ELECTRIC VEHICLES

IV SEMESTER,

By Smt.Loveleena
IC Department
(Sr.Lecturer G.P Umri,KKR)

Instrumentation & Control Engg.Deptt
Govt.Polytechnic Umri,KKR

Syllabus (Electric Vehicles)

UNIT I

Electric Vehicle Machines

Classification of the electric vehicles, understanding electric drivetrain PMSM, PMBLDCM, SRM, synchronous reluctance motor, induction motor for EVs Social and Environmental importance of Hybrid and Electric Vehicles; Components, Vehicle mechanics: Roadway fundamentals, Vehicle kinetics.

UNIT II

Electrochemical Cells

Energy storage devices such as Li-ion battery, supercapacitor, fuel cells, and flow batteries at cell level, Battery Management strategies. Battery State of Charge Estimation, Battery Cell equalization problem, thermal control, protection interface, Energy & Power estimation, battery testing, Battery Leakage, Causes of battery explosions, Thermal Runway: High discharge rates, Short circuits, charging and discharging, Battery Standards

UNIT III

Power Electronics Interface

Analysis, modelling, design and control of switched-mode power converters, On-board Charger (AC/DC), Traction Inverter (DC/AC), battery DC-DC converters. Charging Infrastructure Classification of EV charging infrastructure- AC chargers, DC chargers and Inductive charging. Indian and international standards for dc and ac EV charging.

UNIT IV

Hybrid Electric Vehicles: Types: Parallel, Series, Parallel and Series configurations; Drivetrain; Sizing of components; Basics of Micro, Mild, Mini, Plug-in and Fully hybrid.

Overview of Policies Government policies relevant to electric vehicles.

Unit -1

Electric Vehicles Machine

Electric Vehicles -Electric vehicle is a vehicle that uses one or more electric motors for propulsion. It can be powered by a collector system, with electricity from extravehicular sources, or it can be powered autonomously by a battery (sometimes charged by solar panels, or by converting fuel to electricity using a generator (often known as a hybrid) or fuel cells.

Classification of the Electric vehicles- There are four types of Electric Vehicles

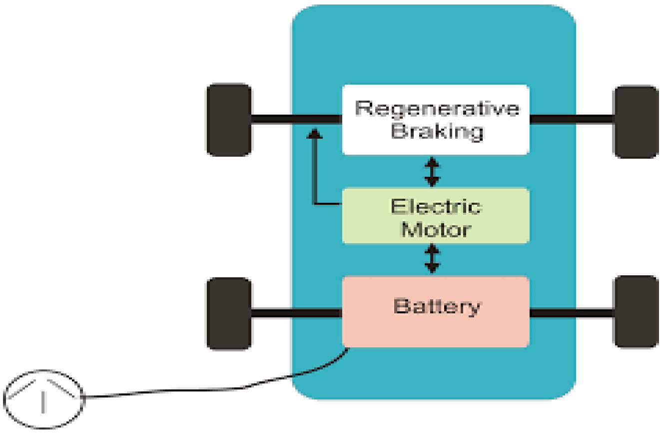
1. BEV (Battery Electric Vehicle)

2. HEV (Hybrid Electric Vehicle)

3. FCEV (Fuel Cell Electric Vehicle)

4. PHEV (Plug-in Hybrid Electric Vehicle)

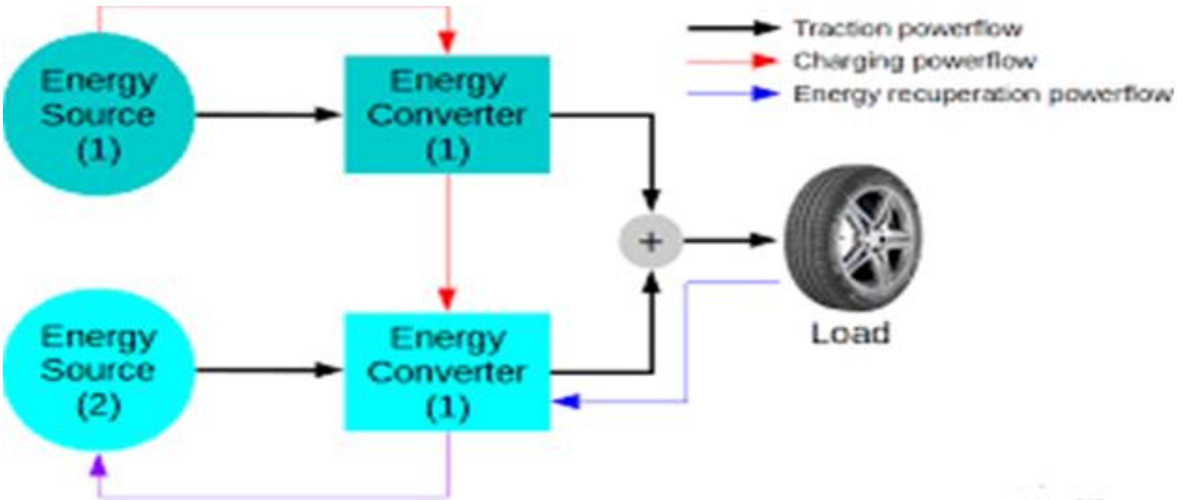
1. BEV (Battery Electric Vehicle)-Vehicles powered solely by one or more electric batteries are known as BEVs. They are more popularly called EVs. Chargeable batteries power then and there is no IC engine (petrol or diesel-powered). All the power comes from the battery pack, which is chargeable from the electricity grid. The charged battery pack sends power to one or more electric motors to move the vehicle.



Components of BEV

- Battery pack
- Electric motor(s)
- Inverter
- Control module
- Drive train
- Charge port

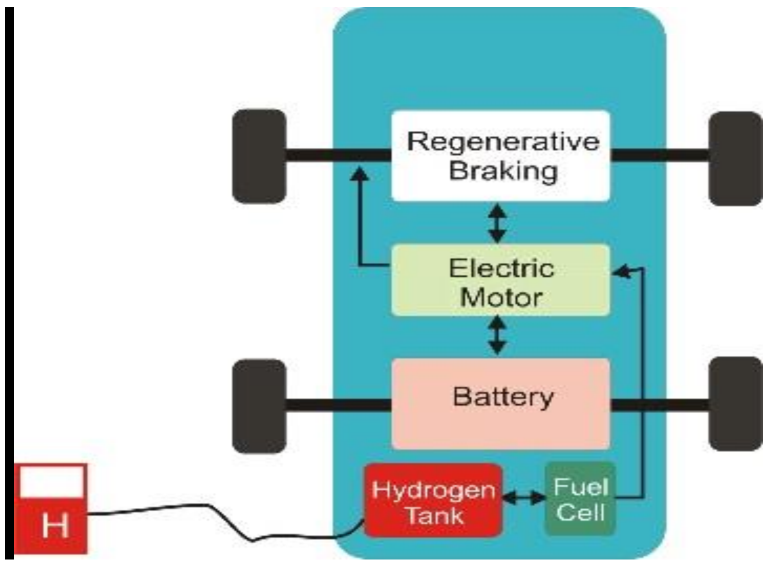
2. HEV (Hybrid Electric Vehicle)-HEVs use an IC engine and an electric motor. The latter derives power from the electricity stored in a battery pack. The main difference between pure EVs and HEVs is that the HEV's battery pack is charged through regenerative braking and engine power, not the regular electric charger. The stored power enables the electric motor to assist the IC engine in various forms, such as longer driving range



Components of HEVs

- Internal Combustion Engine
- Electric motor(s)
- Battery pack
- Inverter
- Control module
- Drive train
- Fuel tank
- Charge port

3. FCEV (Fuel Cell Electric Vehicle)-FCEVs, also known as Fuel Cell Vehicles (FCVs), are a type of EV that utilise 'fuel cell technology' to generate electricity and charge the battery pack. They use the same system as a standard EV powered by one or more electric motors. FCEVs have a gas tank to store hydrogen and can be fueled up within minutes, similar to petrol and diesel powered vehicles.



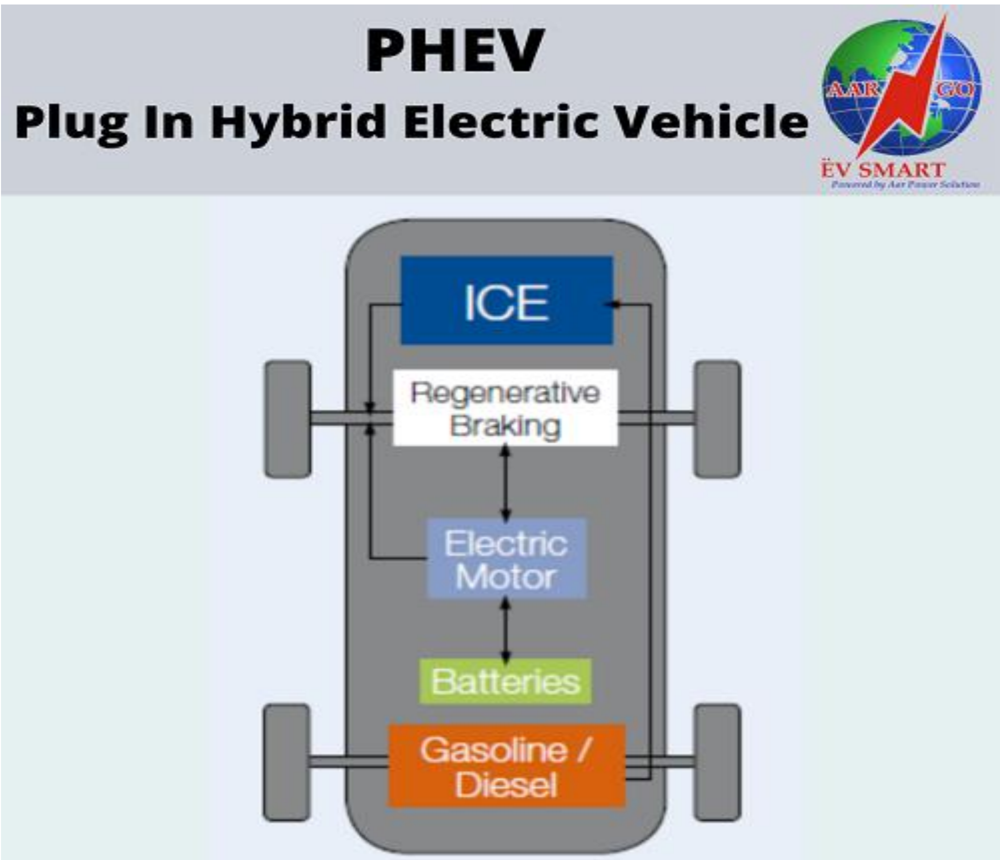
Components of FCEV

- Battery pack
- Electric motor(s)

- Inverter
- Control module
- Drive train
- Fuel cell stack
- Fuel tank

4. PHEV (Plug-in Hybrid Electric Vehicle)-

PHEVs are an extended form of HEVs. They have an internal combustion engine and an electric motor. However, the latter receives power from a chargeable battery, unlike standard HEVs. These types of electric vehicles usually have bigger and more powerful electric motors compared to the standard HEVs.

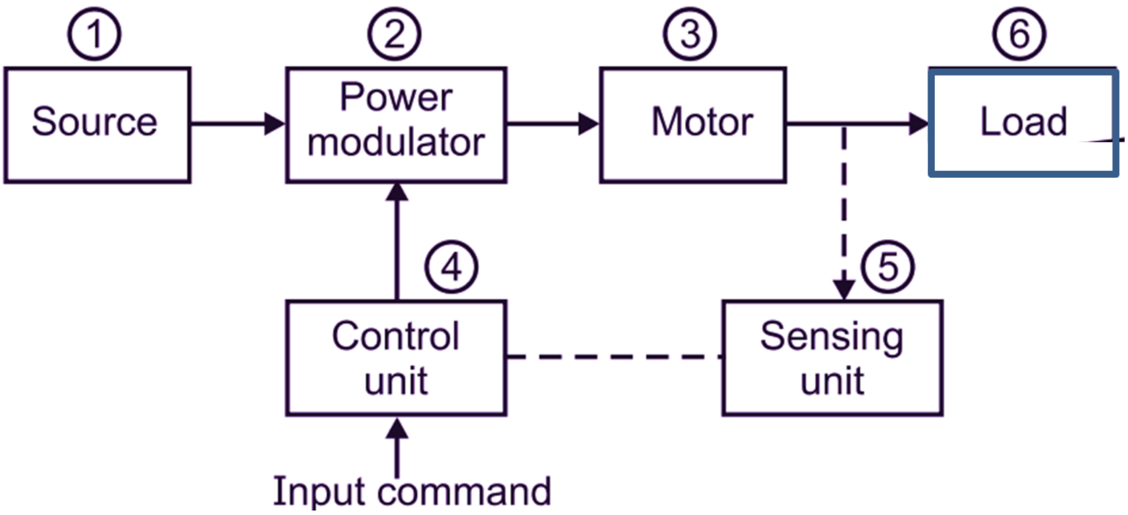


Components of PHEVs

- Internal combustion engine

- Electric motor(s)
- Battery pack
- Inverter
- Control module
- Drive train
- Fuel tank
- Charge port
- Exhaust system

Understanding of Electric drivetrain- The primary electric drivetrain components for fuel cell vehicles are the same as those for any electric vehicle: traction motors, power electronics, and batteries. Electric drive components require their own sets of auxiliaries and management systems, for control and cooling of the equipment.



In EVs, the drivetrain system plays a crucial role as it connects the electric motor, the primary power source, directly to the wheels. Unlike in traditional combustion engine vehicles, where the engine's power must be converted before it can be used to move the vehicle, the electric drivetrain allows for a more efficient and direct power transfer, contributing significantly to EVs' overall efficiency and performance.

The electric vehicle drivetrain system is responsible for delivering power from the battery to the wheels. It is made up of several different moving parts. However, they all fall into the three main components: the electric motor, drive shafts, and transmission.

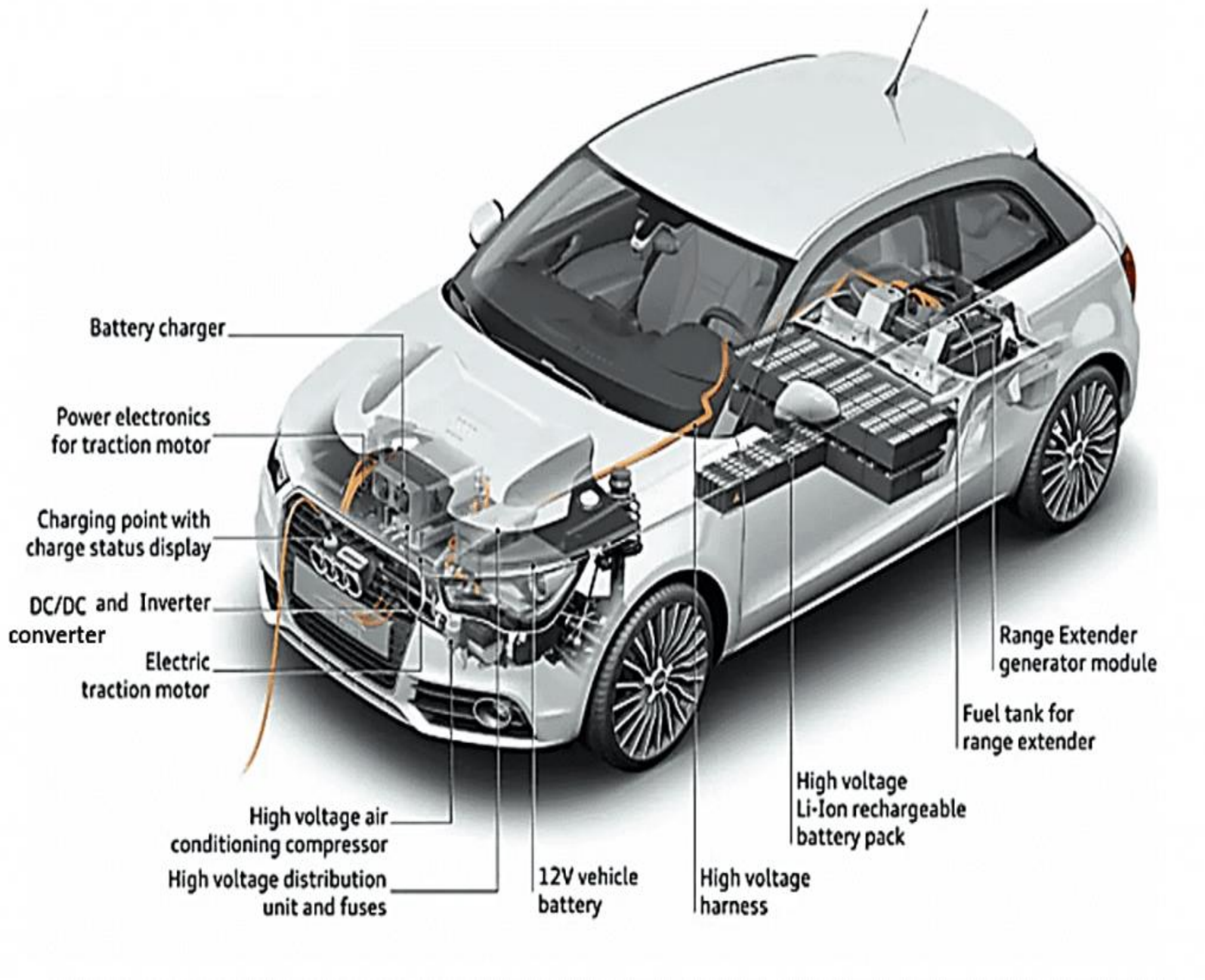
Permanent Magnet Synchronous (PMSM)-PMSM motor Permanent Magnet Synchronous Motor is a type of Permanent Magnet Motor widely used in Electric vehicles. PMSM motors are up to 15 percent more efficient than Induction motors and are the most power-dense type of traction motors.

The electric motor or engine is the part of the system producing the power. It produces usable torque at about 1,200 RPM and peak torque at around 2,500 to 4,000 RPM. It also has an upper usable speed limit of 5,000 to 7,000 RPM. The electric motor is connected to the drive shafts connected to the wheels.

The latest PMSM motors are being used in today’s Electric vehicles (EV) and Hybrid Electric Vehicles (HEV).

Main Components of Electric Vehicles:

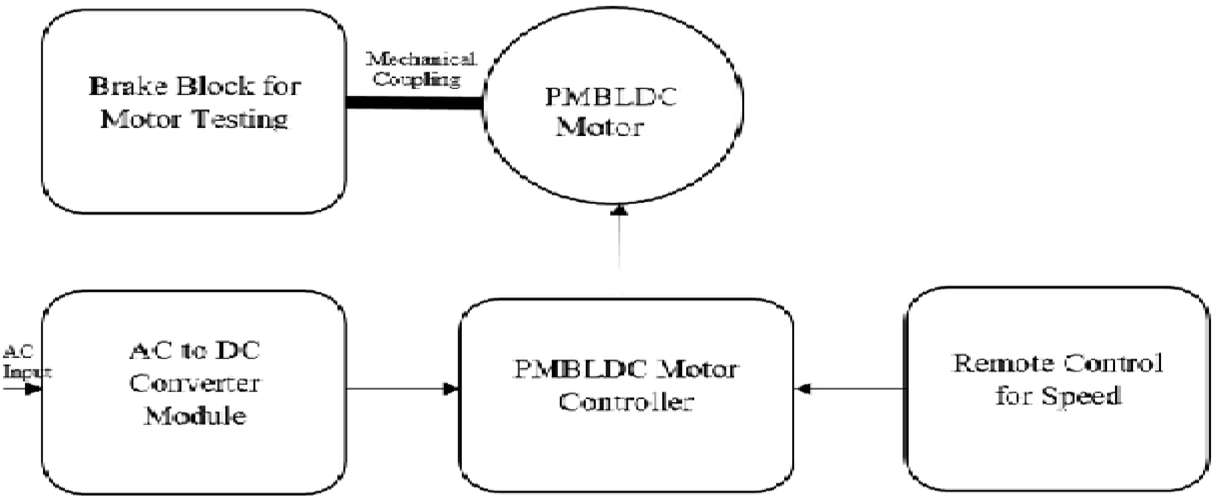
- Traction Battery Pack
- DC-DC Converter
- PMSM Motor
- Power Inverter



- Charge Port
- On-board Charger
- Power Electronics Controller
- Thermal System (Cooling)
- Transmission unit

Permanent magnet brushless DC motor (PMBLDCM)-

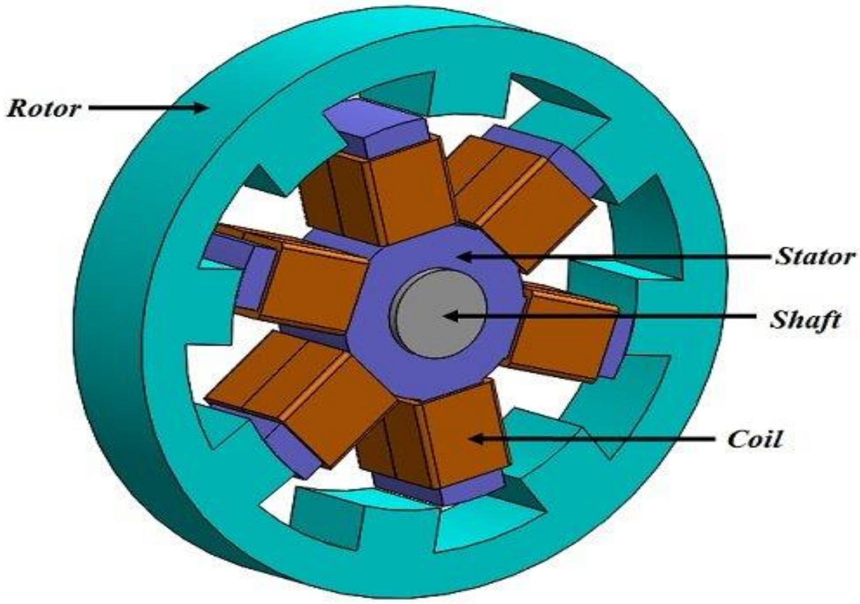
Permanent magnet brushless motor drive system has become the mainstream form of electric vehicle drive motor more and more because of its high efficiency, high power and high reliability. However, it also has problems such as high cost of permanent magnet materials and unadjustable magnetic flux. In recent years, research and development of electric vehicle motor drive systems have focused on permanent magnet brushless motors, which are expected to make full use of hydromagnetic materials and adjust air-gap magnetic fluxes, thus proposing various motor topologies. According to the stator working current and no-load back EMF waveform, permanent magnet brushless motors can be divided into permanent magnet brushless AC motors (BLAC, permanent magnet synchronous motors for short) and permanent magnet brushless DC motors (BLDC). Among them, BLDC has the advantages of simple control, low cost, and the elimination of speed sensors and position sensors, but it has inherent electromagnetic pulsation in principle, which is easy to generate noise at high speed, and it is difficult to obtain stable torque at low speed.



Therefore, BLDC is only used in the accessory systems of hybrid electric vehicles (such as electric pumps, air conditioner compressors, etc.). In comparison, permanent magnet synchronous motors have the advantages of high power and torque density (light weight, small volume, and large torque), high speed, wide speed regulation range, and high efficiency, and are widely used in the electric drive system of most hybrid vehicles.

Switched Reluctance Motor (SRM)-

The switched reluctance motor (SRM) is a type of motor doubly salient with phase coils mounted around diametrically opposite stator poles. There are no windings or permanent magnets on the rotor. The rotor is basically a piece of (laminated) steel and its shape forms salient poles. The stator has concentrated coils. Switched reluctance motors (SRM) have a simple and robust structure, thus they are generally suitable for high-speed applications. High-speed motors have the advantage of high power density, which is an important issue of traction motors in electric vehicles (EV). Therefore, high speed SRM seems to be promising candidates for this application.



The switched reluctance motor

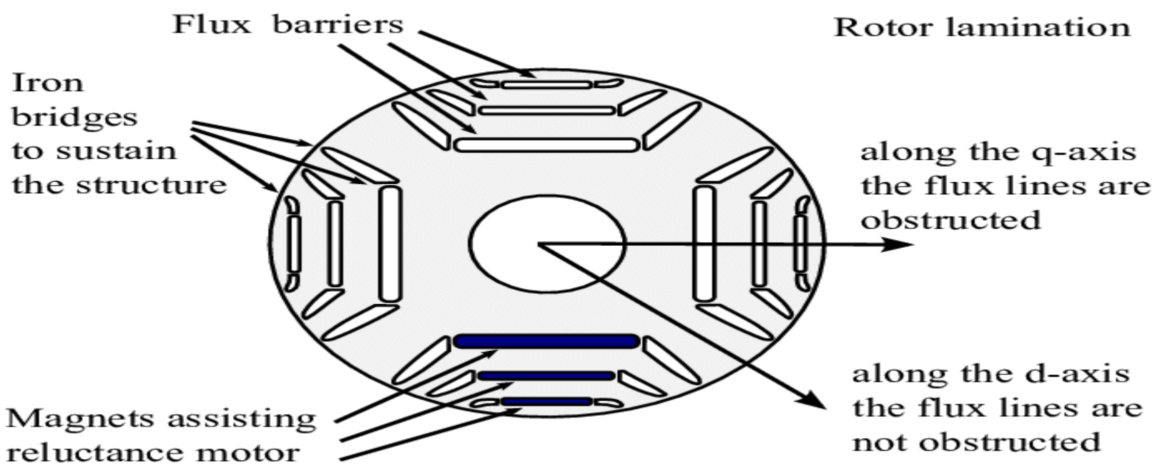
The Synchronous Reluctance Motor-

SRM is becoming of great interest in the recent years and represents a valid alternative for electric and hybrid vehicles due to its simple and rugged construction. The main advantage of the Syn.RM relies on the absence of the rotor cage losses or PM losses, allowing a continuous torque higher than the torque of an Induction Motor (IM) of the same size. Other important features are:

1. The rotor is potentially less expensive than PM motors and IM ones;

2. The specific torque is acceptable and it is not affected by the rotor temperature;

3. The field-oriented control algorithm is simpler with respect to the one of IM drives.



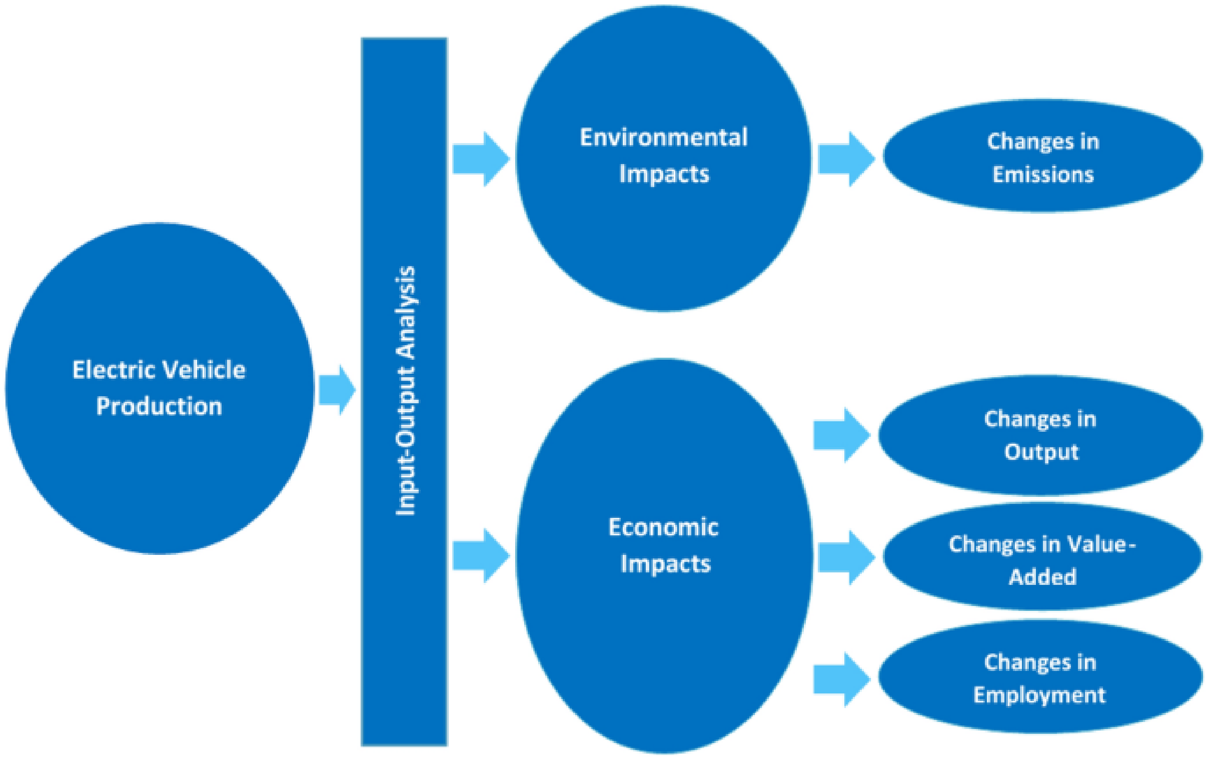
SRM

Social & Environmental importance of Hybrid and Electric Vehicles-

Benefits of electric vehicles on the environment are followings.

1. The development of electric vehicles (EVs) can aid in the reduction of CO2 emissions and demand for petroleum goods. However, the benefits of replacing internal combustion engine (ICE) automobiles with EVs might occasionally be negated by comparatively higher air pollutant emissions from manufacturing plants. But the greatest advantage occurs from not driving an ICE automobile and avoiding local combustion-related pollution.

2. EVs can produce zero direct emissions.



3. Full electric vehicles don't need a tailpipe, as they don't produce emissions. Traditional machines combust gasoline or diesel, creating energy at the cost of producing dangerous carbon emissions.

4. The EVs are fully emission-free. The most common type of battery placed in EVs is the lithium-ion battery. These batteries can be depleted and charged constantly without contributing to air pollution.

5. Even when using fossil fuels, EVs contribute smaller emissions than ICE vehicles. Many electric charging stations use renewable energy to charge EVs. Still, some are powered by charcoal-burning and are thus considered dangerous to the environment

6. Although EVs don't contribute much too state pollution on the road, manufacturing EV batteries can be dangerous if done irresponsibly. Nearly all EV emissions are well-to-wheel emissions created during the battery production process.

As EVs are still a newer technology, industry standards are inconsistent with the batteries, resulting in larger carbon energy sources used for making footprints. But, this scenario has begun to change.

7. One of the major obstacles that EV manufacturers are facing, is producing a functional yet lightweight vehicle. Lighter EVs have a lesser range and lower carbon footprint, but traditional materials make it tricky to achieve this. Still, recycled and organic materials are now similar to traditional materials.

8. Electric motors are relatively much quieter, especially when compared to ICE cars and exhaust systems, and thus produce less noise pollution. While gas and diesel cars may be equipped with silencers to reduce noise, the exhaust headers are frequently louder than the standard equivalents.

9. According to research, EVs generate considerably lower emissions over their lifetime than conventional (Internal Combustion Engine) vehicles.

10. Electric motors are relatively much quieter, especially when compared to ICE cars and exhaust systems, and thus produce less noise pollution. While gas and diesel cars may be equipped with silencers to reduce noise, the exhaust headers are frequently louder than the standard equivalents.

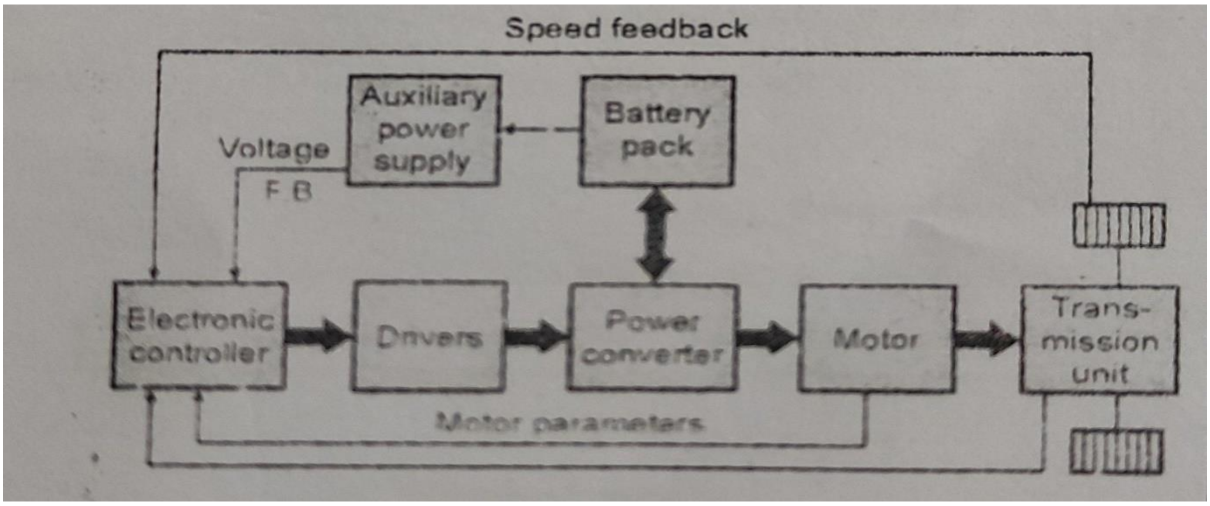
Q.What are the fundamentals of an electric vehicle?

Ans- EVs run on electricity alone. They are powered by one or more electric motors and a battery. The battery is charged by plugging the vehicle into an electric power source and through regenerative braking. PHEV's (Plug in hybrid electric vehicle) can travel moderate distances on electricity alone

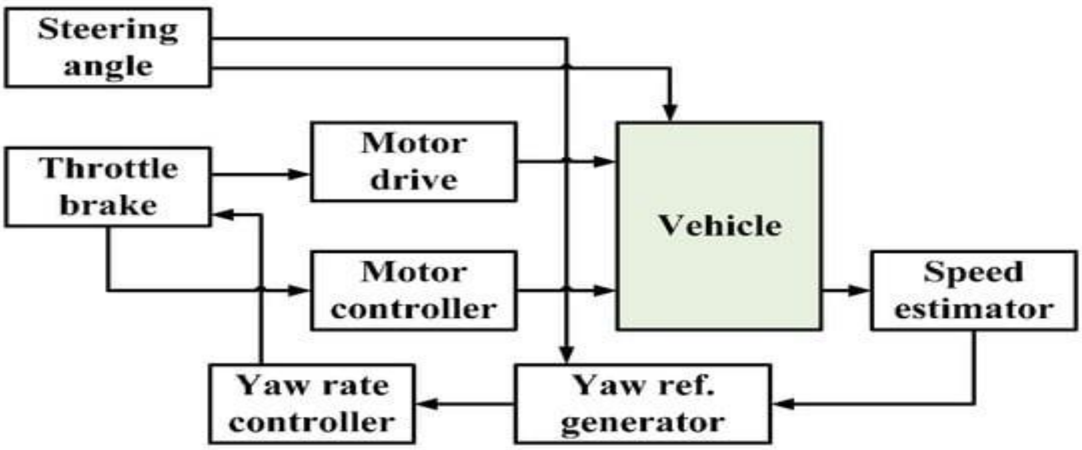
Electric Vehicle Kinetics-

Electric cars work on the principle of transforming electric energy into mechanical energy, which is then used to obtain kinetic energy and enable motion in a vehicle. EVs feature an electric motor instead of a conventional fuel engine.

- Motor
- Power converter
- Electronic controller
- Auxiliary power supply
- Battery
- Transmission Unit
- Drivers



Electric Vehicle Kinetics



Electric Vehicle Kinetic

MCQ Type Questions

Q1. Permanent magnet motors with sinusoidal air gap flux distribution are called

a) Permanent Magnet Synchronous Motors

b) Brushless DC motors

c) Brushless AC motors

d) Permanent Magnet induction Motors

Q2. Which of the following is not a power source combination for Hybrid electric Vehicles

a) ICE and Battery

b) Battery and Ultra capacitor

c) Diesel and ICE

d) Battery and Fuel Cell

Q3.___________Vehicles are powered by battery only

a) Conventional

b) EV

c) HEV

d) PHEV

Q4. Over the years application of which motor to EV and HEV is limited

a) Induction Motor

b) BLDC

c) PMSM

d) SRM

Q5. Permanent magnet motors with trapezoidal air gap flux distribution are called

a) Permanent Magnet Synchronous Motors

b) Brushless DC motors

c) Brushless AC motors

d) Permanent Magnet induction Motors

Short Answer type questions

Q1.What is EV?

Q2.What are the basic components of EV?

Q3. What are the basic components of HEV?

Q4. What are the basic components of PHEV?

Q5. What are the fundamentals of an electric vehicle?

Long Answer type questions

Q1.Define the different types of electrical vehicle.

Q2. Draw the schematic of general configuration of electrical subsystem of anElectric Vehicle (EV) and a Hybrid Electric Vehicle (HEV).

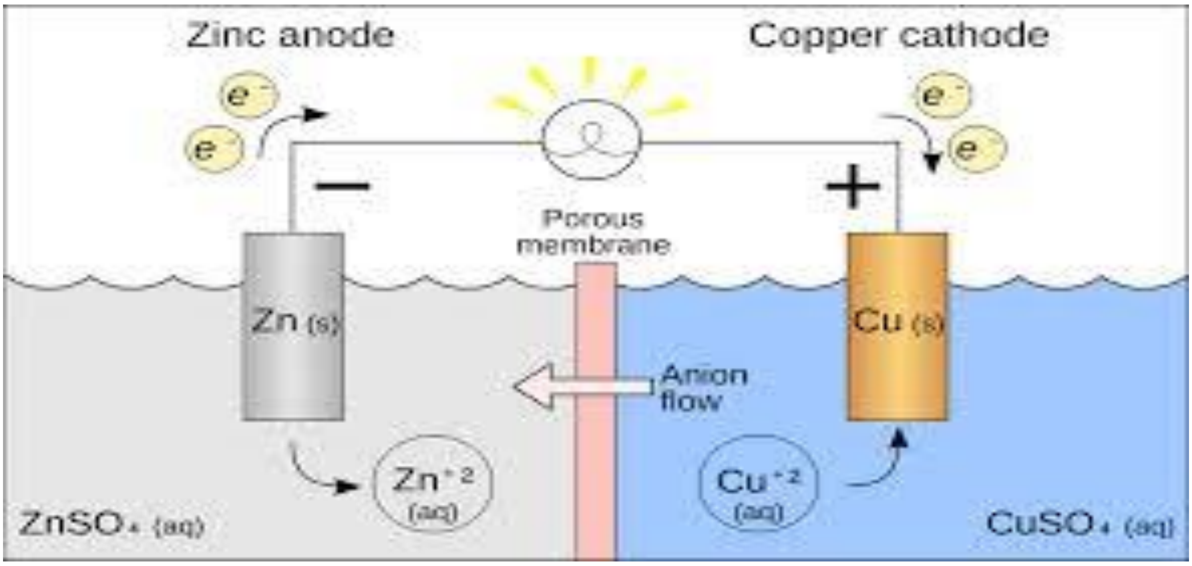
Q3. Write the Social & Environmental importance of Hybrid and Electric Vehicles.

Q4. Define the working of Permanent magnet brushless DC motor (PMBLDCM) in EV.

Unit-2

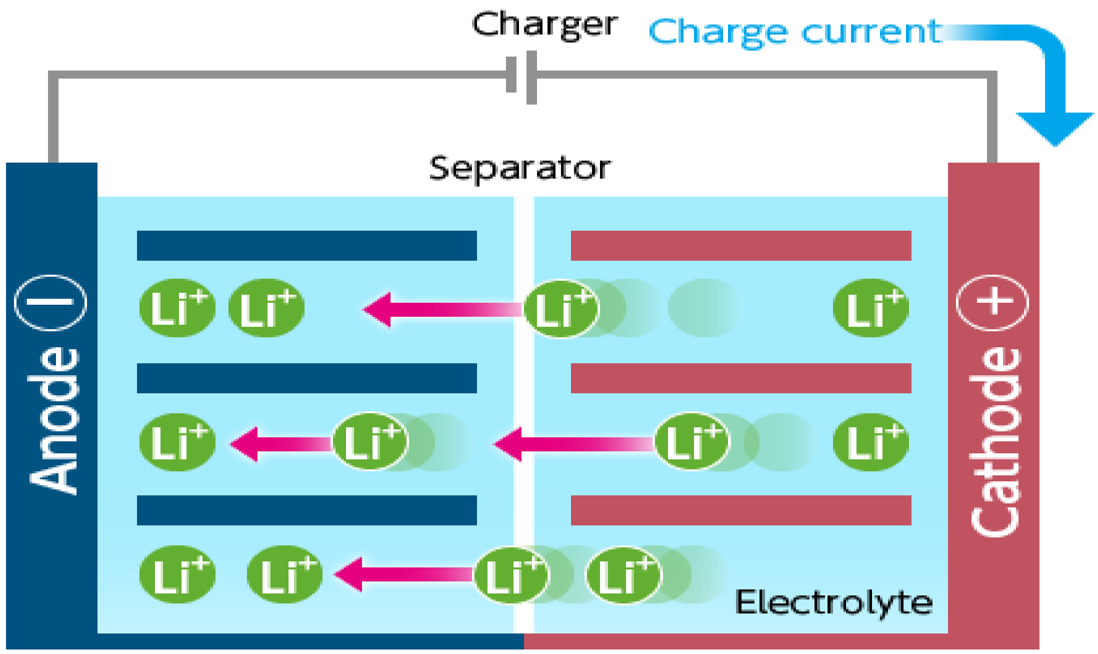
Electrical Vehicle

Electrochemical cell-Electrochemical Cell is a device that may either generate electrical energy from chemical reactions or use electrical energy that is supplied to it to speed up chemical reactions. There are various types of electrochemical cells and they are used in our daily activities such as cells that are used in Watches, TV remotes, Clocks, etc.



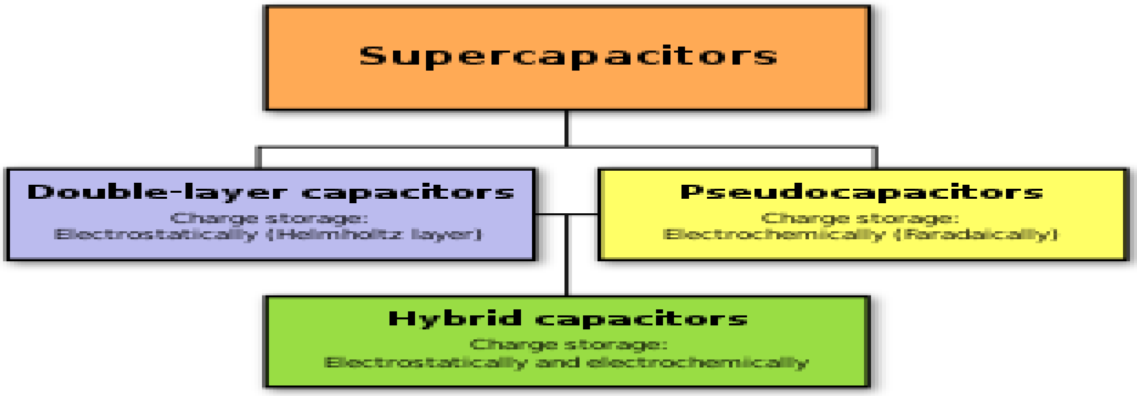
Cathode	Anode
Denoted by a positive sign since electrons are consumed here	Denoted by a negative sign since electrons are liberated here
A reduction reaction occurs in the cathode of an electrochemical cell	An oxidation reaction occurs here
Electrons move into the cathode	Electrons move out of the anode

Energy stored device lithium ion battery-Energy is stored and released as lithium ions travel between these electrodes through the electrolyte. The charger passes current to the battery. Lithium ions move from the cathode to the anode through the electrolyte. The battery is charged by a potential difference between the two electrodes.



More specifically, Li-ion batteries enabled portable consumer electronics, laptop computers, cellular phones, and electric cars, or what has been called the e-mobility revolution. It also sees significant use for grid-scale energy storage as well as military and aerospace applications.

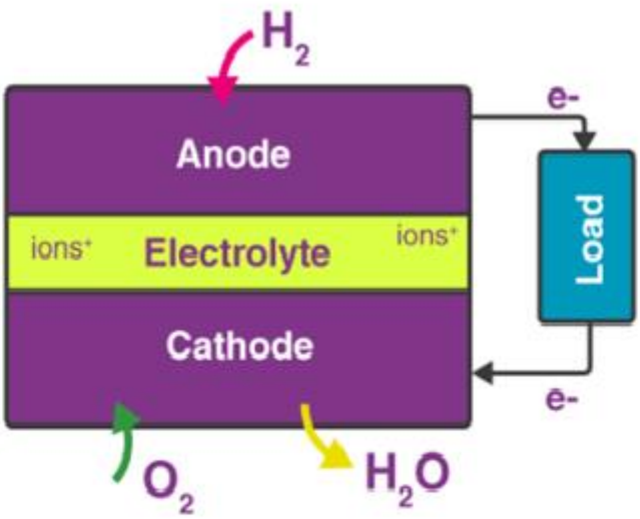
Supercapacitors- Supercapacitors are a type of an electrochemical energy storage systems which have great power density and specific capacitance. These systems have the ability to efficiently release energy with a high density over a relatively short time.



supercapictors

Fuel Cell- A fuel cell can be defined as an electrochemical cell that generates electrical energy from fuel via an electrochemical reaction.

Fuel cells require a continuous input of fuel and an oxidizing agent (generally oxygen) in order to sustain the reactions that generate the electricity. Therefore, these cells can constantly generate electricity until the supply of fuel and oxygen is cut off.

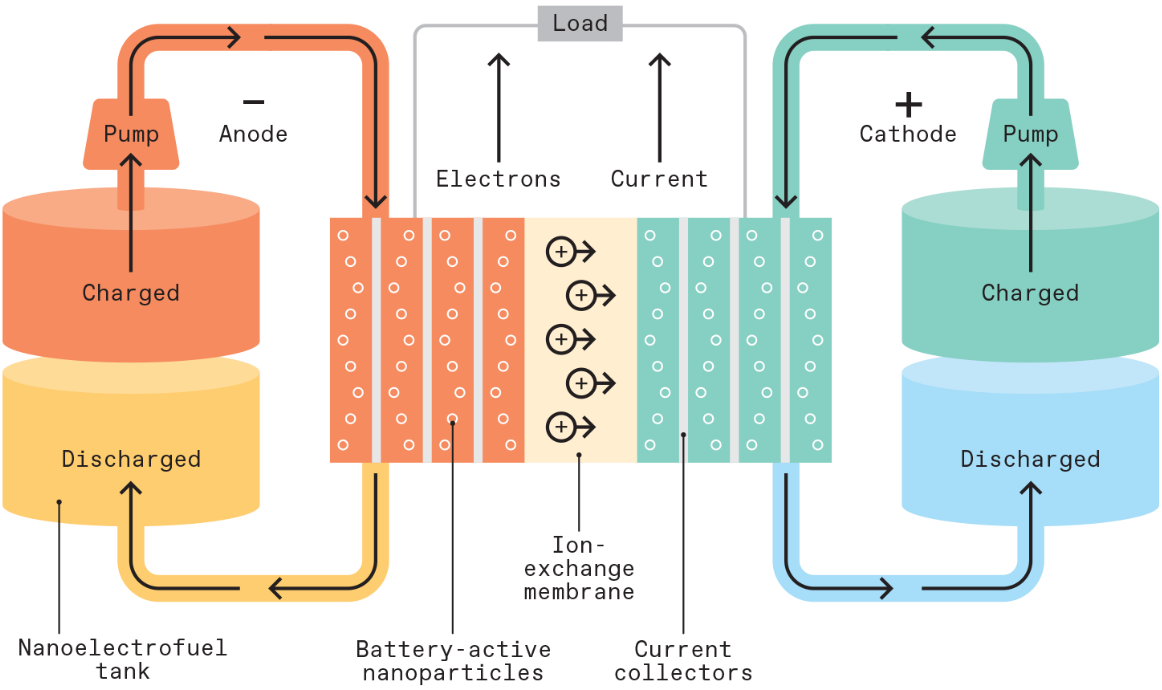


Fuel cell

A fuel cell is similar to electrochemical cells which consists of a cathode, an anode, and an electrolyte. In these cells, the electrolyte enables the movement of the protons

The working of this fuel cell involved the passing of hydrogen and oxygen into a concentrated solution of sodium hydroxide via carbon electrodes.

Flow batteries at cell level- A flow battery is an electrochemical cell, with the property that the ionic solution (electrolyte) is stored outside of the cell (instead of in the cell around the electrodes) and can be fed into the cell in order to generate electricity.

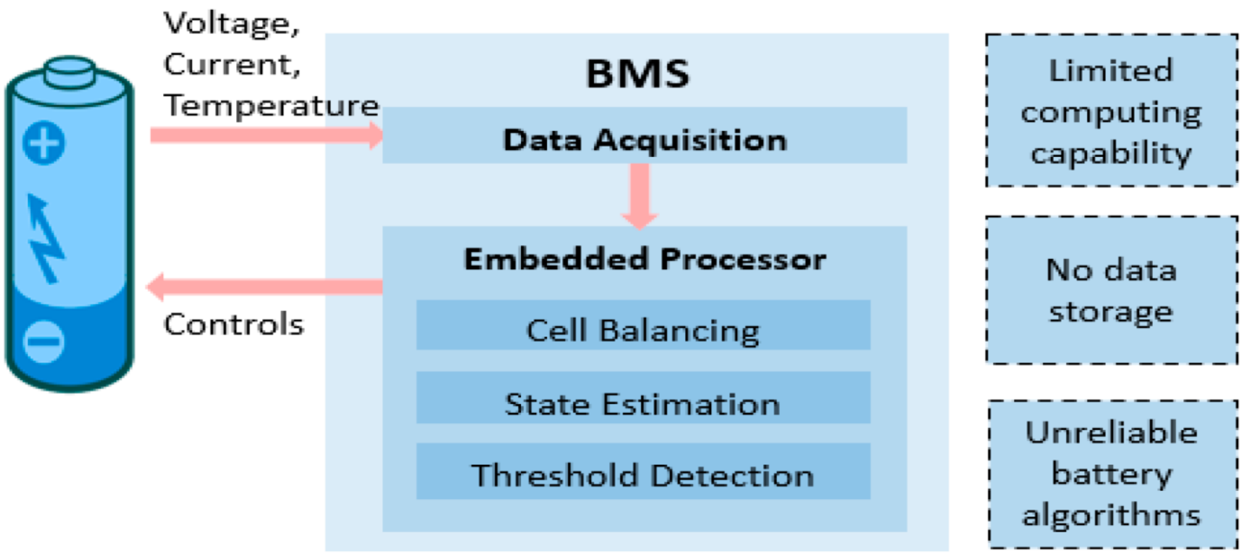


Battery Management Strategies- A battery management system can be comprised of many functional blocks including: cutoff FETs, a fuel gauge monitor, cell voltage monitor, cell voltage balance, real-time clock (RTC), temperature monitors, and a state machine. There are many types of battery management ICs available.

1. Monitoring battery parameters. This is the primary function of a battery management system.

2. Managing thermal temperatures. Temperature is the biggest factor affecting a battery battery management system.

3. Facilitating internal and external communication.



Q. How do you calculate battery state of charge?

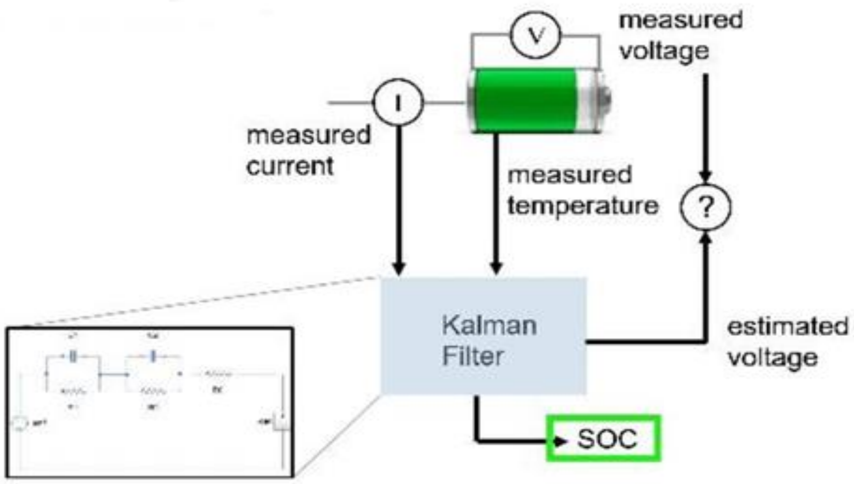
OR

Q.What is state of charge (SOC) in battery?

Ans- Battery state of charge is the level of its charge relative to the current max capacity expressed as a percentage. Simply put, it's the remaining quantity of energy the cell has. To calculate the state of charge, you need to divide the remaining charge by the maximum charge of the battery.

To calculate the state of charge, you need to divide the remaining charge by the maximum charge of the battery.

$$SoC(t) = \frac{Qremaining(t)}{Qmax(t)} * 100\,[\%]$$



Battery Cell Equalization problem- After several charge-discharge cycles, differences appear among the SOC of the individual cells of a battery, due to manufacturing tolerances, uneven temperature distribution, differences in ageing etc. The battery then is said to be unbalanced or un-equalized.

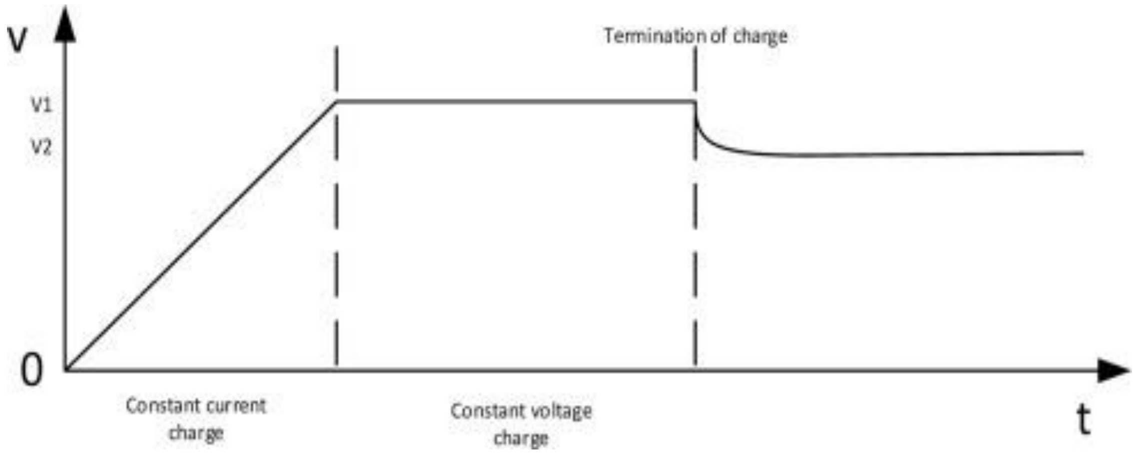
Thermal control- Thermal control regulates the temperature within a structure. It aids in maintaining steady heating and cooling temperatures during season changes throughout the year.

Protection Interface in Electrochemical Cell-Electrode–electrolyte interfaces in Li-ion batteries are usually thermodynamically unstable and are stabilized by surface (solid electrolyte interface, SEI) layers. SEI layers are therefore essential for the performance and stability of Li-ion batteries. SEI layers are naturally formed in contact with the electrolyte or are artificially produced by coating processes. The most important function of the SEI on the positive electrode (cathode) is to minimize electrolyte oxidation at high electrode potentials.

Q.What is the leakage current of a battery?

Ans-Leakage currents are in general considered to be disadvantageous. It flows continually internally that has no use at load.

The internal current which causes the small linear terminal voltage drop after the completion of the post-charge diffusion is the leakage current of the battery.



Q.What is battery acid?

Ans-Battery leakage (commonly known as battery acid) is nasty, corrosive stuff it can burn your skin, contaminate soil, and of course ruin whatever device it has leaked into. For household batteries, this “acid” is actually alkaline.

Q-How do you calculate power and energy of a battery?

Ans-Voltage * Amps * hours = Wh.

Since voltage is pretty much fixed for a battery type due to its internal chemistry (alkaline, lithium, lead acid, etc), often only the Amps*hour measurement is printed on the side, expressed in Ah or mAh (1000mAh = 1Ah). To get Wh, multiply the Ah by the nominal voltage.

Battery capacity is measured in milliamps × hours (mAH). For example, if a battery has 250 mAH capacity and provides 2 mA average current to a load, in theory, the battery will last 125 hours.

Q.What are the causes of battery explosion?

Ans-Primary sources of ignition such as static sparks, naked flames, cigarettes and sparks caused by metal objects touching or shorting the battery terminals, loose battery connections and corroded cables .Below are the main points for battery explosion.

1. Overcharging
2. Current Short Circuit
3. Charging issue
4. Physical damage of the battery

Thermal runaway -

Thermal runaway typically begins with a localized thermal event, such as a short circuit or a failure within the battery cell. This can be caused by physical damage, manufacturing defects, overcharging, over-discharging, exposure to high temperatures, or other factors that disrupt the normal operation of the battery.

Q. What is high discharge rate in batteries?

Ans- High Discharge Rate Battery. The higher-rate battery can release more power within a period of time, can support more high-power applications requirements like jump starter, power tools, and racing devices. Normally high discharge rate batteries can be fast charged.

Q.What do you mean by the short circuit in a battery?

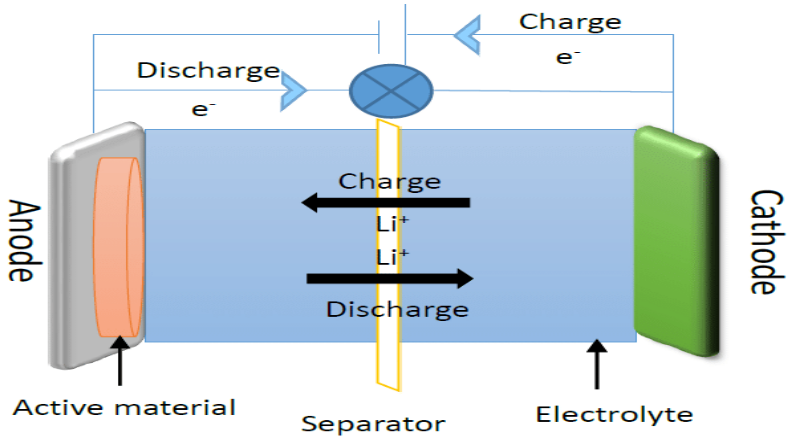
Ans-When a battery is short-circuited then the external resistance becomes zero and therefore the terminal voltage is also zero.

A common type of short circuit occurs when the positive and negative terminals of a battery are connected with a low-resistance conductor, like a wire. With a low resistance in the connection, a high current will flow, causing the delivery of a large amount of energy in a short period of time.

Q. What is charging and discharging of a battery how does it work?

Ans- There are three main components of a battery: two terminals made of different chemicals (typically metals), the anode and the cathode; and the electrolyte, which separates these terminals. The electrolyte is a chemical medium that allows the flow of electrical charge between the cathode and anode. When a device is connected to a battery — a light bulb or an electric circuit — chemical reactions occur on the electrodes that create a flow of electrical energy to the device.

More specifically: "during a discharge of electricity, the chemical on the anode releases electrons to the negative terminal and ions in the electrolyte through what's called an oxidation reaction. Meanwhile, at the positive terminal, the cathode accepts electrons, completing the circuit for the flow of electrons. The electrolyte is there to put the different chemicals of the anode and cathode into contact with one another, in a way that the chemical potential can equilibrate from one terminal to the other, converting stored chemical energy into useful electrical energy."



Charging & discharging of a battery

Battery Standards for Electrical Vehicles-

These regulations are being rolled out in two phases, with Phase 1 commencing on December 1, 2022, followed by Phase 2 scheduled to commence on March 31, 2023. Various tests for battery safety will be compulsory for different vehicle categories. There are some standards as follows-

- IEC 62133 is an international standard for the safety of rechargeable lithium ion batteries, which are commonly used in a wide range of consumer electronics and other
- IEC 61960:2003. Secondary cells and batteries containing alkaline or other non-acid electrolytes - Secondary lithium cells and batteries for portable applications.
- AIS 048 (2009) Battery Safety- This standard covers Traction Battery Safety requirements for L, M & N category vehicles (Including E-Rickshaw/ E-Cart). It covers the Electrical Abuse Test of cells. It includes two types of tests (Short Circuit Test and Over-charge test).

MCQ Type Questions.

Q1. The Fuel Cell provides____energy but__power

a) High, Low

b) Modest, modest

c) Modest, low

d) Low, low

Q2. Which Battery are preferred for EV

a) Lead-acid (Pb-acid)

b) Lithium-ion (Li-ion)

c) Sodium-sulphur (NaS)

d) Nickel-cadmium (NiCd)

Q3. Battery that cannot be charged again is called

a) Primary Battery

b) Secondary Battery

c) Both primary and secondary

d) Nor Primary Neither secondary

Q4. What is the unit of charge capacity in a battery

a) Ahr

b) W hr

c) W/hr

d) W/Ahr

Q5. The____monitors and measures temperature and assures cooling is adequate for battery

a) Hybrid ECU

b) Transmission ECU

c) ICE EMU

d) Battery management system

Short answer type questions

Q1. Explain energy management system in short.

Q2. What is the unit of charge capacity in a battery?

Q3. What is Thermal Control?

Q4. What is high discharge rate in batteries?

Q5. Explain energy management system in short.

Q6. How do you calculate power and energy of a battery?

Long Answer type questions

Q1.What is electrochemical cell, define its working?

Q2.Describe in brief

(a) Supercapacitor (b) Fuel Cell

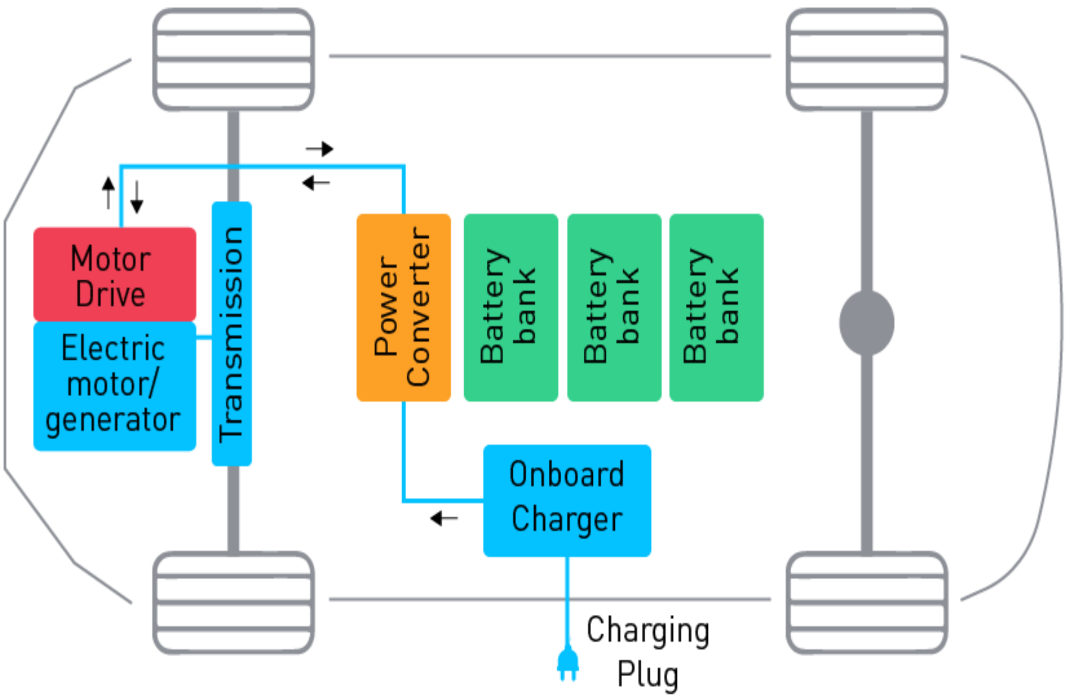
Q3. What is battery management system and battery can be tested.

Unit-3

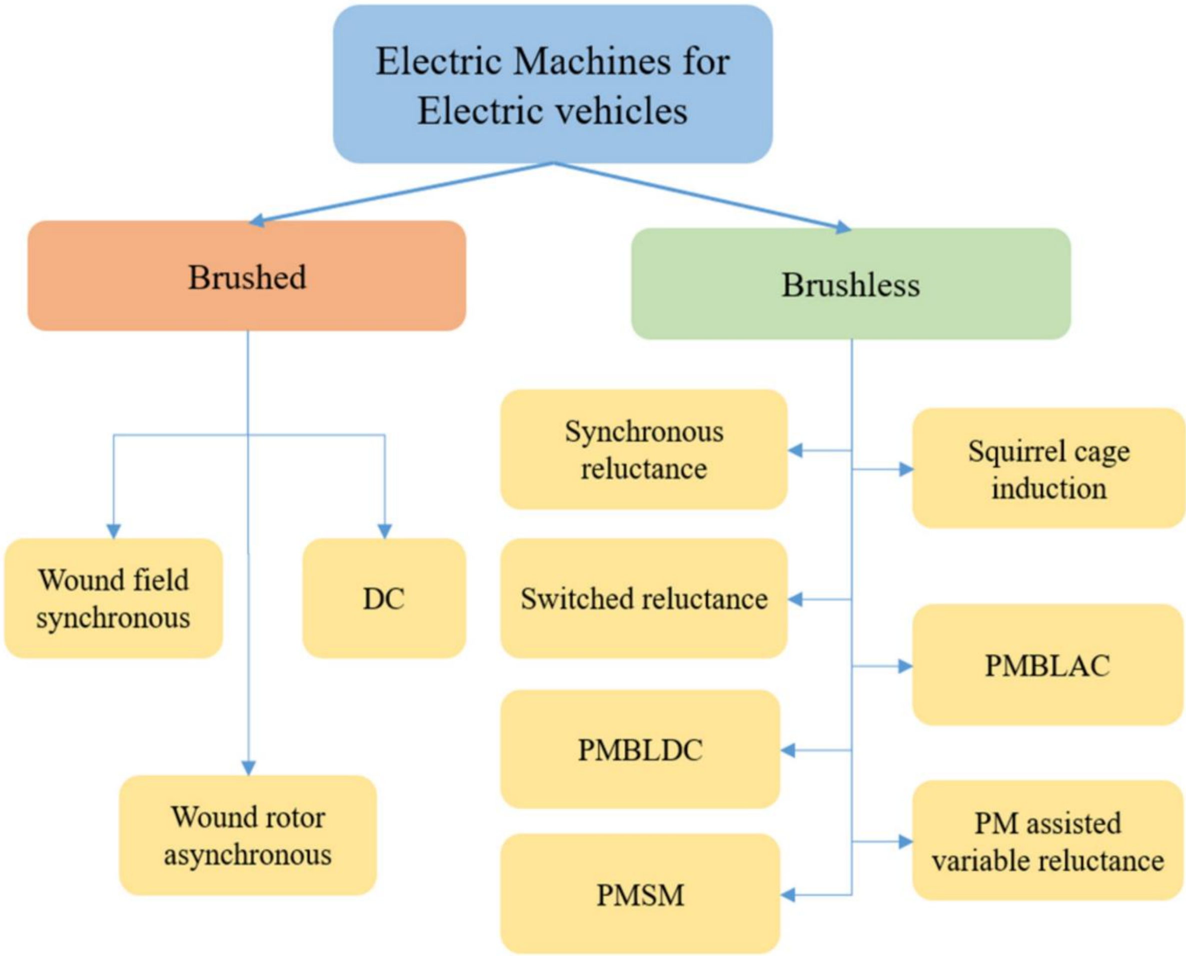
Power Electronics Interface

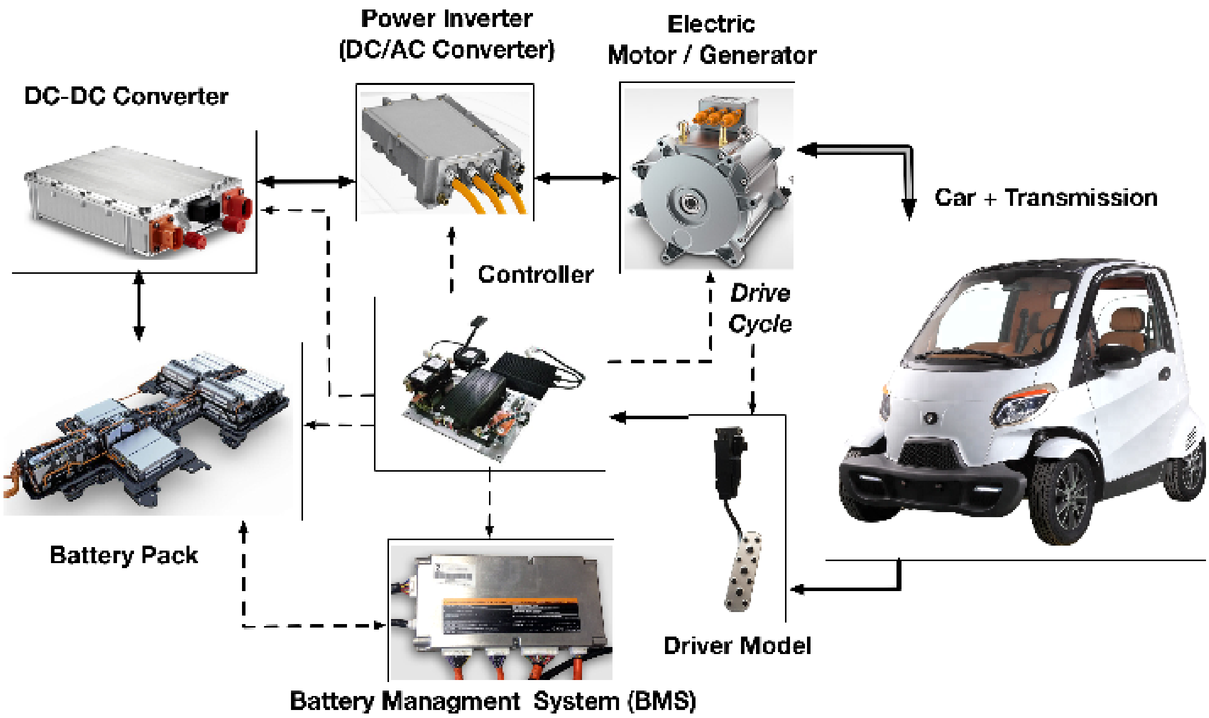
Analysis and Modelling of EV-The increasing focus on electrification for a cleaner environment has fueled the need for electric power in different forms. Power electronics is the branch of electrical engineering that deals with the processing of high voltages and currents to deliver power that supports a variety of needs.

The electronic converters in these systems convert the AC supply into a high-voltage DC output, which can directly charge the vehicle's battery, bypassing the on-board charger. Advanced control strategies are implemented via power electronics to regulate the charge rate and protect the battery from potential harm.



Modelling of EV


Electric Machines for Electric vehicles
Brushed
Brushless
Wound field synchronous
DC
Wound rotor asynchronous
Synchronous reluctance
Switched reluctance
PMBLDC
PMSM
Squirrel cage induction
PMBLAC
PM assisted variable reluctance


Power Inverter (DC/AC Converter)
Electric Motor / Generator
DC-DC Converter
Car + Transmission
Controller
Drive Cycle
Battery Pack
Driver Model
Battery Managment System (BMS)

Design and Control of Switched-Mode Power Converters- Switched mode converters are DC/DC converters, dedicated to the supply of DC loads with a regulated output voltage and protections against over currents and short circuits.

These converters are generally fed from an AC network via a transformer and a conventional diode rectifier. Switched-mode converters (one quadrant) are non-reversible converters that allow the feeding of a DC load with unipolar voltage and current. The switched-mode converters presented in this contribution are classified into two families. The first is dedicated to the basic topologies of DC/DC converters, generally used for low- to mid-power applications. As such structures enable only hard commutation processes, the main draw- back of such topologies is high commutation losses. A typical multichannel evolution is presented that allows an interesting decrease in these losses. Deduced from this direct DC/DC converter, an evolution is also presented that allows the integration of a transformer into the buck and the buck–boost structure.

Switched-mode converters are DC/DC converters, dedicated to the supply of DC loads with a regulated output voltage and protections against overcurrent and short circuits. These converters are generally fed by an AC single-phase or three-phase network.

These converters are generally fed by an AC single-phase or three-phase network, as presented in Fig. 1.

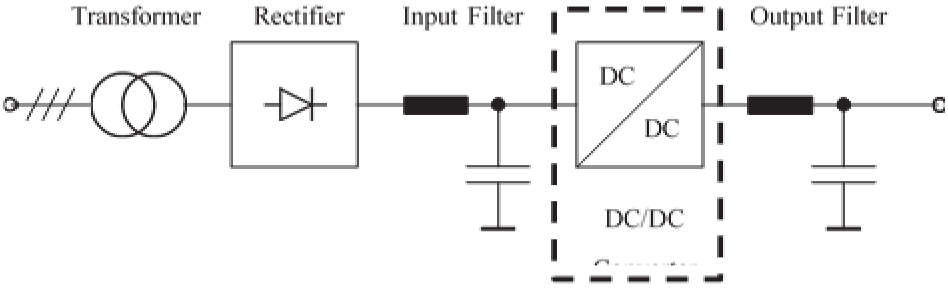


Fig. 1: General scheme of a DC supply

From an AC network, a conventional conversion chain is made of an input transformer dedicated to voltage/current adaptations, offering also galvanic insulation of its secondary side with respect to its primary. Then, a non-controlled rectifier (diode rectifier) realises the conversion from AC to DC. The voltage generated is not regulated, and presents a strong ripple around its averaged value. An LC input filter is introduced in such a way that it cancels or minimizes this voltage ripple. Moreover, this input filter acts as a voltage source for the DC/DC converter needed to regulate the voltage applied to the load. Sometimes, the DC/DC converter has to limit the current absorbed by the load. In a lot of applications, an output filter is required to filter the output voltage ripple.

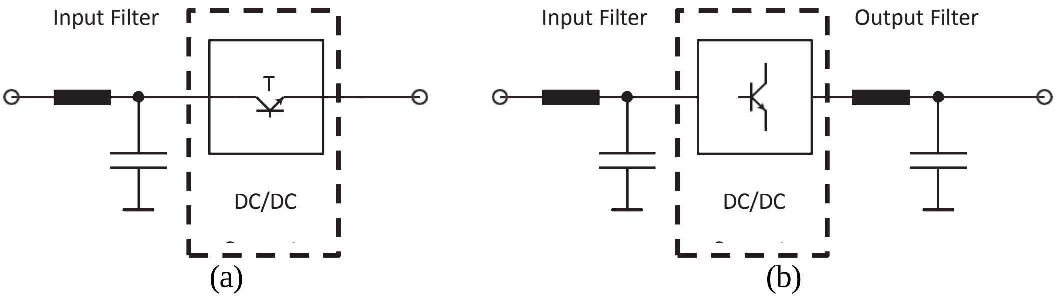


Fig. 2: DC/DC converters: (a) Linear converter. (b) Switched-mode converter.

Generally speaking, one can divide DC/DC converters into two families of converters, as shown in Fig. 2. For low-power applications, the DC/DC converter can be realized with transistors that are series connected to the main current flow Fig. 2(a). Such transistors are driven in their linear mode. They have to support the difference of potential between the non-regulated voltage from the input filter and the voltage requested by the load. Although such a solution offers a high dynamic for the output voltage regulation and a poor output voltage ripple, its efficiency is low since losses are proportional to the current needed by the load and the non-zero voltage the transistor has to maintain. This solution is mainly used in low-power applications.

The only way to obtain a high efficiency in mid- or high-power applications is the use of switched- mode DC/DC converters Fig. 2(b), using transistors as interrupts, switching between their off-state and their saturated mode. Here, losses are related only to the switching losses and low conduction losses, ensuring a higher efficiency and thus a higher power density. This is the main advantage of switched- mode DC/DC converters, even if the commutations lead to non-negligible EMC emissions and if an output filter is needed to lower output voltage ripple.

Converters can be classified into two families:

Direct DC/DC converters: one single stage is used to adjust voltage levels from the input to the output. These converters are generally obtained with one switching cell. Three of them will be presented:

- buck converter (or step-down converter),
- boost converter (or step-up converter),
- buck–boost converter (or step-up/down converter).

From these basic topologies, we shall go on to explain how to increase the efficiency of such solutions thanks to the multi channels technology, allowing the converters to work under soft– switching conditions. Some converters can be adjusted to allow sinusoidal current absorption on the feeding AC network (Fig. 1). This will be illustrated with the boost converter. Moreover, it is possible to add transformers in the switching cell of the buck converter and the buck–boost converter, even if such topologies have not been specifically designed to generate AC voltages or current. Two other topologies offer DC/DC conversion together with galvanic insulation and additional voltage/current adaptation thanks to their internal transformers.

On-board Charger (AC/DC)-

Alternating current (AC) is transmitted via power lines, and there is 230V and 50 Hz in a standard electrical outlet in most parts of Europe. Electric current is produced as alternating and it can be transmitted without much loss and over longer distances then it would be the case with the direct current.

However, most modern electronics are built on integrated circuits and batteries, which need direct current (DC) for their operation. Energy is stored in batteries using chemical energy, which takes place only in one direction.

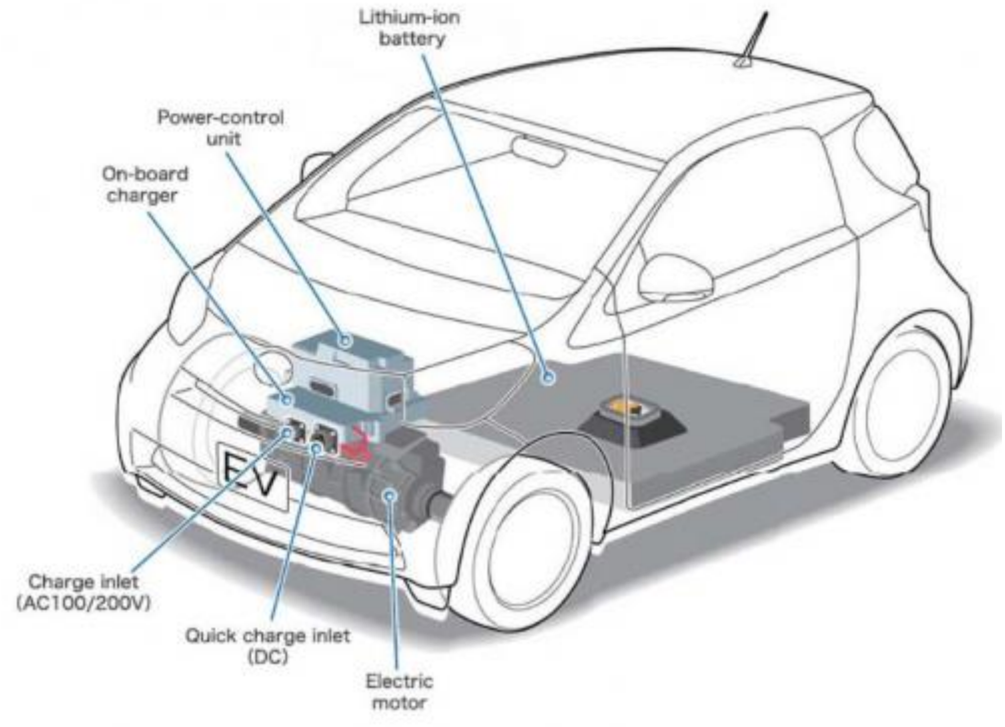
Therefore, a battery-dependent device can only be charged using a charger that converts AC power from a electrical outlet to DC power. A typical example of such a device that converts AC current to DC is a laptop charger or a mobile phone charger. And the same system is needed for an electrical car.

DC Charger

AC charging

When charging an electric car with alternating current, the car's ***on-board system*** (also called the on-board charger) is used and it takes care of the conversion of outlet current into battery current. It therefore receives alternating current (AC) and converts it into direct current (DC), which is then sent to the car battery.

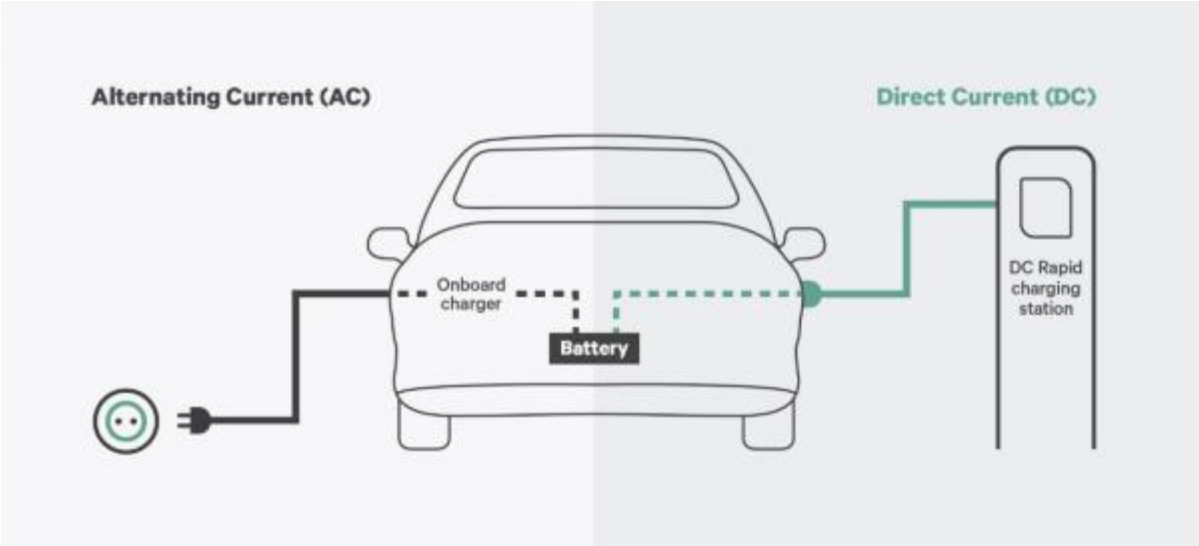
The key parameter when choosing an electric car is the capacity of this on-board (built-in) charger, because the car's charging speed depends on how fast this on-board system can receive the alternating current from the source and also on how many phases it is able to use.



DC charging

DC charging, or so-called fast charging, is done using a DC charging station, which can change the alternating current (AC) to direct current (DC), it then "bypasses" the on-board charger of the electric car and sends this direct current via Battery Management System (BMS) to the battery, as instructed by the vehicle's charging control system.

Charging is therefore not limited by the power of the on-board charger and so it can be much faster. A DC charging station is technologically much more complex and many times more expensive than an AC charging station and moreover it requires a powerful source. In addition, a DC charging station must be able to communicate with the car instead of the on-board charger in order to be able to adjust the output power parameters according to the condition and capability of the battery.

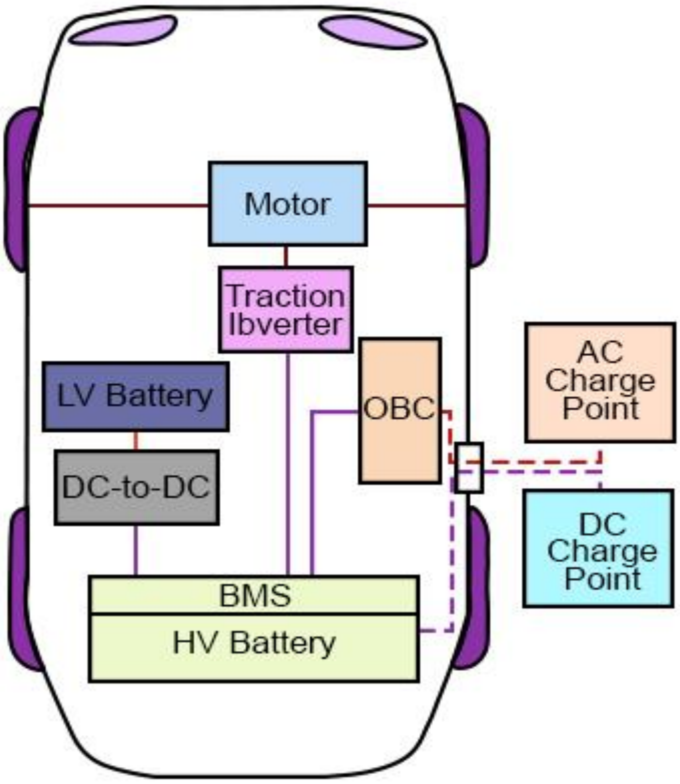


Traction Inverter (DC/AC)-

A traction inverter is a power electronic device that is used in electric and hybrid vehicles to convert the direct current (DC) power from the battery into alternating current (AC) power to drive the electric motor.

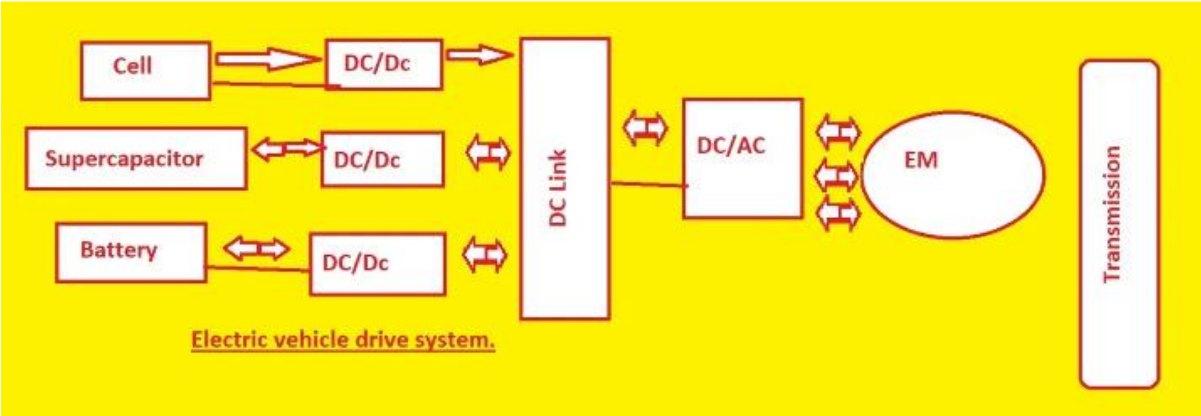
Electric and hybrid electric vehicles are gaining popularity as a sustainable alternative to gasoline or diesel-powered vehicles. One key component that determines the vehicles' operation, efficiency, and performance is the traction inverter.

The term "traction" denotes the act of pulling or drawing something over a surface, thus a traction inverter is an inverter utilized to provide motion over a surface in coordination with an electric motor. Consequently, traction inverters can be found in all types of electric land vehicles, including trains, mining equipment, and increasingly, cars and trucks.



Battery DC-DC converters-The DC-DC converter is an electromechanical device or circuitry used to convert a DC voltage from one level to another based on circuit requirements. Belonging to the electric power converter family, the DC-DC converter can be operated for small voltage applications like batteries, or high voltage applications like HV power transmission.

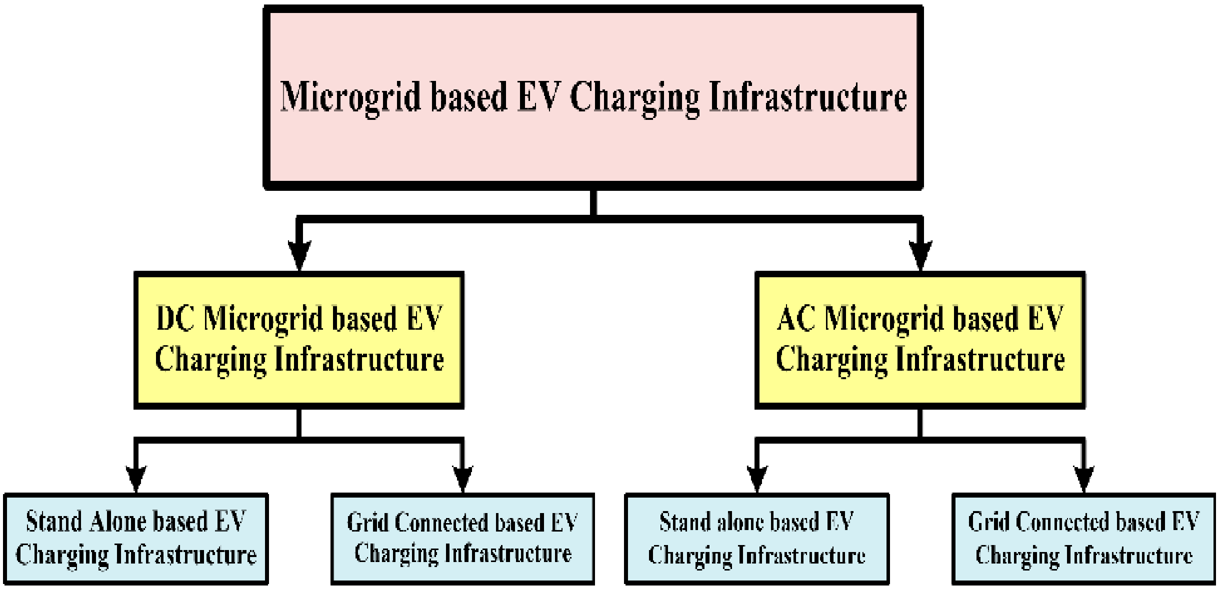
When there were no semiconductors, a common technique for converting DC voltage into higher voltage for low-power projects was to transform it into AC voltage by means of vibrator circuits. Then, a step-up transformer was used to increase the output voltage level, followed by a rectifier circuit for performing the DC conversion. A combination of motor and generator was employed for applications where high power was required. The motor operates the generator, providing the required load voltage. These techniques were expensive and less efficient but used since no alternative method existed at that time.



In above fig, we can see the different types of converters used in electric vehicles. It shows how at least one DC-DC converter interfaces the DC link with the fuel cell battery or supercapacitors module. Electric vehicles have different energy sources, like fuel cells and battery supercapacitors. In EVs, one or more energy storage devices are used. That reduces the overall cost and volume and provides good operation. Commonly used energy storages are batteries and supercapacitors. These devices are configured with fuel cell stacks in different configurations. The normal configuration is a direct connection of two modules in parallel combination: fuel cell or battery, fuel cell or supercapacitors, or battery or supercapacitors. In this method, power is used not in control but can be measured through component impedance value. Impedance depends on different parameters such as efficiency and device health condition. The voltage parameters also match the two components' specifications. This is the case of a fuel cell/battery combination, where the fuel cell must have the same power during the complete time due to the fixed voltage of the battery. In the case of a battery or supercapacitors combination, only very small energy exchange features of capacitors can be used. This is all about the constant value of battery voltage. The DC-DC converter output voltage can be selected and the power of every device can be regulated.

Charging Infrastructure-EV infrastructure is defined as structures, machinery, and equipment necessary and integral to support a EV, including battery chargers, rapid chargers, and battery exchange stations.

Classification of EV charging infrastructure-Charging stations can be divided into two main categories based on the power supply method: AC charging stations and DC charging stations.



AC Charging Stations-

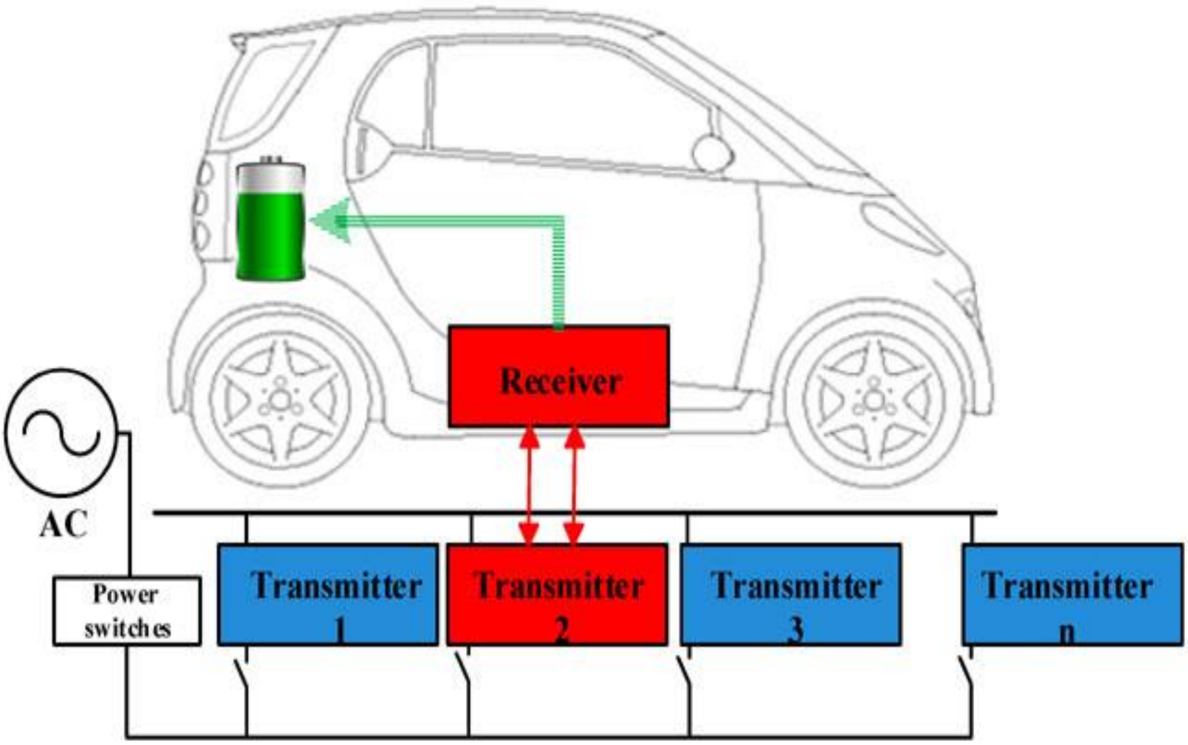
AC charging stations convert the alternating current (AC) from the electrical grid into the suitable AC power for charging electric vehicles (EVs). This charging method is suitable for home use, small-scale commercial charging stations, and small parking lots. In these locations, charging time is usually longer, and the charging power is not particularly high.

DC Charging Stations-

DC charging stations directly provide direct current (DC) from the electrical grid to charge EVs. Compared to AC charging stations, DC charging stations offer faster charging speeds and higher power output. They are suitable for locations that require rapid charging, such as highway service areas, public parking lots, and urban fast-charging stations.

Inductive charging-Inductive charging (also known as wireless charging or cordless charging) is a type of wireless power transfer. It uses electromagnetic induction to provide electricity to portable devices. Inductive charging is also used in vehicles, power tools, electric toothbrushes, and medical devices. The portable equipment can be placed near a charging station or inductive pad without needing to be precisely aligned or make electrical contact with a dock or plug.

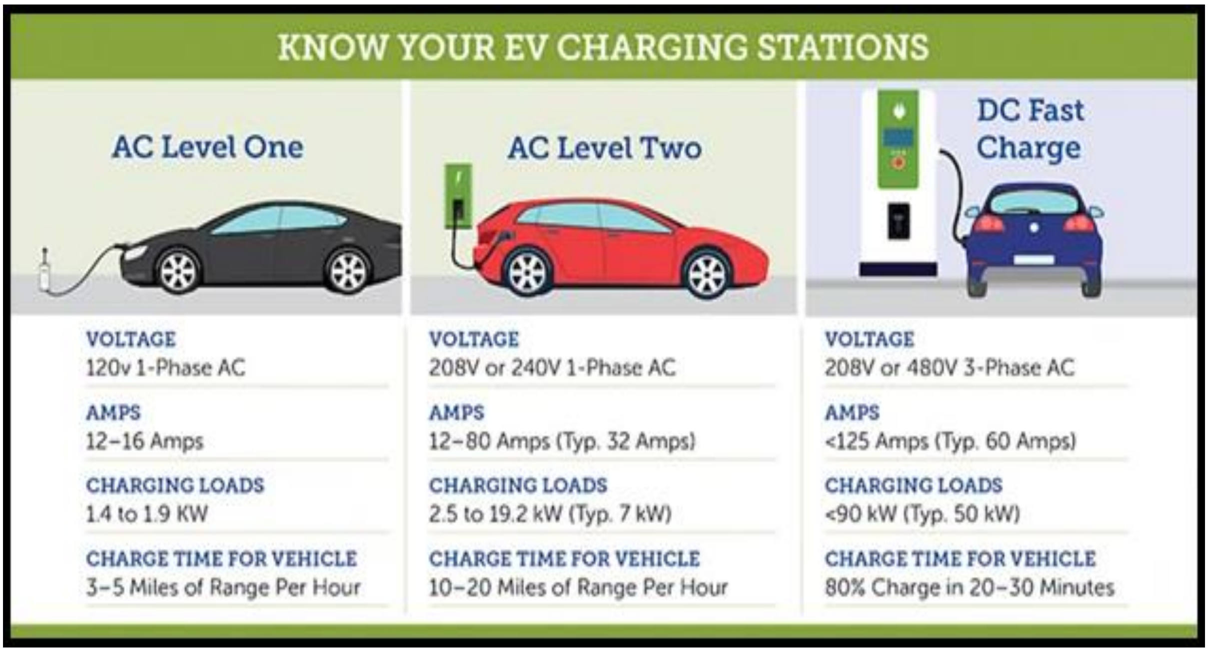
Energy companies, suppliers, and large car manufacturers are working on technology that will enable electric car batteries to be charged rapidly without a charging cable. In concrete terms, they are developing inductive charging systems and working on their standardisation, for a future where charging fits seamlessly into electric car drivers' everyday lives. Inductive charging uses electromagnetic fields, with no physical connection.



The principle behind it is this: a stationary coil embedded in the ground builds up a magnetic field to a secondary coil fixed under the vehicle. And electricity flows into the car. In Braunschweig, Germany, electric buses are already equipped with this technology. They are charged inductively with 200 kW at the terminus – so quickly that it all happens while the driver is taking a break.

Indian and international standards for dc and ac EV Charging-

BIS is a member of the International Electro technical Commission (IEC), which is the global body that is developing reference standards to ensure interoperability and minimize trade barriers for electric vehicles and their components. While Indian standards for electric vehicle charging are compliant with global standards, local climate considerations and the difference in vehicle types available in the country necessitate modifications that are specifically applicable to India.



Indian Standards for AC Charging-

IS 17017 is the key electric vehicle charging standard in India comprising three parts and six sections. IS-17017- Part-1 provides the basic features of all electric vehicle charging systems. An AC EVSE must adhere to this standard, and specific AC connector standard in the IS-17017-Part-2. Both AC and DC EVSE need to conform to the technical standards IS-17017-Parts 21 & 22. Additional Indian standards for AC EVSEs have been approved for light electric vehicles and e-cars (in the form of low-cost charging points), for use in parking areas.

Indian Standards for DC Charging-

IS-17017-Part-23 describes the requirements for DC charging stations, with power output of 50kW to 200kW. Beyond this, high power charging standards are required to cater to buses and other heavy vehicles. Recently, the BIS has finalized the IS-17017-Part-25, which is specifically for providing low DC power of less than 7kW for light EVs. Due to the requirement of digital communications between the DC EVSE and the EV, data communication standards are specified in IS-17017-Part 24. When the Combined Charging System (CCS) standard is deployed, which can provide both AC and DC charging, communications will be as per the IS-15118 series.

Indian Standards For battery swapping-

Separate projects have been initiated for battery swapping standards for LEVs and buses. They will be two series of standards documents, covering the form factor of the battery pack, inter-operable connection systems, communication between the battery management system (BMS) and the EV and charging station, and network management. Any electric vehicle may utilize a battery pack conforming to these standards. The removable battery packs can be charged using AC or DC charging systems. The BIS is yet to develop Indian standards for EV roaming and grid-related management functions.

MCQ type questions

Q1. The batteries cannot be recharged simply by reversing the current

a) Li-Ion Battery

b) Lead Acid battery

c) Li-poly Battery

d) Aluminium Air battery

Q2. A traction inverter is a power electronic device that is used in electric and hybrid vehicles to convert the……….

a) DC to AC

b) AC to DC

c) DC to DC

d) AC to AC

Q3. Which Battery are preferred for EV

a) Lead-acid (Pb-acid)

b) Lithium-ion (Li-ion)

c) Sodium-sulphur (NaS)

d) Nickel-cadmium (NiCd)

Q4.Switched mode converters are

a) DC to AC

b) AC to DC

c) DC to DC

d) AC to AC

Short Answer type questions

Q1.What is On-board Charger (AC/DC)

Q2.What is Traction Inverter (DC/AC)

Q3.Define the Indian Standards for DC Charging

Q4.Define the Modelling of EV

Long Answer type questions

Q1. What are the design and control of switched-mode power converters?

Q2. What are the Classification of EV charging infrastructure?

Q3.Define the Indian and international standards for dc and ac

Q4.Write the short notes on the followings

a) DC and AC EV charging.

b) AC chargers, DC chargers

c) Battery DC-DC converters

Unit-4

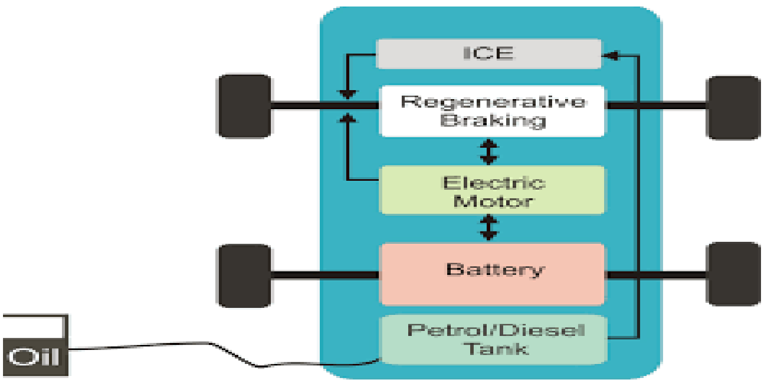
Hybrid Electric Vehicle

Introduction-A Hybrid Electric Vehicle is a type of vehicle that uses a combination of an Internal Combustion (IC) engine and an electric propulsion system. The electric power train may enhance fuel efficiency, increase performance, or independently propel the vehicle on pure electric power, depending on the type of hybrid system.

In simple words, an HEV is a vehicle that comprises a conventional fuel engine and an electric power train, wherein the electric motor assists the engine to extract more performance, and better fuel economy, depending on the type of the system.

Key components of a Hybrid Electric Vehicle-

An HEV combines a conventional engine and electric power train. Hence, you can find engine-related and electric power train components in an HEV. Below are the key components of a Hybrid Electric Vehicle.



Internal combustion engine: The primary power source of an HEV is a conventional engine. Hence, it is the main component responsible for propelling the vehicle. An HEV cannot run alone on an electric power train without an engine.

Electric motor: The secondary power source of an HEV is the electric motor. It assists the engine during initial acceleration to improve performance and fuel economy. It runs on electrical energy stored in the battery pack. It can also charge the battery when the vehicle is braking or coasting via the regenerative braking system.

Battery pack: A battery pack powers the electric motor. Basically, it acts as a fuel tank for the battery, wherein it stores the electrical energy via regenerative braking and the generator driven by the IC engine. The battery pack can also power auxiliary electrical components such as lights.

Generator: It is an essential component found in the series hybrid vehicle. We will touch upon what series hybrid is in the upcoming sections. A generator draws power from the IC engine to power the electric motor and charge the battery pack. In simple words, a generator converts mechanical energy into electrical energy.

Transmission: Typically, hybrid vehicles use conventional transmissions similar to petrol or diesel cars. It transmits the power produced by the IC engine to the drive shaft. The basic working principle of transmission remains the same, even in an HEV. It is one of the crucial components required to propel the vehicle.

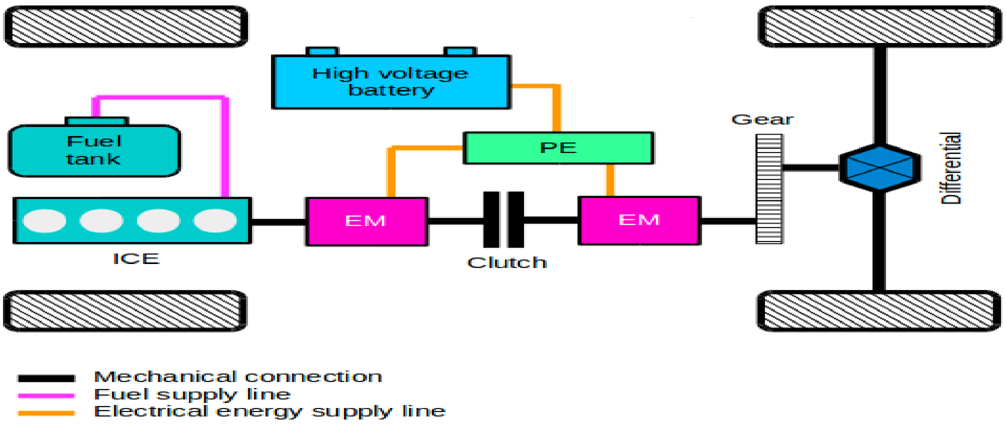
Fuel tank: Similar to a conventional car, hybrid electric vehicles also have a fuel tank to store the conventional fuel. With the electric power train involved in a hybrid car, the fuel consumption will be comparatively less than a vehicle purely relying on an IC engine.

Types of Hybrid Electric Vehicles-There are three types of HEVs based on power delivery and distribution. Below are more details on the same.

1. Series hybrid-In a series hybrid system, the IC engine powers the electric generator, which drives the electric motor and charges the battery. In this setup, the engine does not directly power the wheels. Series hybrid is also called a range extender since the engine powers the electric motor and the battery pack.

2. Parallel hybrid-In this system, both the engine and electric motor work parallel to propel the vehicle. The engine and the electric motor deliver optimum power for the efficient functioning of the car. The battery pack gets charged via regenerative braking. If you wonder what regenerative braking is, here's a brief explanation. Regenerative braking is a process of utilizing the kinetic energy produced while slowing the vehicle down to charge the battery pack.

3. Series-Parallel Hybrid Configuration- A series hybrid becomes a series-parallel hybrid by adding a mechanical connection (clutch) between the two electric machines. The advantage of this architecture is that at low speeds, with the clutch open, the powertrain behaves as a series hybrid, running the engine at the most efficient operating point. At high vehicle speed, the clutch is closed and the engine can transmit torque to the driving wheel thus the powertrain becoming a parallel hybrid.



Compared with the series hybrid, the series-parallel hybrid has the advantage of a smaller power rating of the generator since the excess power of the engine can be transferred directly to the drive wheels. The disadvantage is that, by adding a mechanical connection (clutch), we lose the flexibility in terms of packaging.

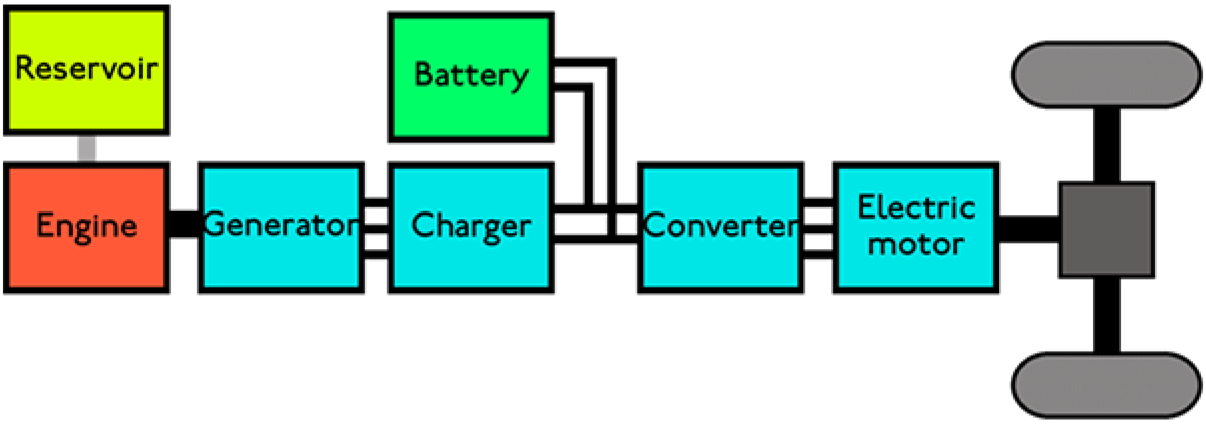
In terms of powertrain functions, a series-parallel hybrid is capable of:

- Engine stop & start
- Energy recuperation
- Torque assist/boost
- Electric driving
- Charge at standstill

Compared with a parallel hybrid, a series-parallel hybrid uses two electric machine and performs the same tasks. For these reasons, the series-parallel powertrain architecture with a clutch connection between the two electric machine is not widely used by automotive manufacturers.

Q.What is a drivetrain?

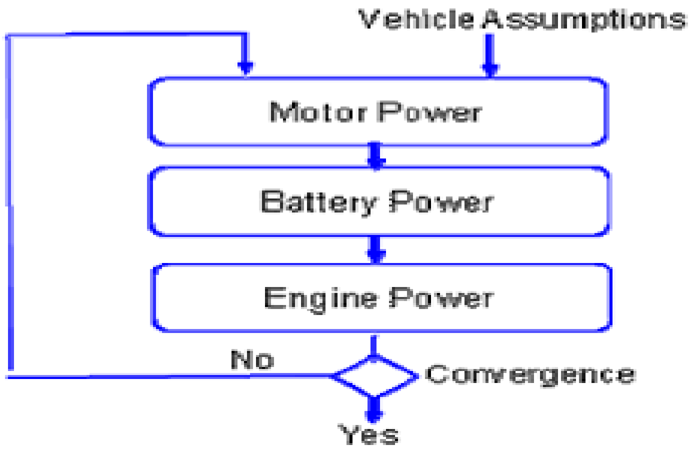
Ans-A drivetrain is the collection of components that deliver power from a vehicle's engine or motor to the vehicle's wheels. In hybrid-electric cars, the drivetrain's design determines how the electric motor works in conjunction with the conventional engine. The drivetrain affects the vehicle's mechanical efficiency, fuel consumption, and purchasing price.



Hybrids that use a series drivetrain only receive mechanical power from the electric motor, which is run by either a battery or a gasoline-powered generator.

In hybrids with parallel drivetrains, the electric motor and internal combustion engine can provide mechanical power simultaneously. Series/parallel drivetrains enable the engine and electric motor to provide power independently or in conjunction with one another.

Sizing of Components in EV-Component sizing is essential to meet the performance requirements with the optimum resources and at the same time prevents unwanted wastage of energy resources and losses. Equation based calculators provide component sizing estimation results by considering only a single opera.



Sizing of Components

Micro Electric vehicle-A micro electric vehicle (micro-EV) is a one- or two-seater vehicle powered by compact battery pack with electric propulsion power.

Micro electric vehicles offer advantages such as small size for congested road and minimal parking space, great maneuverability, low emissions, ease of usage, and affordable initial and recurring costs. Furthermore, the younger generation seeks mobility services that serve a specific purpose, and micro-EVs could meet these needs. They could also serve as an inexpensive alternative to e-bikes and EVs, as micro-EV prices remain much lower than those of other EV types, and certain models are competitively priced when compared to regular EVs.

Mild Electric vehicle-

A mild hybrid refers to a vehicle with an internal combustion engine that is also supported by a small electric drive. The electric motor recovers braking energy ("recuperation") and makes it available later as additional drive power to reduce overall fuel consumption.

These are most commonly referred to as 48-volt systems. Although it can’t power the car on its own, the 48-volt MHEV system usually starts the car and also brakes or slows it. During the braking process, the MHEV recovers the kinetic energy created as the vehicle slows.

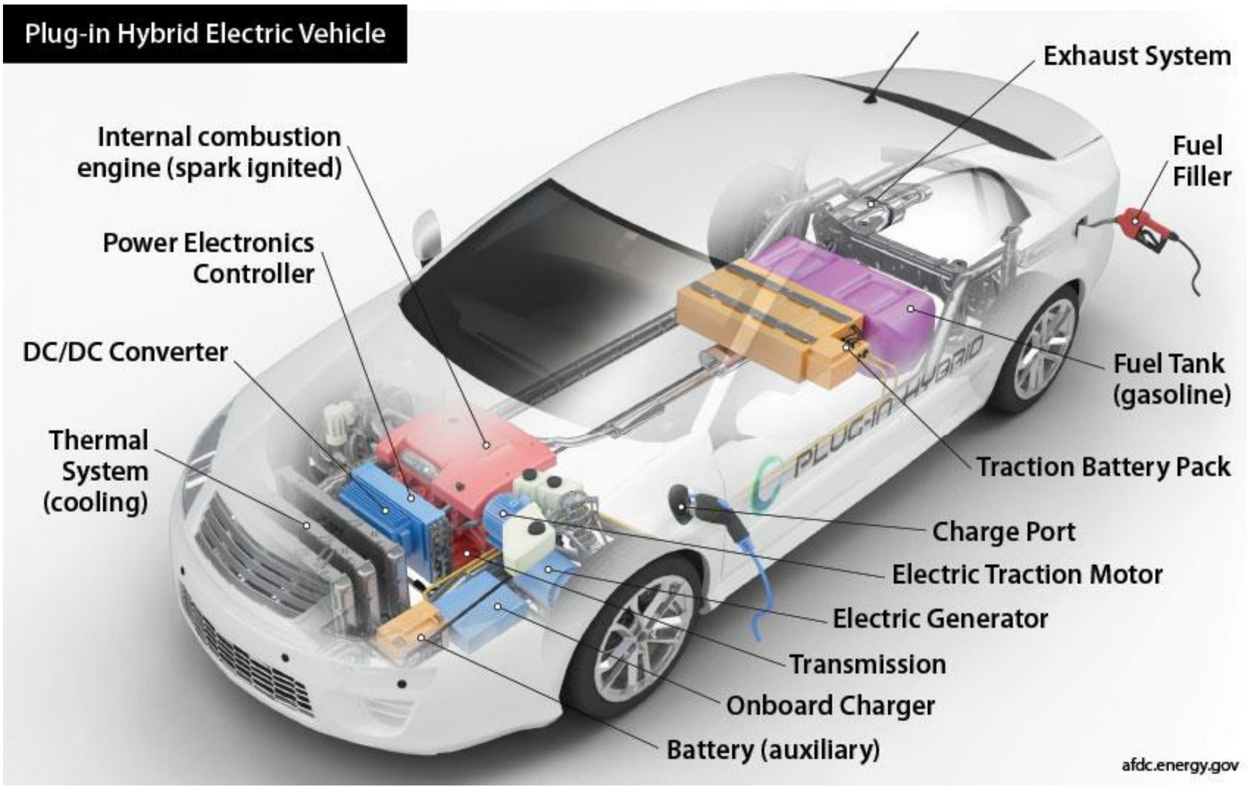
This is called regenerative braking. That energy is transformed into electricity and stored in the MHEV's battery. The MHEV system then draws on that stored energy to help the ICE accelerate the car from a standstill. Therefore, the ICE uses less fuel when accelerating from a stop, resulting in a modest gain in fuel economy.

Essentially, an MHEV system employs some or all of the following components to reduce the load on the ICE, lowing fuel consumption:

- Modest electric motor
- Small battery pack
- More powerful electrical system
- Regenerative braking system

Plug-in and Fully Hybrid EV- A plug-in hybrid electric vehicle (PHEV) uses a battery to power an electric motor and uses another fuel, such as gasoline or diesel, to power an internal combustion engine.

The battery pack in a PHEV is generally larger than in a standard hybrid electric vehicle. The larger battery pack allows the vehicle to operate predominantly on electricity during short trips. For longer trips, a PHEV can draw liquid fuel from its onboard tank to provide a driving range similar to that of a conventional vehicle. An onboard computer decides when to use which fuel according to which mode allows the vehicle to operate most efficiently.



The battery can be charged by plugging into an electric power source, through regenerative braking, and by the internal combustion engine. In regenerative braking, kinetic energy normally lost during braking is captured and stored in the battery.

Q.What is the need and importance of EV and HEV?

Ans-1.Lower running costs-The running cost of an electric vehicle is much lower than an equivalent petrol or diesel vehicle. Electric vehicles use electricity to charge their batteries instead of using fossil fuels like petrol or diesel. Electric vehicles are more efficient, and that combined with the electricity cost means that charging an electric vehicle is cheaper than filling petrol or diesel for your travel requirements.

2. Low maintenance cost-Electric vehicles have very low maintenance costs because they don't have as many moving parts as an internal combustion vehicle. The servicing requirements for electric vehicles are lesser than the conventional petrol or diesel vehicles. Therefore, the yearly cost of running an electric vehicle is significantly low.

3. Zero Tailpipe Emissions-Driving an electric vehicle can help you reduce your carbon footprint because there will be zero tailpipe emissions. You can reduce the environmental impact of charging your vehicle further by choosing renewable energy options for home electricity.

4. Tax and financial benefits-Registration fees and road tax on purchasing electric vehicles are lesser than petrol or diesel vehicles. There are multiple policies and incentives offered by the government depending on which state you are in.

5. Petrol and diesel use is destroying our planet-The availability of fossil fuels is limited, and their use is destroying our planet. Toxic emissions from petrol and diesel vehicles lead to long-term, adverse effects on public health. The emissions impact of electric vehicles is much lower than petrol or diesel vehicles. From an efficiency perspective, electric vehicles can covert around 60% of the electrical energy from the grid to power the wheels, but petrol or diesel cars can only convert 17%-21% of the energy stored in the fuel to the wheels. That is a waste of around 80%. Fully electric vehicles have zero tailpipe emissions, but even when electricity production is taken into account, petrol or diesel vehicles emit almost 3 times more carbon dioxide than the average EV. To reduce the impact of charging electric vehicles, India is ambitious to achieve about 40 percent cumulative electric power installed capacity from non-fossil fuel-based energy resources by the year 2030. Therefore, electric vehicles are the way forward for Indian transport, and we must switch to them now.

MCQ Type Questions

Q1**.** The hybrid electric vehicle is combination of

a) IC Engine + electric motor

b) Only electric motor

c) NGV + gasoline engine

d) None of these

Q2. Which of the following is not a power source combination for Hybrid electric Vehicles

a) ICE and Battery

b) Battery and Ultra capacitor

c) Diesel and ICE

d) Battery and Fuel Cell

Q3. In a hybrid electric vehicle one energy source is ____& the other is a conversion of a___

a) Combustion, energy to fuel

b) Storage, energy to fuel

c) Storage, energy to energy

d) Storage, Fuel to energy

Q4. In series hybrid vehicle___is coupled with the Internal combustion

Engine to produce electricity for propulsion

a) diesel engine

b) Gas engine

c) Hydrogen engine

d) Generator

Q5. Over the years application of which motor to EV and HEV is limited

a) Induction Motor

b) BLDC

c) PMSM

d) SRM

Short Answer type questions.

Q1.What are the Key components of a Hybrid Electric Vehicle?

Q2. What is a drivetrain?

Q3. Explain basic EV AC and DC Chargers.

Q4.What is series Hybrid Electric Vehicle?

Long Answer type questions

Q1.Define the working of Plug-in and Fully Hybrid EV.

Q2.What are the types of Hybrid Electric Vehicles.

Q3.What are the basics of Micro, Mild, and Mini EV.

Q4. What is the need and importance of EV and HEV?