or normal hybrid, is powered by both an internal combustion (IC) engine and an electric motor.

In these vehicles, the IC engine runs on fuel, while the electric motor draws energy from a battery. Both the gasoline engine and the electric motor work together to rotate the gearbox, which drives the wheels simultaneously, providing improved efficiency and performance compared to conventional vehicles.

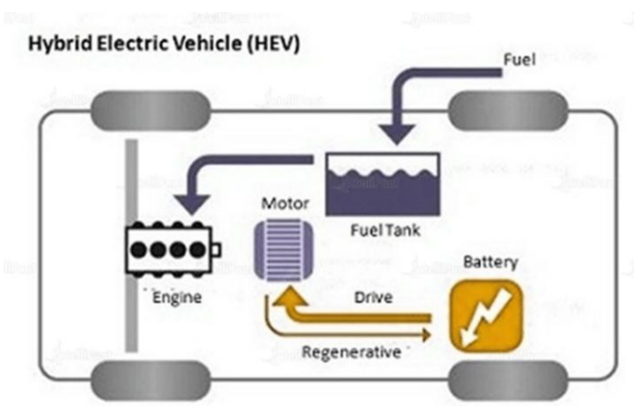

Fig 2.2 : Configuration of Hybrid electric Vehicle(HEV)

similar to a standard automobile that has a fuel tank that delivers gas to the engine.

It also contains a battery pack that powers an electric motor.

Both the engine and the electric motor may turn the gearbox simultaneously

2.3 Plug-In Hybrid Electric Vehicle (PHEV)

A Plug-In Hybrid Electric Vehicle (PHEV) is a hybrid vehicle that has both an Internal Combustion Engine (ICE) and a motor, known as a series hybrid.

Such electric automobiles come with a variety of fuel options. These types of electric vehicles are propelled by a conventional fuel or a rechargeable battery pack.

The battery can be charged by connecting it to an electric car charging station (EVCS).

PHEVs have two modes of operation:

Allele citric(AC) Mode: In this mode, the motor and battery supply all of the energy for the vehicle.

Hybrid Mode: In this mode, both electricity and fuel are used.

Plug-In Hybrid Electric Vehicles start in all-electric mode and run on energy until their battery pack is dead.

When such electric vehicles reach highway cruising speeds of 60 miles/hour or 70 miles/hour, they switch to hybrid mode.

When the battery runs out, the engine kicks in and the car works as a standard, non-plug-in hybrid.

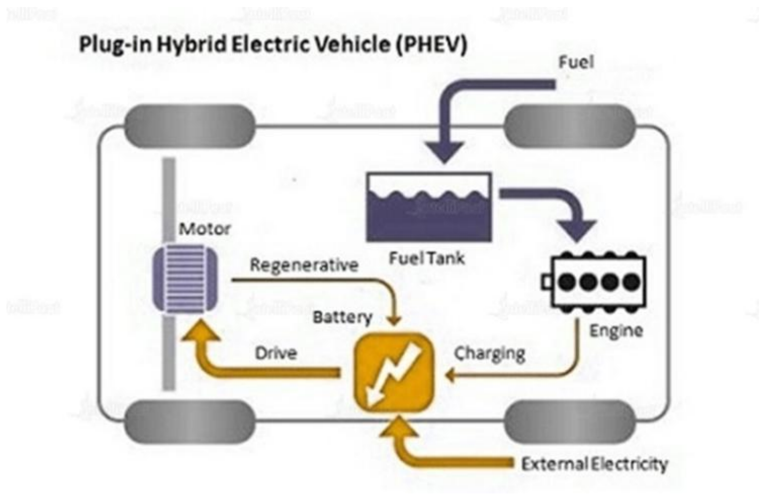

Fig 2.3: : Configuration of Plug-In Hybrid electric Vehicle(PHEV)

PHEV batteries can be charged by an internal combustion engine or regenerative braking, in addition to connecting to an external electric power source.

During braking, the electric motor functions as a generator, transferring energy to the battery. Because the electric motor supports the engine's power, smaller engines can be used, enhancing fuel efficiency without sacrificing performance.

2.4 Fuel Cell Electric Vehicle

Fuel Cell Electric Vehicles (FCEVs), also known as fuel cell vehicles (FCVs) or Zero Emission Vehicles, are electric vehicles that use "Fuel Cell Technology" to create the electricity needed to power the vehicle.

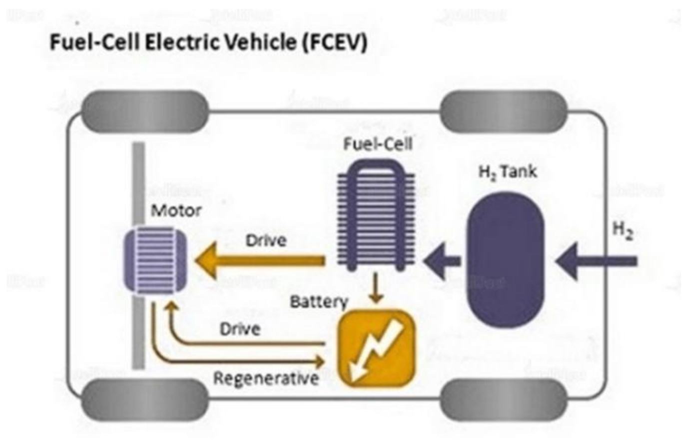

Fig 2.4: : Configuration of Fuel Cell electric Vehicle

The chemical energy of the gasoline is turned directly into electric energy in this sort of vehicle.

The operation of a ‘fuel cell’ electric car differs from that of a ‘plug-in’ electric vehicle.

This sort of electric car exists because the FCEV creates the electricity needed to power the vehicle.

CHAPTER 3 - MAJOR COMPONENTS OF ELECTRIC VEHICLE

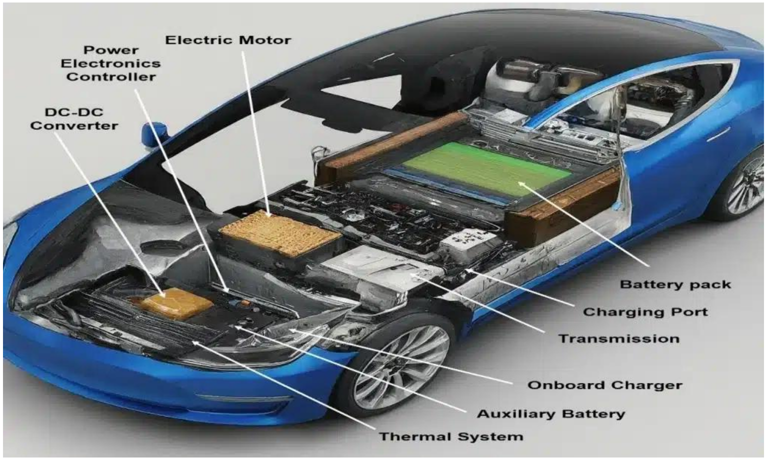

Fig 3.1 : Major Parts of EV

3.1 BATTERY PACK

The battery pack is the heart of an EV, storing the electrical energy that powers the car. Lithium-ion batteries are the most common type of battery used in EVs due to their high energy density and long lifespan.

Composition and Structure

Cells: The battery pack consists of many individual cells. These cells can be of different types, such as cylindrical, prismatic, or pouch cells. The most common chemistry used in EV batteries is lithium-ion. Modules: Cells are grouped into modules to make handling and management easier. Pack: Multiple modules are then assembled into a battery pack, which includes cooling systems, battery management systems (BMS), and structural supports.

Capacity and Range

Capacity: Measured in kilowatt-hours (kWh), the capacity of a battery pack determines how muchenergy it can store. Higher capacity generally translates to a longer driving range.Range: The actual range an EV can achieve on a full charge depends on various factors including thevehicle’s efficiency, driving conditions, and battery capacity.

Charging

AC Charging: Using a standard home outlet or dedicated EV charging station. This is typically slower and more suited for overnight charging. DC Fast Charging: Provides much quicker charging and is available at specialized public charging stations. It can recharge the battery to about 80% capacity in a short period.

Battery Management System

It monitors and manages the battery pack’s state of charge, temperature, health, and safety. Balances the charge among individual cells to ensure optimal performance and longevity. The BMS is crucial for the safe and efficient operation of the battery pack. It Monitors the state of charge (SOC) and state of health (SOH) of the battery. Balances the charge among cells to ensure uniform performance and longevity. Manages temperature through cooling and heating systems to keep the battery within the optimal temperature range. Provides safety mechanisms to prevent overcharging, deep discharging, and short circuits.

Cooling and Thermal Management

During the cold winter months, EVs can experience reduced range since they naturally produce less wasted heat than a traditional internal combustion engine (ICE) which would normally be converted into thermal comfort for the cabin. Instead EVs must utilize more power from the battery for all systems to function properly under extreme cold temperatures. The active cooling and thermal management system helps regulate the temperature of the battery pack at both extremes by cooling it in hot weather, often using liquid coolant that circulates through the battery pack and heating it in cold weather with electric heaters or heat pumps to ensure optimal operating temperatures for the battery.

3.2 TYPES OF BATTERIES

4 types of batteries are used as energy storage in electric vehicles in India

1.LITHIUM-ION BATTERIES

Over recent years, Lithium-ion batteries have rushed in popularity. Li-ion batteries are most commonly used in electric light motor vehicles because of their high power-to-weight ratio, good high-temperature performance, excellent specific energy, and low self-discharge rate.

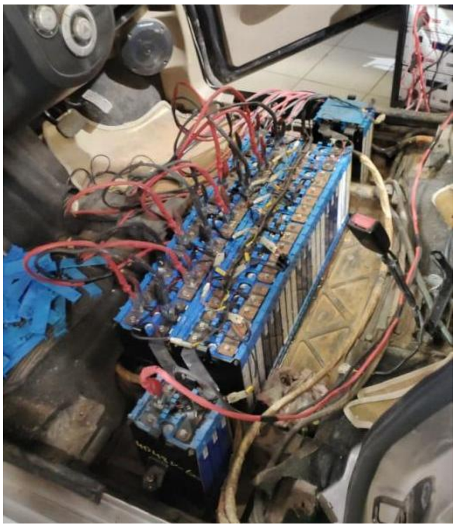

Fig 3.2 : Lithium-ion batteries

Lithium-ion batteries are better than other batteries at maintaining the ability to hold a full charge over time. These battery parts are recyclable so it is a good option regarding the environmental aspect. They have long cycle life even though they support higher energy costs, exceptional power efficiency, longer service life, and eco-friendliness. They are designed to be discharged up to 90% of the total capacity.

Li-ion batteries-based cars give better mileage due to their lightweight. A car has to overcome its inertia. When someone has to accelerate the car from zero, lithium-ion can better propel the vehicle and can discharge faster and supply more power, which is very beneficial for HEV.

2. LEAD-ACID BATTERIES

Lead-acid battery technology is still in the development phase advancing. These batteries have a comparatively wide operating temperature range and have low energy density.

Fig 3.3 : Lead-acid battery

They are easier to recycle. About 95% of the content of the battery can be reused, which is better for the environment. Lead-acid batteries have a relatively low depth of discharge so it directly impacts their cycle life. These batteries tend to be expensive because they don't last as long so they often need to be replaced within 4 to 15 years depending on their type.

Lead-acid batteries do not discharge more than 30-40%. Which typically go on to damage the battery.

3. NICKEL- METAL HYDRIDE BATTERIES

In a Nickel-Metal Hydride battery, one pole has Nickel alloy whereas another pole has Nickel oxyhydroxide with the electrolyte of Potassium hydroxide.

It is usually slower to charge and discharge the battery, and it contains less power per weight so it takes a longer time to charge the battery. In extreme heat, Ni-MH batteries can deteriorate faster. This makes Ni-MH less ideal.

Fig 3.4 : Nickel-Metal Hydride battery

These batteries have a wide operating temperature range. They are also reliable and safe. Ni-MH batteries have a typical cycle life of over 3000 cycles. They are environmentally friendly. The voltage provided by Ni-MH is 1.2 V.

This technology has replaced Ni-Cud technology. These batteries are widely used in automotive batteries, computers, medical instruments as well as equipment, and electric razors.

4. ULTRACAPACITORS

Ultracapacitors in Electric Vehicles– Unlike batteries, Ultracapacitors hold the charge as static energy. They can provide a higher current so they have a far higher specific power.

Ultracapacitors don’t have any heating problems. The main advantage of ultracapacitors is that they can do millions of charging cycles. They are already used in multiple applications for instance in buses, trains, and microgrids.

Fig 3.5 : Ultracapacitors

Nevertheless, these technologies will continue to improve and over time we might see changes in electric vehicles. Battery electric vehicles have become a significantly feasible option in the automotive marketplace for consumers.

Having a low self-discharge rate, and outstanding specific energy, it appears that variants of Li-ion batteries are now the leading type that is mostly utilized in BEVs.

Meanwhile, lead-acid and Ni-MH batteries do not appear to be suitable for use, though these batteries are still frequently utilized in some electric vehicles.

Lithium-Ion batteries are the best for electric vehicles because they offer high energy density, long lifespan, and fast charging. Among them, **NCM and NCA types** provide excellent performance and range, while **$LiFePO_4$ batteries** are safer and more affordable options.

BATTERY TYPE	ENERGY DENSITY	POWER TO WEIGHT RATIO	COST	LIFE SPAN	THERMAL STABILITY	COMMON USAGE
Li-ion	High	High	Medium	2000 - 3000	Moderate	EV's , PHEV
Nickel-metal hydride	Medium	Low	High	1000 - 2000	Low	HEV
Lead-acid	Low	Low	Low	500-1000	High	Auxiliary functions
Ultra-capacitors	Very low	Very High	High	50000+	Very High	Power Boost

3.3 TYPES OF MOTORS USED IN EV'S

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

DC MOTORS

High starting torque capability of the DC 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 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.

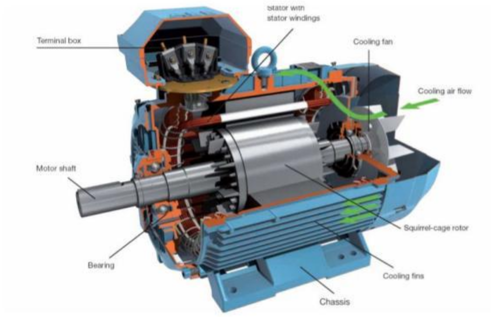

Fig 3.6 : DC motor

BRUSHLESS DC MOTOR

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. You can learn more about BLDC motors by comparing it with normal brushed motor.

BLDC motors further have two types:

i. 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.

Fig 3.7 : Out-runner type BLDC Motor

ii. 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 motor 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.

Fig 3.8 : In-runner type BLDC Motor

It is due to these reasons it is widely preferred motor for electric vehicle application. 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.

3. 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.

Fig 3.9 : Permanent Magnet Synchronous Motor(PMSM)

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, Hinda Accord, BMW i3, etc use PMSM motor for propulsion.

4. INDUCTION MOTOR

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.

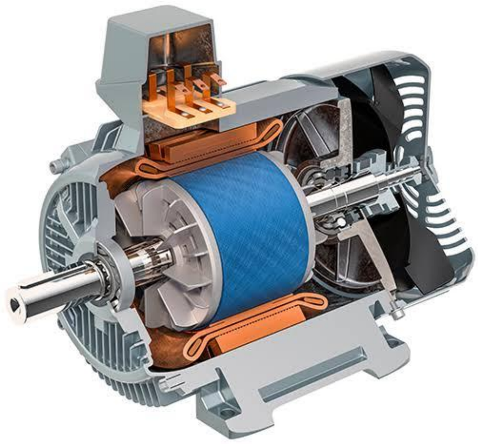

Fig 3.10 : Induction motor

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. The two-wheeler manufacturer TVS motors will be launching an electric scooter which uses induction motor for its propulsion. Induction motors are the preferred choice for performance oriented electric vehicles due to its cheap cost. The other advantage is that it can withstand rugged environmental conditions. Due to these advantages, the Indian railways has started replacing its DC motors with AC induction motors.

5. SWITCHED RELUCTANCE MOTOR (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 are 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.

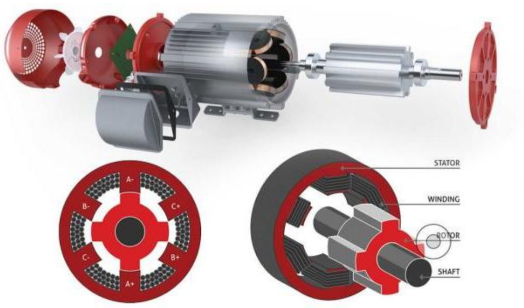

Fig 3.11 : Switched Reluctance Motor (SRM)

CHAPTER 4 - CHARGING METHODS

4.1 AC FAST CHARGING

Let's begin with the familiar 15A AC (Alternating Current) plug point. Yes, the broad 3-pin socket that you plug in your heavy-duty appliances at home can also power up your EV, and as the 15A point is pretty ubiquitous, it's convenient. But with an output of just 3.3kW, it's also slow.

Still, for a small battery, an overnight charge will easily top it up. For example, the Citroen eC3's 29.2kWh battery pack can go from 10-100 percent in 10.5 hours on a wall socket. But larger batteries can take well over a day. So the 15A socket works best for small batteries like in electric two-wheelers and smaller cars, and since it's easy to find, the 15A socket is also a good back-up in case you are stranded.

Next up is the AC wall charger. These are units that, like the 15A socket, also deliver AC power but at a higher wattage, typically somewhere between 7kW and 22kW. They are pretty compact, can be installed at homes and most companies offer such a charger with their products. For instance, the Tiago EV has an optional 7.2kW charger that can charge the 24kWh battery from 10-100 percent in 3 hours 35 minutes, whereas the standard 3.3kW charger takes 6 hours 20 minutes.

On Board Charging

On-board charging refers to the system where the charger is installed inside the electric vehicle. It converts the alternating current (AC) from an external power source, such as a household socket or public AC charging point, into direct current (DC) to charge the vehicle's battery. This type of charging is commonly used for home and workplace charging because it is convenient and requires only a standard AC supply. However, it offers slower charging speeds compared to fast chargers since the power conversion depends on the vehicle's built-in charger capacity. On-board charging is reliable, safe, and suitable for daily charging needs.

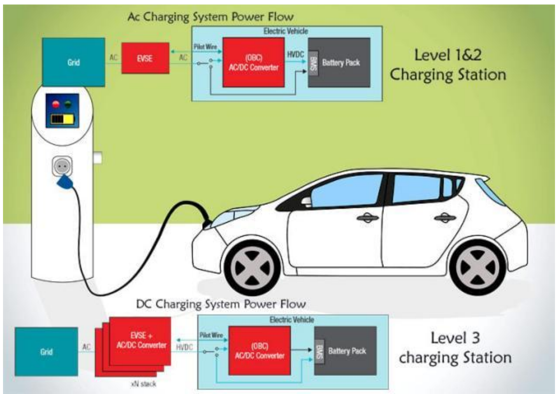

Fig 4.1: On-board charging

4.2 DC FAST CHARGING

In general, batteries function on direct current; even when you plug in your phone, the charger converts electricity from AC to DC to charge your phone's battery. It's the same with EVs too. However, you can bypass the AC to DC convertor of your EV and allow the batteries to soak in some direct current. You do this by plugging into a DC charger, which converts the grid's alternating current to direct current and sends that straight to your battery. In this way, EVs so designed can handle a much higher charging rate. Taking the Tiago EV as an example again, Tata Motors says the 24kWh battery on a DC fast charger with a 50kW output will take 57 minutes to go from 10 to 80 percent.

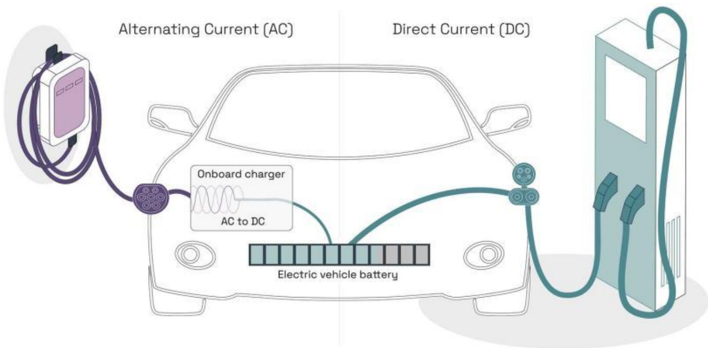

Fig 4.2: AC&DC Charging

These chargers aren't for home use though, they are large and need special installation, and thus, are only found at specific public charging outlets. The speed of DC chargers is also increasing and today, some chargers can go up to 350kW. In India, companies like Kia, for example, have installed 240kW DC chargers, but remember, while your vehicle may be able to handle a DC charger, the maximum speed at which it will take on the direct current will depend on what it's designed to handle plus other limiting factors, details of which we will get into later in this article. On a DC charger, you also have the option to select either the time, energy or total cost that you want to charge with.

Off Board Charging

Off-board charging refers to a system where the charger is located outside the electric vehicle. In this method, the external charging station converts alternating current (AC) from the grid into direct current (DC) and supplies it directly to the vehicle's battery. This setup enables much faster charging compared to on-board systems, as the external charger can handle higher power levels. Off-board charging is commonly used in public DC fast-charging stations, especially for long-distance travel or commercial vehicles. Although it requires expensive infrastructure and specialized equipment, it significantly reduces charging time and enhances the convenience of electric vehicle usage.

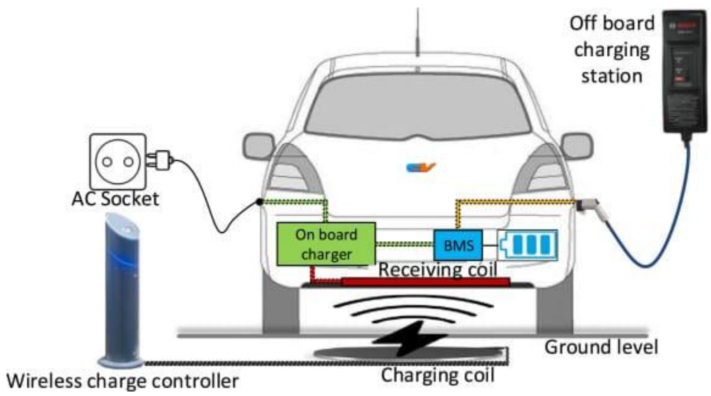

Fig 4.3: Off-board charging

4.3 VEHICLE TO VEHICLE CHARGING (V2V)

Much like siphoning fuel from one car to fill another, you can also use the battery charge of one vehicle to top up another, but this is generally very slow and best only if a car is stranded. For this to work, both vehicles – donor and recipient – need to be designed for V2V charging as beyond the ability to reverse the flow of electricity, both vehicles' onboard power electronic systems need to be able to communicate with each other to allow the exchange to take place. This isn't very common, but there are a few models capable of this; the Hyundai Ioniq 5 and Kia EV6, for instance. Besides this method, an EV low on charge can also be plugged into another EV that has a regular 3-pin AC outlet.

Fig 4.4: V2V charging

CHAPTER 5 - POWER ELECTRONICS IN EV

Power electronics control and convert electrical energy in EVs for efficient operation. Key components like **Inverters**, **DC-DC converters**, and **Controller** manage power flow between the battery, motor, and charging system. They regulate voltage, control motor speed, and enable regenerative braking, improving efficiency and vehicle performance.

5.1 DC - DC CONVERTER

As we continue our expedition through the components of an EV powertrain, we encounter a discreet yet necessary component: the DC-DC converter. While often overshadowed by its more prominent counterparts, the DC-DC converter plays a pivotal role in optimizing the functionality of various auxiliary systems within an EV.

To comprehend the DC-DC converter's significance, let's explore its primary purpose. In the intricate ecosystem of an EV, power sources can vary. While the main battery pack generates high-voltage direct current (DC) that propels the vehicle, other auxiliary systems within the EV—such as lighting, infotainment, and air conditioning—often require lower-voltage DC. This is where the DC-DC converter enters the scene.

The DC-DC converter serves as a bridge between these disparate voltage levels. It takes the high-voltage DC from the main battery and transforms it into the lower-voltage DC needed to power the ancillary systems. By facilitating this conversion, the DC-DC converter ensures that these systems receive a stable and appropriate power supply, to prevent system failures from excessive voltage delivery.

Within the compact confines of the DC-DC converter lies a network of power electronics and circuitry. These components work in harmony to manage the transformation of voltage levels. Capacitors, inductors, and semiconductor devices, such as diodes and transistors, orchestrate the conversion process. The converter carefully controls the flow of electrical energy, maintaining a delicate balance between power input and output.

As we journey through the realm of power electronics in EVs, each component unveils its unique role in shaping the future of transportation. In our next segment, we'll illuminate the intricacies of the vehicle control unit, a powerhouse of intelligence that orchestrates the symphony of an electric vehicle's operations. Stay tuned as we delve deeper into the layers of technology propelling the EV revolution forward

Buck Converter (step - down)

A buck converter lowers the battery voltage to supply stable power to low-voltage components such as lights, infotainment systems, and sensors. It operates efficiently by switching the voltage instead of wasting it as heat. Buck converters also help in extending battery life and improving overall energy management in the EV.

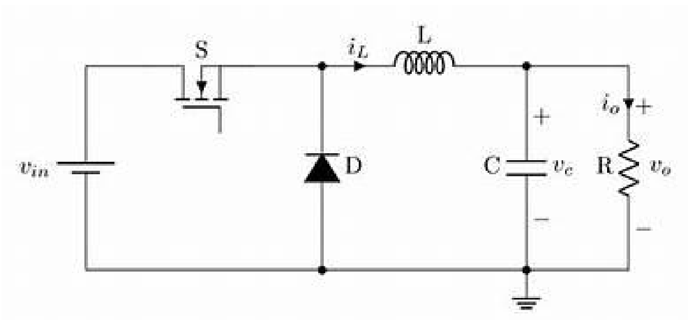

Fig 5.1: circuit diagram of Buck Converter(Step-Down)

Boost Converter (step - up)

A boost converter raises the battery voltage to meet the higher voltage requirements of the electric motor or power electronics. It ensures consistent motor performance even when the battery charge is low. Boost converters are crucial for maintaining speed, torque, and efficiency in EV operation.

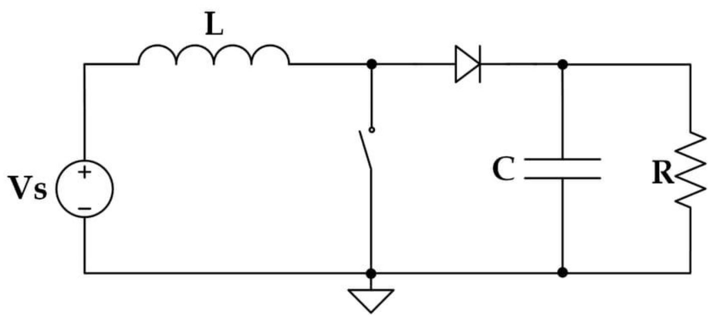

Fig 5.2: circuit diagram of Boost Converter(Step-Up)

Bidirectional Converters

In electric vehicles (EVs), bidirectional converters play a crucial role in managing energy flow between the battery and other vehicle components. These converters can transfer energy in both directions—from the battery to the motor for driving and from regenerative braking back to the battery for charging. They are used to adapt voltage levels efficiently, either stepping up or down DC voltage for the motor or auxiliary systems. The main types include bidirectional DC–DC converters, which manage voltage between the battery and vehicle systems, and bidirectional inverters (AC–DC), which convert battery DC to AC for motor operation and vice versa during regenerative braking. Their key benefits include enabling energy recovery through regenerative braking, improving overall energy efficiency, and supporting vehicle-to-grid (V2G) applications where the EV can supply energy back to the grid.

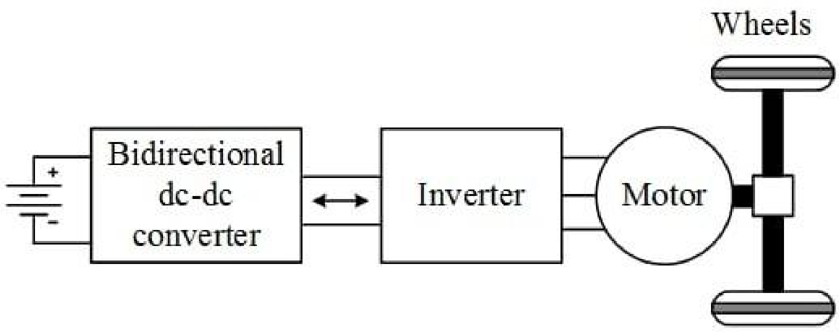

Fig 5.3: Block diagram of Bidirectional Converter

5.2 INVERTER

One of the cornerstones of an EV's power electronics is the traction inverter. At the most basic level, the traction inverter, as its name implies, is responsible for "inverting" the DC stored in the batteries to AC used by the motor to propel the vehicle.

However, the traction inverter's job doesn't just stop at conversion. It also plays a pivotal role in controlling the speed and torque of the electric motor. It does this by adjusting the frequency and amplitude of the AC current supplied to the motor. The frequency determines the speed at which the motor runs, while the amplitude affects the motor's torque. By carefully controlling these factors, the traction inverter dictates the vehicle's speed and acceleration.

Inside the robust casing of a traction inverter, we will find a complex array of Printed Circuit Boards (PCBs). These PCBs house numerous electronic components such as capacitors, resistors, and semiconductor devices like Insulated-Gate Bipolar

Transistors (IGBTs) or Silicon Carbide (SiC) transistors. Each of these components plays a critical role in controlling and managing the flow of electricity.

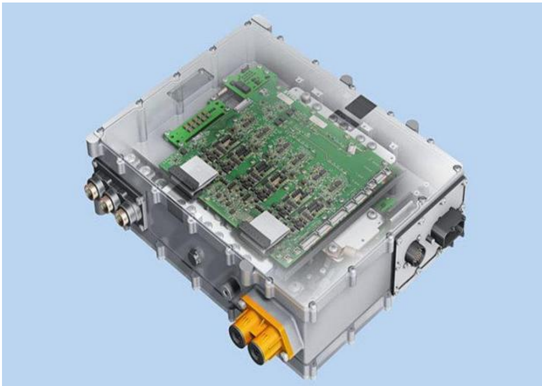

Fig 5.4: Inverter

The IGBTs or SiC transistors act as high-speed switches that turn on and off thousands of times per second. When these switches are off, the current doesn't flow, but when they're on, the current does flow, creating a 'pulse' of energy. By varying the width and frequency of these pulses (a technique known as pulse-width modulation), the inverter can create a waveform that closely mimics AC.

Considering the crucial role it plays, it's clear that the efficiency and reliability of the traction inverter can significantly impact an EV's performance. This is where Exro Technologies Inc. has made a game-changing contribution with its Coil Driver™ technology.

Exro's Coil Driver™ uses next-gen coil switching technology in its traction inverter to enhance EV performance. The coil switching technology makes it possible for electric motors to operate at optimal efficiency across a broader range of speeds and loads. In other words, it allows the motor to adapt to varying driving conditions in real-time, ensuring that the motor always operates at its highest efficiency. This results in increased energy efficiency, extended range, and overall improved performance of the vehicle.

5.3 VEHICLE CONTROL UNIT

Moving forward in our journey through the world of EV power electronics, we encounter the vehicle control unit. If we consider the traction inverter to be the 'heart' of an EV, converting and directing electrical power, then the vehicle control unit is the 'brain', controlling and coordinating all the vehicle's primary functions, offering complete control across the EV powertrain.

The vehicle control unit acts as the central communication hub for the vehicle, gathering and processing data from numerous sensors and controllers spread across the vehicle's systems. These could include components related to the electric motor, battery, and charging system, among others. After processing this data, the vehicle control unit determines the most efficient and effective response and sends out appropriate control signals.

For instance, when you press the accelerator, the vehicle control unit computes how much power is needed from the battery, communicates with the traction inverter to convert the right amount of energy, and ensures the motor receives it and delivers the torque to the wheels to provide the desired acceleration. Moreover, the vehicle control unit continuously optimizes vehicle performance, balancing power distribution, managing battery charging, and ensuring safety features function correctly.

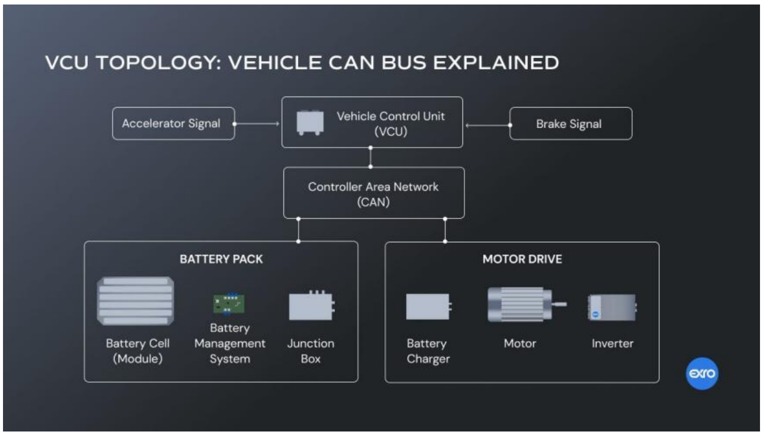

Fig 5.4: Vehicle Control unit

Considering the vehicle control unit's integral role, it's evident that having a robust and reliable vehicle control unit is paramount. Not only must the hardware be capable of handling complex tasks and high data volumes, but the embedded software also must be dependable and highly efficient.

Exro Technologies Inc. understands the importance of the vehicle control unit in the EV ecosystem. Exro Vehicle Systems (EVS) provides comprehensive vehicle control unit solutions designed for reliable and efficient performance to ensure seamless communication and coordination between all the components within the EV powertrain, facilitating optimum vehicle performance and safety.

5.4 POWER DISTRIBUTION UNIT

As our exploration of the intricate web of power electronics in EVs continues, we turn our focus to a key orchestrator behind the scenes: the power distribution unit. Often operating quietly and out of the spotlight, the power distribution unit plays a vital role in distributing and managing electrical energy within the EV's complex architecture.

The power distribution unit is responsible for handling the distribution of high-voltage electricity from the battery to various EV powertrain components such as the traction inverter. Its primary task is to ensure that each system receives the right amount of power, at the right voltage, and at the right time. This orchestration is crucial for optimizing performance, enhancing efficiency, and maintaining the overall health of the EV powertrain.

At its core, the power distribution unit is composed of intricate circuitry and power electronics. Its components, which include relays, switches, fuses, and sometimes advanced semiconductor devices, form a sophisticated network that carefully directs electrical currents. By intelligently routing energy to where it's needed most, the power distribution unit helps prevent overloading of certain systems while enabling others to operate at peak efficiency.

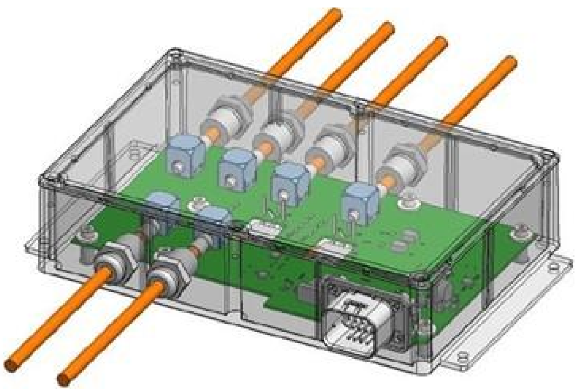

Fig 5.4: Power Distribution Unit

In a rapidly evolving EV landscape, the role of the power distribution unit becomes even more pivotal. As new technologies emerge and the demand for energy-efficient features increases, the power distribution unit must adapt to accommodate higher power levels and more intricate energy management requirements. Furthermore, the power distribution unit's ability to handle different voltage levels becomes increasingly important as EVs transition from traditional 400-volt battery systems to more advanced 800-volt architectures.

In the dynamic interplay of power electronics, the Power distribution unit ensures that every subsystem receives its designated share of energy, contributing to a harmonious and efficient driving experience.

5.5 REGENERATIVE BREAKING SYSTEM

In conventional internal combustion engine (ICE) vehicles, energy from braking is wasted as heat. When a driver applies the brakes, the kinetic energy of the moving vehicle is converted into heat through friction and dissipated into the atmosphere. In contrast, regenerative braking captures this energy and converts it into electricity that can be stored in the vehicle's battery.

Regenerative braking works by reversing the electric motor's function during deceleration. When the driver applies the brakes, the electric motor switches to generator mode, and instead of consuming energy, it generates it. The kinetic energy of the moving vehicle turns the motor, which then produces electrical energy, sending it back to the vehicle's battery. This process helps slow the vehicle down while also recovering energy that would otherwise be lost

HOW REGENERATIVE BREAKING SYSTEM WORKS ?

In an electric vehicle, the electric motor plays a dual role: it powers the wheels to drive the vehicle and acts as a generator to recover energy during braking. When the driver lifts their foot off the accelerator or applies the brakes, the regenerative braking system activates.

Here's a step-by-step breakdown of how the regenerative braking system works in an EV:

1. Deceleration Trigger: When the vehicle slows down, the energy that would normally be wasted through conventional friction brakes is harnessed. The electric motor, which powers the vehicle, switches to generator mode.
2. Kinetic Energy Conversion: As the vehicle decelerates, its kinetic energy (the energy of motion) is converted into electrical energy by the motor-generator. The motor's rotating components create a resistance, slowing the vehicle while generating electricity.

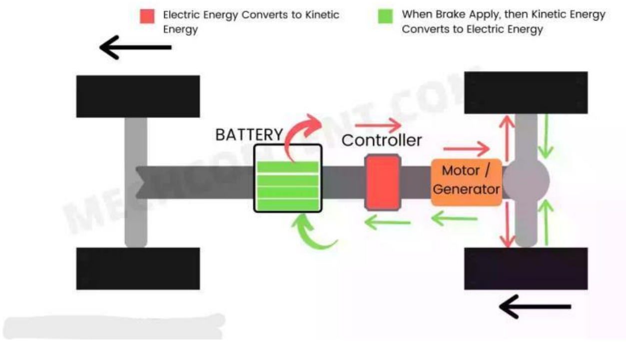

Fig 5.5: Configuration Diagram of Regenerative Breaking System

3. Energy Storage: The electricity generated during braking is sent to the EV's battery, where it is stored for later use. This recovered energy can be used to power the vehicle's systems or provide additional range.
4. Blended Braking: Many EVs use a combination of regenerative braking and traditional friction brakes. This is especially necessary in situations where rapid deceleration is required or when the battery is fully charged and cannot accept more energy. The onboard computer system intelligently manages the transition between regenerative and friction braking to ensure safe and smooth braking.

CHAPTER 6 - ENERGY EFFICIENCY AND PERFORMANCE ANALYSIS

Electric Vehicles (EVs) have emerged as one of the most promising solutions to address the growing concerns over fossil fuel depletion, greenhouse gas emissions, and environmental pollution. They play a vital role in transitioning from conventional internal combustion engine (ICE) vehicles to a cleaner, more sustainable mode of transportation. The efficiency and performance of an EV depend on its energy conversion system, battery technology, drivetrain configuration, and operating conditions. This report presents an analysis of the energy efficiency, energy consumption, power losses, and a comparison between EVs and ICE vehicles.

6.1 EFFICIENCY OF ELECTRIC VEHICLE SYSTEMS

Efficiency is one of the key advantages of electric vehicles. Unlike ICE vehicles that convert chemical energy from fuel into mechanical energy with significant losses, EVs directly convert stored electrical energy from the battery into mechanical power through an electric motor.

The electric motors used in EVs — such as Brushless DC (BLDC) motors, Permanent Magnet Synchronous Motors (PMSM), and Induction Motors — typically have efficiencies in the range of 85–95%, whereas ICE engines generally operate with efficiencies between 20–30%. The major reason for this difference is the absence of combustion and friction losses in electric systems.

Additionally, EVs feature regenerative braking systems, which allow the motor to function as a generator during braking. This process recovers kinetic energy that would otherwise be lost as heat in traditional braking systems, converting it back into electrical energy stored in the battery. The simplified drivetrain of an EV — with no gearbox, clutch, or exhaust system — further enhances its overall efficiency.

When evaluated from battery to wheel, the overall efficiency of electric vehicles is typically 70–80%, compared to around 25% for ICE vehicles. This high efficiency means that a larger portion of the energy drawn from the battery is effectively used for vehicle propulsion.

6.2 ENERGY CONSUMPTION PER KILOMETER

Energy consumption is a vital parameter in determining the performance and running cost of electric vehicles. It is usually expressed in kilowatt-hours per kilometer (kWh/km) and represents the amount of electrical energy consumed to travel one kilometer.

For small electric cars, the energy consumption typically ranges from 0.12 to 0.20 kWh/km, while for medium-sized vehicles, it ranges between 0.18 and 0.25 kWh/km. Larger vehicles like electric buses or trucks may consume 1.0 to 1.5 kWh/km due to their greater weight and load requirements.

Several factors influence energy consumption:

1. Vehicle Mass and Aerodynamics: Heavier vehicles require more energy for acceleration and climbing gradients.
2. Driving Conditions: Stop-and-go traffic, frequent acceleration, and high-speed driving increase energy usage.
3. Auxiliary Loads: Air conditioning, heating, lighting, and entertainment systems consume additional energy.
4. Battery Efficiency and Ambient Temperature: Extreme temperatures can reduce battery performance and increase energy consumption.

For example, if an EV consumes 0.18 kWh/km, it requires 18 kWh of energy to travel 100 km, which is significantly more efficient than a petrol vehicle consuming around 6 liters of fuel for the same distance.

6.3 POWER LOSSES AND MITIGATION

Power losses in electric vehicles occur at various stages of energy conversion, from the battery to the wheels. The main sources of losses include the battery, inverter, motor, and mechanical components. Battery losses arise due to internal resistance and heat generation during charging and discharging, which can be reduced by using high-efficiency lithium-ion or solid-state batteries along with advanced thermal management systems. Inverter and converter losses occur due to switching and conduction losses in power electronics, which can be mitigated by using wide bandgap semiconductors such as silicon carbide (SiC) and gallium nitride (GaN). Motor losses, including copper and core losses, can be minimized through optimized motor design, superior magnetic materials, and effective cooling methods. Mechanical losses from friction in bearings and tires can be reduced by employing lightweight materials and low-friction components. Overall, reducing these losses improves vehicle range, performance, and energy efficiency.

MITIGATION TECHNIQUES

Mitigation of power losses in electric vehicles focuses on improving efficiency through advanced materials and smart control systems. Electrical losses are reduced by using high-conductivity materials, wide bandgap semiconductors (SiC, GaN), and efficient battery management systems. Magnetic losses are minimized with laminated steel cores and optimized motor design. Mechanical losses are lowered using low-friction bearings, lightweight parts, and proper tire maintenance. Effective thermal management with liquid cooling prevents overheating, while optimized regenerative braking and energy storage systems enhance energy recovery. Together, these methods significantly improve EV performance, range, and reliability.

CHAPTER 7 : ENVIRONMENTAL IMPACTS

7.1 ENVIRONMENTAL AND ECONOMIC IMPACT

1. REDUCTION IN CO_2 EMISSIONS

Battery electric vehicles (BEVs) generally produce lower lifecycle CO_2 emissions than equivalent petrol vehicles, although the exact saving depends strongly on the electricity grid mix and real-world driving patterns. A recent meta-analysis of Indian studies found BEVs can emit up to ~38% less CO_2 than petrol cars on a life-cycle basis under typical Indian conditions, while noting substantial variability driven by grid carbon intensity and driving assumptions. This means EV adoption—when paired with cleaner electricity—can deliver meaningful emissions reductions at the fleet level.

2. ENERGY CONSUMPTION COMPARISON

Electric drivetrains are far more efficient at converting stored energy into wheel motion than internal-combustion engines. Typical EVs convert a large share of electrical energy to propulsion (often cited >70% overall system efficiency including regenerative braking), while petrol engines typically convert under 30–35% of the fuel's chemical energy to motion, the rest being lost as heat. In practical terms this means an EV that uses ~15–20 kWh/100 km often outperforms a petrol car that consumes ~5–7 L/100 km (one litre of petrol ≈ 8.9 kWh of energy), so the electric option is significantly more energy-efficient per km.

3. COST ANALYSIS

Running cost (cost per km):

Multiple Indian studies and market analyses show EVs — especially two-wheelers — have lower operating costs. For example, electric two-wheelers in India can cost around ₹1.5/km vs ~₹2.4/km for petrol scooters, reflecting lower energy (electricity) cost per km and cheaper servicing. For cars the savings per km are also significant but depend on vehicle class and local electricity/fuel prices.

Maintenance:

EVs have fewer moving parts (no oil changes, simpler transmission, less brake wear due to regenerative braking) and typically have lower routine maintenance costs. Five-year maintenance cost estimates often put EVs substantially below petrol counterparts, though warranty packages and local service availability matter.

Battery replacement:

Battery packs are the largest long-term cost concern. Typical battery lifetimes are quoted at 7–10 years or around ~1.5 lakh km depending on use and climate. Replacement today can cost several lakhs (₹3–6+ lakh) for larger car packs, though prices are falling and many OEMs offer 8-year warranties that mitigate near-term replacement risk. Battery second-life, recycling and declining pack costs are important factors that will reduce total ownership cost over time.

7.2 CHALLENGES IN EV ADOPTION

Despite the rapid progress in electric vehicle (EV) technology, their widespread adoption still faces several challenges that affect consumers, manufacturers, and policymakers alike. The key barriers include high initial cost, limited driving range, longer charging times, inadequate charging infrastructure, and concerns related to battery disposal and recycling. Addressing these challenges is essential for ensuring a sustainable transition to electric mobility in India and globally.

1. High Initial Cost

One of the primary barriers to EV adoption is the high upfront purchase cost compared to conventional internal combustion engine (ICE) vehicles. The major reason lies in the battery pack, which can account for 30–40% of the total vehicle cost. Although lithium-ion battery prices have dropped significantly over the past decade (from over $1,000/kWh in 2010 to around $150/kWh in 2025), they still make EVs more expensive than petrol or diesel vehicles of similar capacity. In India, even after subsidies under the FAME-II scheme and state-level incentives, EVs often have higher sticker prices, which discourages cost-sensitive buyers. However, the total cost of ownership (TCO) over time tends to be lower due to reduced fuel and maintenance expenses, though consumers often focus on initial affordability rather than long-term savings. Further reductions in battery cost and local manufacturing through programs like "Make in India" and the Production Linked Incentive (PLI) scheme for advanced chemistry cells will be crucial to make EVs more price-competitive.

2. Limited Range

Range anxiety — the fear that an EV will run out of charge before reaching a destination — remains a significant psychological and practical barrier. Most affordable EVs in India, especially two-wheelers and compact cars, offer a real-world driving range of 100–300 km per full charge, depending on battery capacity, terrain, and usage patterns. While this range is adequate for daily urban commuting, it poses challenges for long-distance travel, especially in regions with underdeveloped charging networks. Factors such as air conditioning use, driving speed, payload, and terrain can further reduce effective range. Although technological advancements are improving energy density and efficiency, the need for higher-capacity batteries and fast-charging networks remains critical to overcome this limitation.

3. Charging Time and Infrastructure Limitations

Unlike petrol refueling, which takes only a few minutes, charging an EV can take anywhere from 30 minutes (fast DC charging) to several hours (home AC charging). The lack of widespread and reliable public charging stations in many parts of India limits the convenience of EV ownership. Urban areas such as Delhi, Bengaluru, and Hyderabad have seen a rise in charging points, but rural and semi-urban regions still face scarcity. Additionally, the existing power distribution networks may require significant upgrades to handle increased loads from widespread EV adoption. Challenges also exist in standardizing charging connectors, payment systems, and interoperability between different charging providers. Governments and private companies are working to establish more fast-charging corridors along highways and public spaces, but until a dense and reliable charging network is achieved, range anxiety and charging delays will continue to discourage buyers.

4. Battery Disposal and Recycling Issues

As EV adoption grows, battery waste management becomes a critical environmental concern. Lithium-ion batteries contain valuable materials such as lithium, cobalt, nickel, and manganese, but also pose risks of toxic leakage and fire hazards if not properly recycled or disposed of. India currently lacks a large-scale, efficient battery recycling ecosystem, with only a few authorized recyclers operating under strict environmental norms. The recovery and reuse of raw materials from used batteries can reduce dependence on imported minerals and lower production costs, but this requires technological and regulatory support. The Battery Waste Management Rules (2022) introduced by the Indian government aim to enforce Extended Producer Responsibility (EPR), making manufacturers responsible for the collection and recycling of used batteries. Developing a circular battery economy — where batteries are reused, repurposed for stationary storage, and finally recycled — will be key to ensuring sustainability in the EV sector.

7.3 COMPARISION BETWEEN EV&IC ENGINE VEHICLE

EVs vs. ICE: The Future of Efficiency, Reliability, and Cost

Aspect	EVs (Electric Vehicles)	ICE Vehicles (Internal Combustion Engine)
Maintenance Costs	**$300-$500/year** for routine checks and minor repairs.	**$1,200-$2,000/year** including oil changes, engine repairs, and exhaust fixes.
Oil Changes	**0 per year** (not required).	**3-4 per year** on average, costing **$50-$100 per oil change**.
Transmission System	**Single-speed** transmission, minimal repair risk.	**Multi-speed** transmission, prone to wear and can cost **$1,500-$4,000** for repairs.
Reliability	Average lifespan of **15-20** years with fewer breakdowns.	Average lifespan of **10-15 years**, with more frequent engine-related repairs.
Total Cost of Ownership	Lifetime savings of **$6,000-$10,000** in maintenance and fuel compared to ICE.	Higher total cost due to fuel and maintenance, **$8,000+** more than an EV over the vehicle's lifespan.
Key Component Lifespan	Battery warranties often cover **8-10 years** or **100,000-150,000 miles**.	Engines often need major repairs or replacements after **100,000-150,000 miles**.
Efficiency (MPGe vs. MPG)	Typical EVs average **100-120 MPGe** (miles per gallon equivalent).	ICE vehicles average **20-30 MPG** depending on model.
Noise and Driving Comfort	EVs produce **50-60 dB** during operation, significantly quieter.	ICE vehicles typically produce **70-90 dB** depending on engine type and speed.
Risk of Component Failure	No exhaust system or catalytic converter to fail.	Exhaust systems need replacement every **5-7 ye**ars, costing **$600-$2,000**.
Durability	Fewer mechanical issues result in **25-30% fewer repairs** over vehicle lifespan.	Higher wear and tear lead to more frequent breakdowns and part replacements.
Environmental Impact	Zero tailpipe emissions, reducing carbon footprint by **4.6 metric tons per year.**	Produces **4.6 metric tons of CO2 per year** on average.
Noise Pollution	Quiet operation reduces city noise by **30-40%**.	Contributes significantly to urban noise pollution.
Repair Simplicity	Repairs generally take **20-40% less time** due to fewer parts.	More complex repairs take longer due to the number of mechanical components.
Space Efficiency	**10-20% more cabin/cargo space** due to the absence of a traditional engine and exhaust.	Engine and transmission take up more space, reducing interior/cargo volume.
Battery vs. Fuel System	Batteries typically last **8-15 years**, cost of replacement ranges from **$5,000-$15,000**.	Fuel systems degrade, needing parts like fuel injectors and filters replaced every **5-7 years**.

CONCLUSION

The internship on Electric Vehicles (EVs) provided a deep understanding of their technology, working principles, and growing importance in modern transportation. EVs have emerged as an efficient and eco-friendly alternative to conventional internal combustion engine vehicles, offering benefits such as zero emissions, low maintenance, and high energy efficiency. The study covered key components including batteries, motors, converters, and control systems, highlighting advancements like regenerative braking and bidirectional converters that enhance performance and efficiency.

Although challenges such as high initial cost, limited driving range, and inadequate charging infrastructure still exist, ongoing technological developments and supportive government initiatives like the FAME-II scheme are rapidly improving the EV ecosystem. Overall, Electric Vehicles play a vital role in achieving sustainable mobility, reducing environmental pollution, and promoting a cleaner, greener future. This internship has strengthened both theoretical and practical knowledge, inspiring further exploration in the field of electric mobility.