KSR COLLEGE OF ENGINEERING, (Autonomous) TIRUCHENGODE-637 215
DEPARTMENT OF AUTOMOBILE ENGINEERING

Year / Sem	:	**IV / VIII**
Subject Code & Name	:	**18AU811 – ELECTRIC AND HYBRID VEHICLES**
Faculty Name	:	**Dr. R. VENKATACHALAM**

UNIT-I
NEED FOR ALTERNATIVE SYSTEM

Objective

To comprehend general aspects of Electric and Hybrid Vehicles (EHV), including architectures, modeling, sizing, sub system design and hybrid vehicle control.

Need for hybrid vehicles

When compared to conventional vehicles, hybrids offer better power and fuel efficiency as they combine the benefits of high fuel efficiency and low emissions. When hybrid vehicles are cruising or while braking, the result is excess power which is used to charge the batteries.

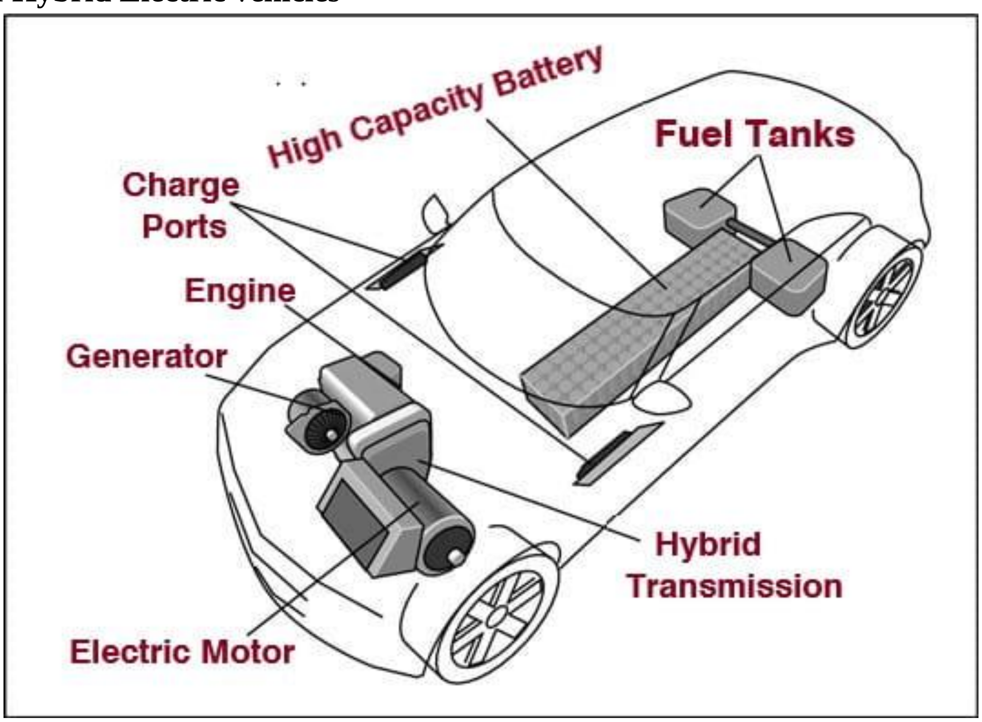
Hybrid electric vehicles are powered by an internal combustion engine and an electric motor, which uses energy stored in batteries. A hybrid electric vehicle cannot be plugged in to charge the battery. Instead, the battery is charged through regenerative braking and by the internal combustion engine.

Need for Electric vehicles

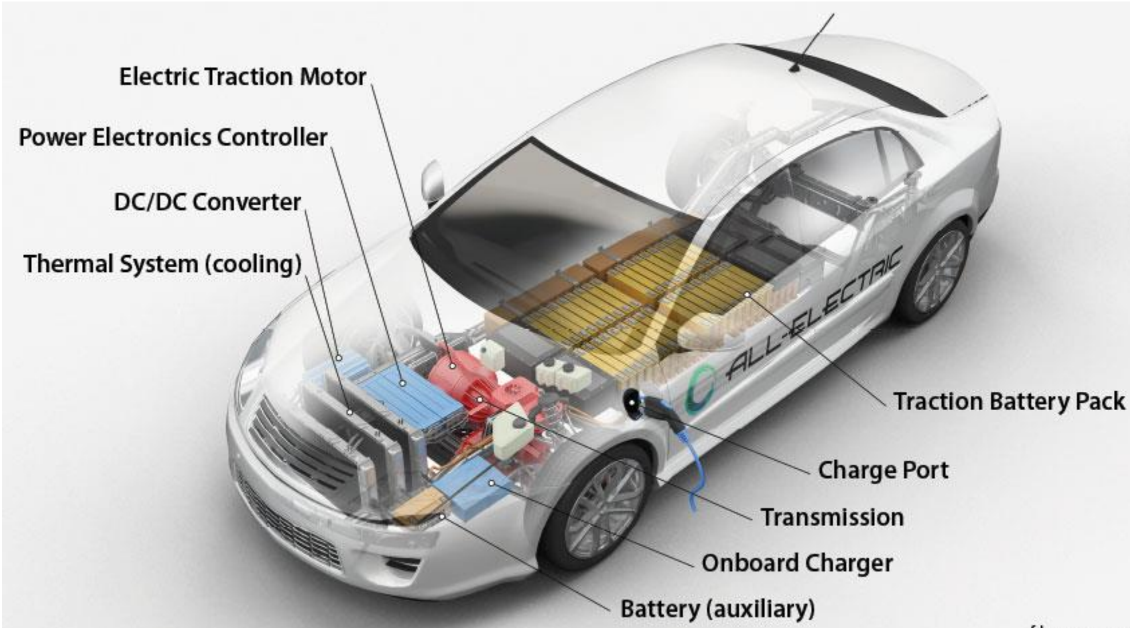
The use of electric vehicles is an active action in conserving the environment. The use of these vehicles promotes the protection of the environment by reducing greenhouse gas emissions while promoting renewable energy sources that are less likely to amount to the carbon footprint.

An electric vehicle (EV) 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 fuel cells or a generator) EVs include, but are not limited to, road and rail vehicles, surface and underwater vessels, electric aircraft and electric spacecraft.

Main components of Hybrid Electric vehicles

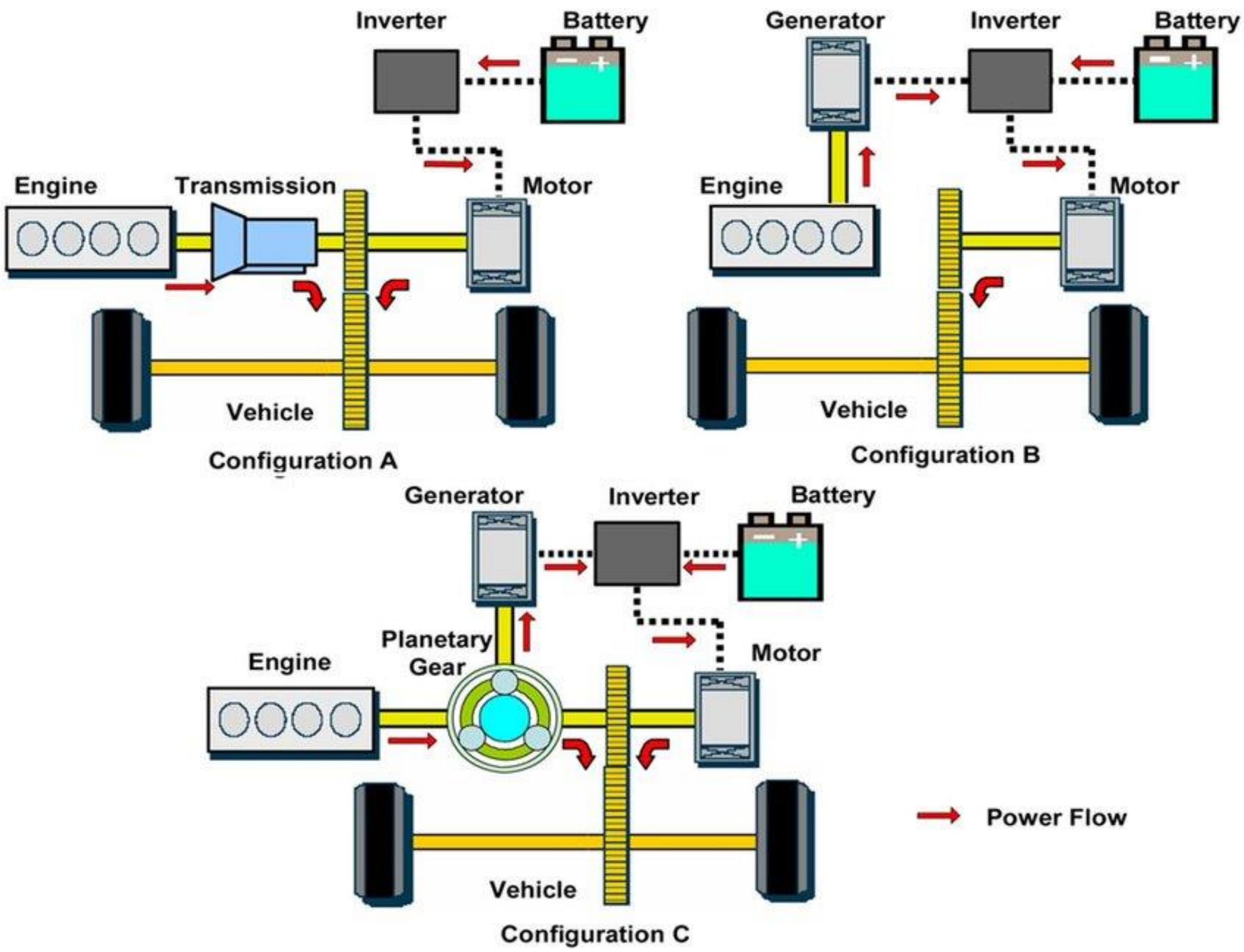


Main components of Electric vehicles



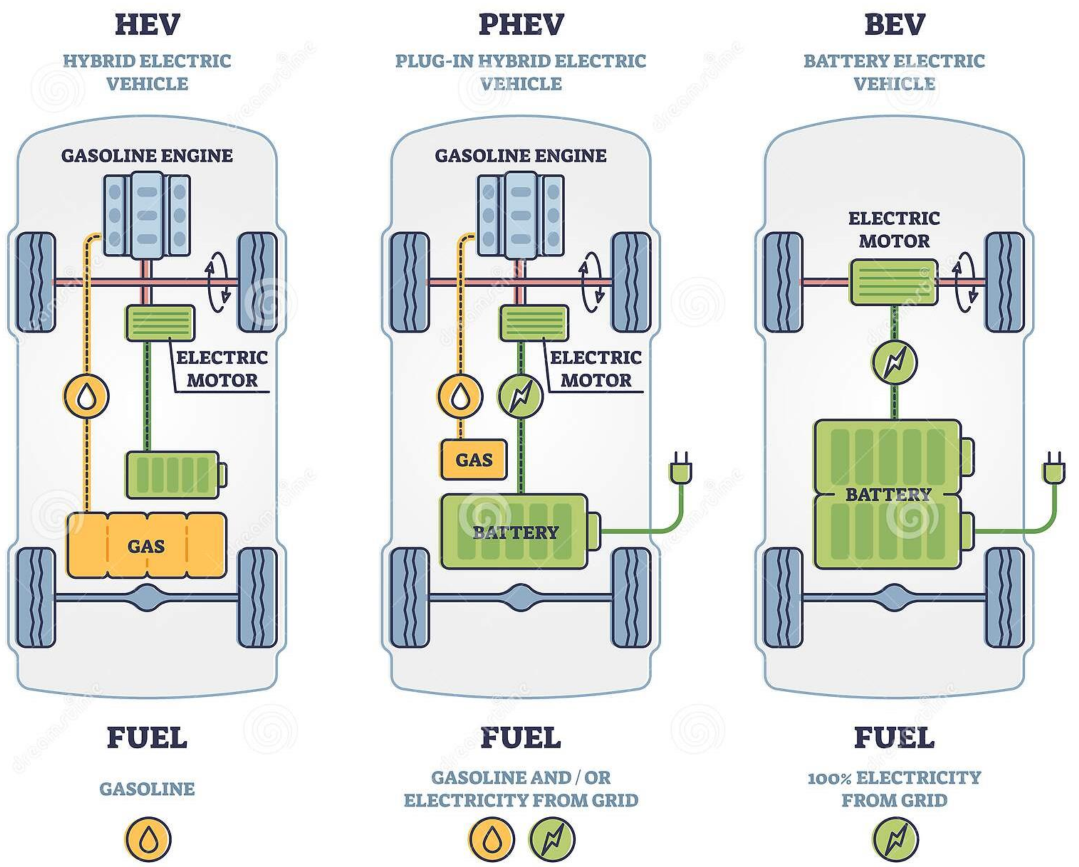
Different configurations of hybrid and electric vehicles

Typically, hybrid electric vehicles are classified into two basic configurations, series and parallel hybrids, although other configurations exist. In the series hybrid mode, there is no mechanical connection between the internal combustion engine and the wheels.



Hybrid vehicle configurations: (A) parallel; (B) series; and (C) power-split (parallel/series).

Different configurations of electric vehicles



Comparative study of diesel, petrol, hybrid and electric Vehicles.

Description	Diesel	Petrol	Hybrid EV	EV
Power	High	Moderate	Moderate	Moderate
Initial cost	Medium	Less	High	Medium
Maintenance	Medium	Medium	Low	Very Low
Operating cost	Medium	High	Low	Very Low
Range	High	High	High	Low
Availability	Medium	High	Low	Low
Emission	High	Medium	Low	Very low
Durability	High	High	Moderate	Moderate
Resale Value	High	High	Moderate	Low
Depreciation	Low	Low	Moderate	High
Battery cost	Very Low	Very Low	Low	High
Regenerative	Very Low	Very Low	Low	High
Smoothness	Very Low	Low	Moderate	High

Advantages and Limitations of hybrid vehicles

Advantages

1. Environmentally Friendly
2. Financial Benefits

3. Less Dependence on Fossil Fuels
4. Regenerative Braking System
5. Built from Light Materials
6. Assistance from Electric Motor
7. Smaller Engines
8. Automatic Start and Stop
9. Electric-Only Drive
10. Higher Resale Value

Limitations

1. Less Power
2. Can be Expensive
3. Poorer Handling
4. Higher Maintenance Costs
5. Accident from High Voltage in Batteries
6. Battery Replacement is Pricey
7. Battery Disposal and Recycling
8. Hydrogen Fuel Cell Issues

Advantages and Limitations of electric vehicles

Advantages

1. Less Strain on the Environment
2. Electricity is Renewable, unlike Gasoline
3. Low Maintenance
4. Quieter and Smoother Motion

Limitations

1. High upfront Costs
2. Limited Selection
3. Charging Complications
4. Battery Life

Specification of electric and hybrid vehicles

Specification	**Hybrid vehicles**	**Electric vehicles**
Power/Fuel Source	Electricity and Fossil Fuel (Petrol and Diesel)	Electricity Through Battery Pack (DC)
Engine	Internal Combustion Engine (ICE) and Electric Motor(s)	Electric Motor(s)
Fuel Efficiency	Combination of ICE and Battery Range	Depends on Battery Range
Emission Levels	Higher Compared to Electric Cars	Lower Compared to ICE and Hybrid Cars
Price Range	Similar to Conventional ICE Cars	High
Charging	Not Needed	Needed

1. A case study on Tayota Camry Hybrid car
2. A case study on Tata Nexon Electric car

Course Outcomes: On Completion of this course, the student will be able to

CO1: Summarize the electric and hybrid vehicle operation and architectures.

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UNIT-II

SUBSYSTEMS OF HYBRID AND ELECTRIC VEHICLES

Objective

To acquire the knowledge on subsystems of hybrid and electric vehicles.

Power Split devices for Hybrid Vehicles

Power-split hybrid or series-parallel hybrid are parallel hybrids that incorporate power-split devices, allowing for power paths from the ICE to the wheels that can be either mechanical or electrical. The main principle is to decouple the power supplied by the primary source from the power demanded by the driver.

Micro hybrids

Micro hybrid is a general term given to vehicles that use some type of start-stop system to automatically shut off the engine when idling. Strictly speaking, micro hybrids are not real hybrid vehicles, because they do not rely on two different sources of power.

Mild hybrids

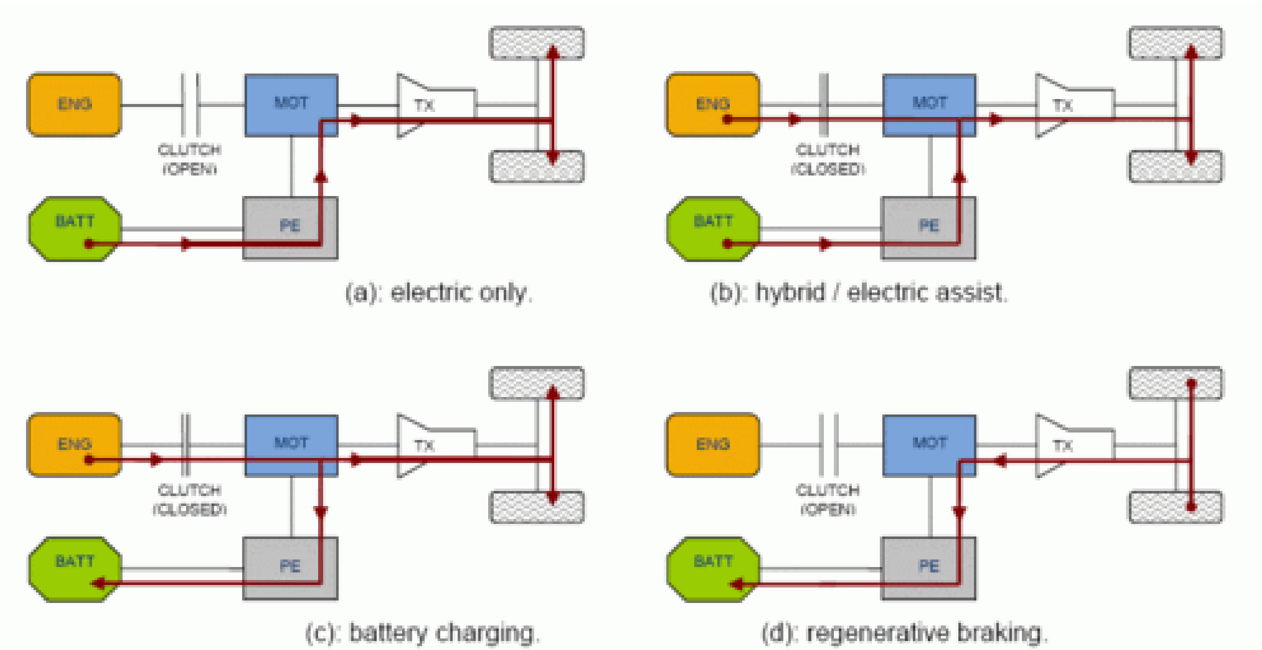
Mild hybrids are essentially conventional vehicles with some hybrid hardware, but with limited hybrid features. Typically, they are a parallel hybrid with start-stop and modest levels of engine-assist or regenerative braking. Mild hybrids generally cannot provide all-electric propulsion.

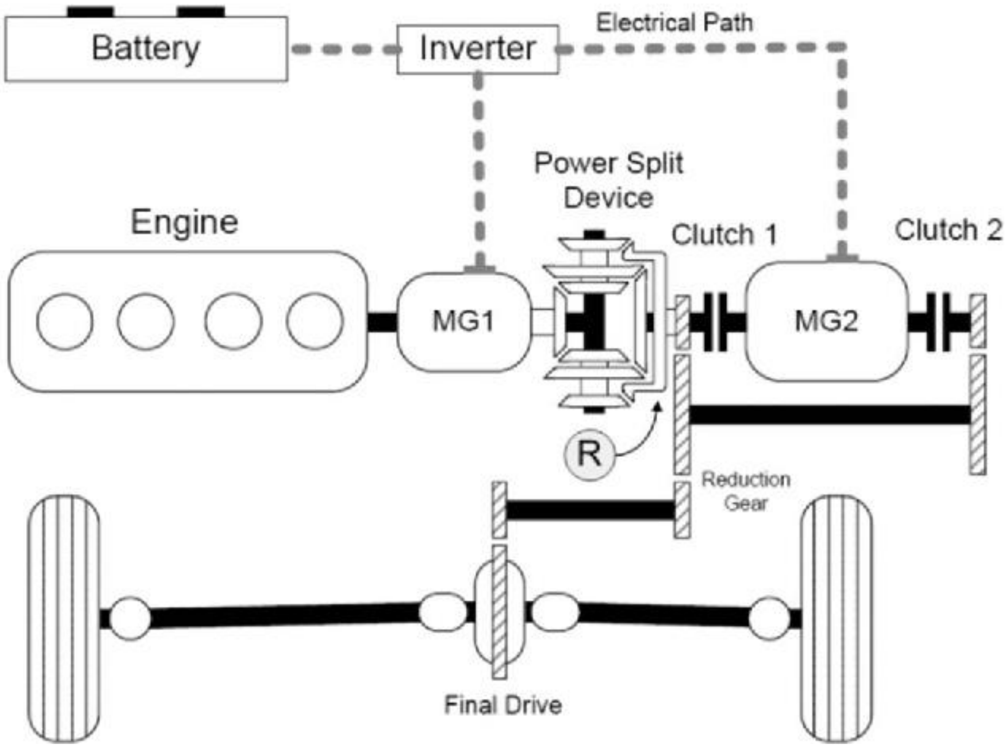
Full hybrids

A full hybrid, sometimes also called a strong hybrid, is a vehicle that can run on just the engine, the batteries, or a combination. The Toyota Prius, Toyota Camry Hybrid, Ford Escape Hybrid/Mercury Mariner Hybrid, Ford Fusion Hybrid/Lincoln MKZ Hybrid/Mercury Milan Hybrid, Ford C-Max Hybrid, Kia Optima Hybrid etc.

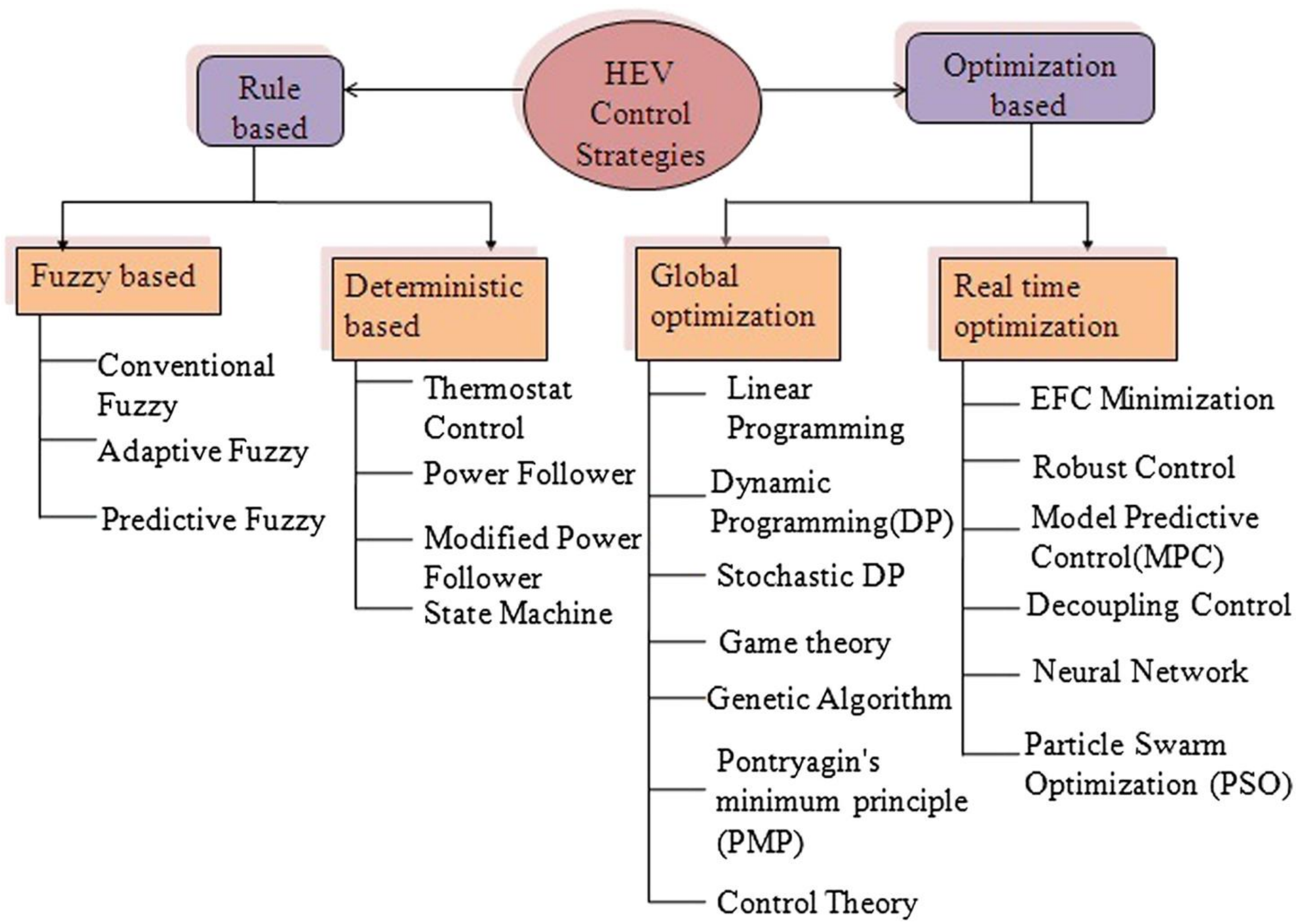
Hybrid vehicle operation modes

Hybrid vehicles can be used in different modes. The figure shows some typical modes for a parallel hybrid configuration.

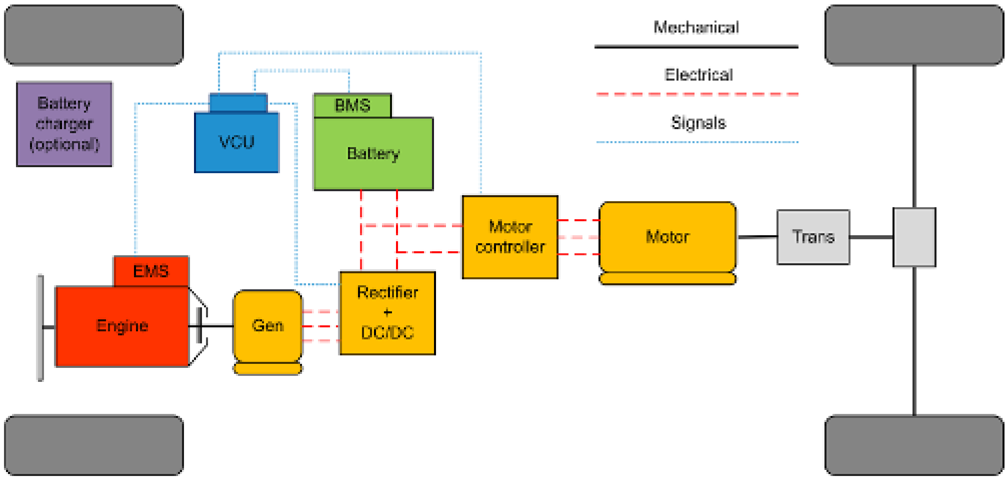




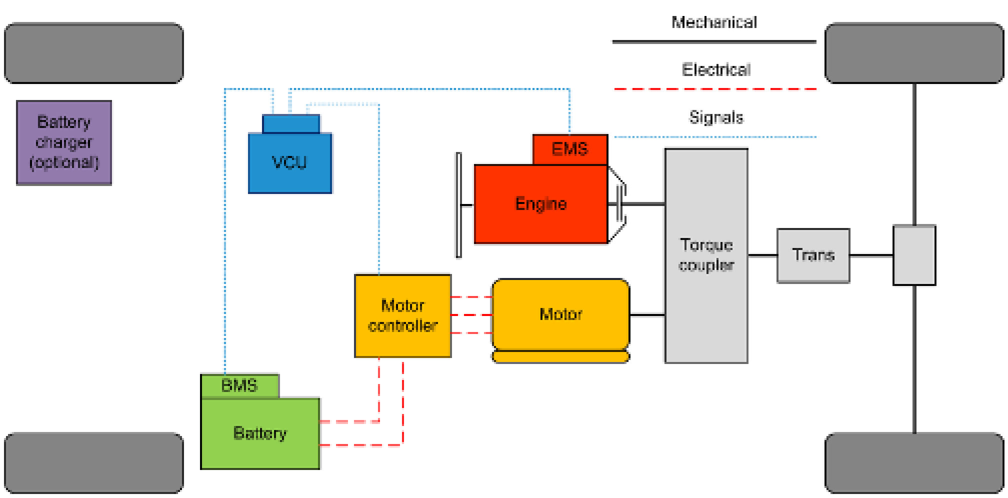
Control Strategies for Hybrid Vehicles



Series



Parallel



Economy of hybrid Vehicles

1. One of the main benefits of a hybrid car is the greater fuel economy, with hybrids using up to 30% less fuel per mile than conventional fuel-powered vehicles meaning you'll be able to save money on your fuel.
2. By including an electric motor and regenerative braking, hybrids offer greater fuel economy than equivalent non-hybrid models, and have been an important contributor to firm compliance with Corporate Average Fuel Economy (CAFE) standards.
3. The main advantages of a hybrid electric motor include comparatively less gas usage and reduced CO_2 emission than traditional gas or diesel-engine vehicle. The most recent types of plug-in hybrid electric-hybrid vehicles are the most effective green automobiles, featuring a much-improved eco-friendly engine.

Course Outcomes: On Completion of this course, the student will be able to

CO2: Design and develop the systems of electric and hybrid vehicles.

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UNIT-III

ENERGY SOURCES

Objective

To design the required energy storage devices.

Battery Parameters

Storage Capacity

It determines for number of hours for which the battery can be discharged at a constant current to a defined cut-off voltage. It is represented by the Coulomb SI unit (Amperes per second) but since this unit is usually very small, the Ampere-hour (Ah) unit is used instead (1 Ah represents 3600 C).

The value of this capacity depends on the ambient temperature, the age of the battery, and the discharge rate. The higher the discharge rate, the lower the capacity, although it affects each battery technology differently. Additional to the Ampere-hour unit, the storage capacity can also be defined in Watt-hours (Wh=V x Ah), where 1 Wh represents 3600 J.

Energy Density

The energy density is the amount of energy that can be stored, per cubic meter of battery volume, expressed in Watt-hour per cubic meter (Wh/m3). This is a very important parameter to select a specific battery technology for transportation applications, where space availability is critical.

Specific Power

This parameter is defined as the power capacity per kilogram of battery, in W/kg. Some battery technologies offer high energy density but low specific power, which means that even though they can store a large amount of energy, they can only supply a small amount of power instantly. In transportation terms, this would mean that a vehicle could run for a long distance, at low speed. On the contrary, batteries with high specific power usually have low energy density, because high discharge currents usually reduce the available energy rapidly (e.g., high acceleration).

Cell Voltage

The cell voltage is determined by the equilibrium thermodynamic reactions that take place inside the cell, however, this value is often difficult to measure and therefore, the open circuit voltage (OCV) measured between the anode and cathode terminals is used instead. For some battery technologies (e.g., lead-acid), the OCV can be used as a basic estimate of the state of charge (SoC). Another measure often used is the closed circuit voltage (CCV), which depends on the load current, state of charge, and cell's usage history. Finally, battery manufacturers provide the nominal voltage value, from the cell's characterization and therefore, cannot be experimentally verified.

Charge and Discharge Current

During the discharging process in a battery, electrons flow from the anode to the cathode through the load, to provide with the required current and the circuit is completed in the electrolyte. During the charging process, an external source supplies with the charging current and the oxidation takes place at the positive electrode while the reduction takes place at the negative electrode. For practical purposes, the term C-rate is used to express the charge or discharge current relative to the rated capacity. For example, a discharge rate of 1 C means that the battery will be fully discharged in 1 h.

State of Charge

The state of charge (SoC) defines the amount of stored energy relative to the total energy storage capacity of the battery. Depending on the battery technology, different methods are used to estimate this value.

Depth of Discharge

Often referred to as DoD (in %), this parameter expresses the battery capacity that has been discharged relative to the maximum capacity. Each battery technology supports different maximum recommended levels of DoD to minimize its impact on the overall cycle life.

Cycle Life

The cycle life determines the number of charge/discharge cycles that the battery can experience before it reaches a predetermined energy capacity or other performance criteria. The current rate at which the battery is charged/discharged as well as environmental conditions (e.g., temperature and humidity) and the DoD can affect this number, since it is originally calculated by the manufacturer based on specific charge and discharge conditions.

Self-discharge

This parameter defines the reduction in energy capacity of the battery under no-load conditions (e.g., open circuit), as a result of internal short-circuits and chemical reactions. This parameter can be affected by environmental conditions such as temperature and humidity, as well as the DoD and the battery's charge/discharge history. Additionally, this parameter is particularly important for long-term shelf storage of batteries.

Round-Trip Efficiency

Due to internal losses and material degradation, not all the energy supplied to the battery during charging can be recovered during discharge. The amount of energy that can be taken from the battery during the discharging process over the energy supplied determines the round-trip efficiency. This efficiency is sensitive to the charging and discharging currents. At higher currents, thermal losses increase and therefore the efficiency is reduced.

Types of Batteries

Lead Acid Battery

The lead–acid battery is a type of rechargeable battery first invented in 1859 by French physicist Gaston Planté. It is the first type of rechargeable battery ever created. Compared to modern rechargeable batteries, lead–acid batteries have relatively low energy density. Despite this, their ability to supply high surge currents means that the cells have a relatively large power-to-weight ratio. These features, along with their low cost, make them attractive for use in motor vehicles to provide the high current required by starter motors.

Nickel Metal Hydride Battery

A nickel metal hydride battery (NiMH or Ni–MH) is a type of rechargeable battery. The chemical reaction at the positive electrode is similar to that of the nickel–cadmium cell (NiCd), with both using nickel oxide hydroxide (NiOOH). However, the negative electrodes use a hydrogen-absorbing alloy instead of cadmium. NiMH batteries can have two to three times the capacity of NiCd batteries of the same size, with significantly higher energy density, although much less than lithium-ion batteries.

Lithium Ion Battery

A lithium-ion battery or Li-ion battery is a type of rechargeable battery composed of cells in which lithium ions move from the negative electrode through an electrolyte to the positive electrode during discharge and back when charging. Li-ion cells use an intercalated lithium compound as the material at the positive electrode and typically graphite at the negative electrode. Li-ion batteries have a high energy density, no memory effect (other than LFP cells) and low self-discharge. Cells can be manufactured to either prioritize energy or power density. They can however be a safety hazard since they contain flammable electrolytes and if damaged or incorrectly charged can lead to explosions and fires.

Sodium Based Battery

In sodium-based batteries, anodes can develop filaments called dendrites that could cause electrical shorts and increase the chances of a fire or explosion. This new sodium-based technology resists dendrite growth and recharges as fast as a lithium-ion battery.

Metal Air Battery

A metal-air battery uses some type of metal (like aluminum) for the anode, air as the cathode, along with a liquid electrolyte. In the case of aluminum, oxygen from the air then combines with the metal to create aluminum hydroxide, which activates the electrolysis process and creates a current.

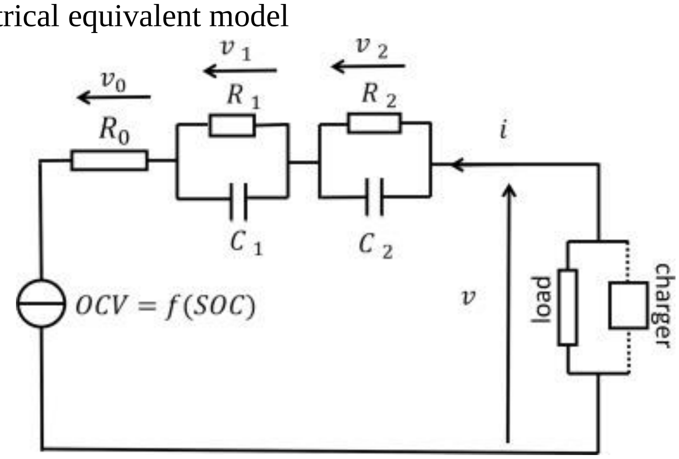
Battery Modelling

Battery modelling is an excellent way to predict and optimize some batteries' basic parameters like state of charge, battery lifetime and charge/discharge characteristic. Over the years, many different types of battery models have been developed for different application areas.

Equivalent circuit models

Battery equivalent circuit models (ECMs) are widely employed in online battery management applications. The model parameters are known to vary according to the operating conditions, such as the battery state of charge (SOC).

S. No.	Battery model
1.	Rint model
2.	Thevenin electric model
3.	Second order RC Thevenin model
4.	Accurate electrical equivalent model



Battery equivalent circuit model using decoupled least squares technique.

Basic Battery Charging Methods

Constant Voltage

A constant voltage charger is basically a DC power supply which in its simplest form may consist of a step down transformer from the mains with a rectifier to provide the DC voltage to charge the battery. Such simple designs are often found in cheap car battery chargers. The lead-acid cells used for cars and backup power systems typically use constant voltage chargers. In addition, lithium-ion cells often use constant voltage systems, although these usually are more complex with added circuitry to protect both the batteries and the user safety.

Constant Current

Constant current chargers vary the voltage they apply to the battery to maintain a constant current flow, switching off when the voltage reaches the level of a full charge. This design is usually used for nickel-cadmium and nickel-metal hydride cells or batteries.

Taper Current

This is charging from a crude unregulated constant voltage source. It is not a controlled charge as in V Taper above. The current diminishes as the cell voltage (back emf) builds up. There is a serious danger of damaging the cells through overcharging. To avoid this the charging rate and duration should be limited. Suitable for SLA batteries only.

Pulsed Charge

Pulsed chargers feed the charge current to the battery in pulses. The charging rate (based on the average current) can be precisely controlled by varying the width of the pulses, typically about one second. During the charging process, short rest periods of 20 to 30 milliseconds, between pulses allow the chemical actions in the battery to stabilize by equalizing the reaction throughout the bulk of the electrode before recommencing the charge. This enables the chemical reaction to keep pace with the rate of inputting the electrical energy. It is also claimed that this method can reduce unwanted chemical reactions at the electrode surface such as gas formation, crystal growth and passivation. If required, it is also possible to sample the open circuit voltage of the battery during the rest period.

Burp Charging

Also called Reflex or Negative Pulse Charging Used in conjunction with pulse charging, it applies a very short discharge pulse, typically 2 to 3 times the charging current for 5 milliseconds, during the charging rest period to depolarize the cell. These pulses dislodge any gas bubbles which have built up on the electrodes during fast charging, speeding up the stabilization process and hence the overall charging process. The release and diffusion of the gas bubbles is known as "burping". Controversial claims have been made for the improvements in both the charge rate and the battery lifetime as well as for the removal of dendrites made possible by this technique. The least that can be said is that "it does not damage the battery".

IUI Charging

This is a recently developed charging profile used for fast charging standard flooded lead acid batteries from particular manufacturers. It is not suitable for all lead acid batteries. Initially the battery is charged at a constant (I) rate until the cell voltage reaches a preset value - normally a voltage near to that at which gassing occurs. This first part of the charging cycle is known as the bulk charge phase. When the preset voltage has been reached, the charger switches into the constant voltage (U) phase and the current drawn by the battery will gradually drop until it reaches another preset level. This second part of the cycle completes the normal charging of the battery at a slowly diminishing rate. Finally, the charger switches again into the constant current mode (I) and the voltage continues to rise up to a new higher preset limit when the charger is switched off. This last phase is used to equalize the charge on the individual cells in the battery to maximize battery life.

Trickle Charge

Trickle charging is designed to compensate for the self-discharge of the battery. Continuous charge. Long term constant current charging for standby use. The charge rate varies according to the frequency of discharge. Not suitable for some battery chemistries, e.g. NiMH and Lithium, which are susceptible to damage from overcharging. In some applications the charger is designed to switch to trickle charging when the battery is fully charged.

Float Charge

The battery and the load are permanently connected in parallel across the DC charging source and held at a constant voltage below the battery's upper voltage limit. Used for emergency power back up systems. Mainly used with lead acid batteries.

Random Charging

All of the above applications involve controlled charge of the battery, however there are many applications where the energy to charge the battery is only available, or is delivered, in some random, uncontrolled way. This applies to automotive applications where the energy depends on the engine speed which is continuously changing. The problem is more acute in EV and HEV applications which use regenerative braking since this generates large power spikes during braking which the battery must absorb. More benign applications are in solar panel installations which can only be charged when the sun is shining. These all require special techniques to limit the charging current or voltage to levels which the battery can tolerate.

Quick Charging Devices

There are three main types of EV Chargers – rapid, fast, and slow. Measurement of power is in kilowatts (kW). Take note these represent the power outputs and therefore charging speeds, possible to charge an EV.

RAPID Chargers

These are the fastest charger for any EV, usually located at locations close to main routes in the country. The devices provide high power direct current (DC) or alternating current (AC) to recharge a car as rapidly as attainable.

Depending on the model and brand, EVs can be recharged to 80% within 20 minutes, though an average modern EV would take around an hour on a standard 50 kW rapid charge point. At first, the car charges at normal-speed, though the car will reduce charging speed as the battery gets closer to full charge. As such, terms are quoted at the-charge of 80%, after which the charging speed contracts significantly. It maximises charging efficiency and helps protect the battery. These rapid chargers can be used only with vehicles with rapid-charging capability.

Types:

Rapid DC: Most common chargers in India. These chargers provide power at 50 kW (125A). Connectors typically charge an EV to 80% in 20 minutes to an hour, depending on battery capacity and starting state of charge.

Ultra-Rapid DC: Provide power at 100 kW or more. These are mostly either 100 kW, 150 kW, or 350 kW – though other maximum speeds between these figures are possible. According to Zap-Map, "These are the next-generation of rapid charge points, able to keep recharging times down despite battery capacities increasing in newer EVs."

FAST Chargers

These are Type-2 AC Chargers. Fast chargers are rated at either 7 kW or 22 kW (single- or three-phase 32A). Charging times vary on unit speed and the vehicle, but a 7 kW charger will recharge a compatible EV with a 40 kWh battery in 4-6 hours and a 22 kW charger in 1-2 hours. Fast chargers tend to be found at locations such as car parks, shops, supermarkets, or leisure centres, where you are likely to be parked for an hour or more.

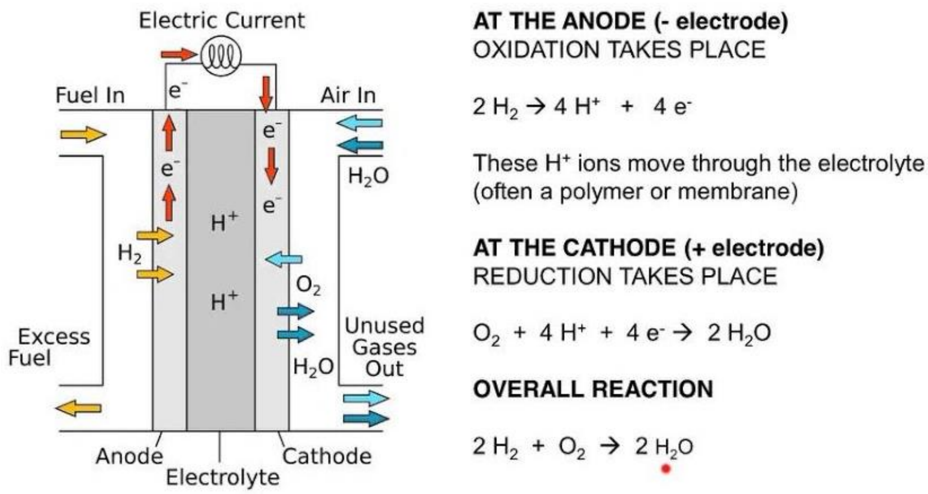
Untethered units are therefore more flexible and could be used by any EV with the correct cable. Charging rates when using a fast charger will depend on the car’s on-board charger, with not all models able to accept 7 kW or more. These models can still be plugged into the charge point, but will only draw the maximum power accepted by the on-board charger. Almost all EVs and PHEVs can charge on Type 2 units, with the correct cable at least. It is by far the most common public charge point standard around, and most plug-in car owners will have a cable, with a Type 2 connector charger-side. The vast majority of fast chargers provide AC charging, though some networks are installing 25 kW DC chargers with CCS or CHAdeMO connectors.

SLOW Chargers

These are the most commonly available chargers in the Indian market. Power output is 3 kW – 6 kW and the car will be charged between 8 - 12 hours. You will have to keep your car overnight to be in full-charge.

Fuel Cell

A fuel cell is an electrochemical cell that converts the chemical energy of a fuel (often hydrogen) and an oxidizing agent (often oxygen) into electricity through a pair of redox reactions.



Fuel cells are different from most batteries in requiring a continuous source of fuel and oxygen (usually from air) to sustain the chemical reaction, whereas in a battery the chemical energy usually comes from metals and their ions or oxides that are commonly already present in the battery, except in flow batteries. Fuel cells can produce electricity continuously for as long as fuel and oxygen are supplied.

Fuel cell Characteristics

Fuel cells work like batteries, but they do not run down or need recharging. They produce electricity and heat as long as fuel is supplied. A fuel cell consists of two electrodes—a negative electrode (or anode) and a positive electrode (or cathode)—sandwiched around an electrolyte.

Electrical energy is produced from oxidation reactions. Which term refers to an electrochemical cell that uses a spontaneous redox reaction to produce an electric current.

Types of Fuel Cells

Fuel cells are classified primarily by the kind of electrolyte they employ. This classification determines the kind of electro-chemical reactions that take place in the cell, the kind of catalysts required, the temperature range in which the cell operates, the fuel required, and other factors. These characteristics, in turn, affect the applications for which these cells are most suitable. There are several types of fuel cells currently under development, each with its own advantages, limitations, and potential applications. Learn more about the following types of fuel cells.

Half reactions of fuel cell

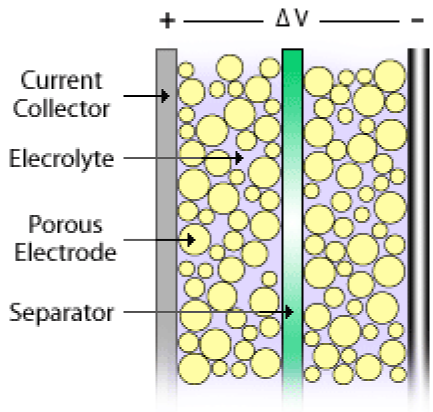
Like batteries, fuel cells create electricity through chemical reactions that involve the transfer of electrons. Chemists call these reactions oxidation-reduction, or redox, reactions. Redox reactions can be split into two parts, the oxidation half and the reduction half.

Ultra capacitors

Ultra capacitors are used in some electric vehicles, such as AFS Trinity's concept prototype, to store rapidly available energy with their high power density, in order to keep batteries within safe resistive heating limits and extend battery life.

However, ultra-capacitors are not a substitute for batteries in most electric vehicles - yet. Li-ion batteries are likely going to be the go-to power supply for EVs for the near to distant future.

The electrodes for commercial ultra-capacitors are usually made from nanostructured carbon-based materials, like carbon nanotubes, porous activated carbons, or carbon aerogels. These materials have a high surface area, and good conductivity, making them ideal for use in ultra-capacitors.



Battery Management System

The lithium-ion batteries can be used only in specified conditions, and therefore battery management system (BMS) is necessary in order to monitor battery state and ensure safety of operation. The different BMS structures have been compared and their advantages have been shown depending on battery system size.

A battery management system allows users to monitor individual cells within a battery pack. As cells work together to release energy to the load, it is crucial to maintain stability throughout the whole pack.

A battery management system can be comprised of many functional blocks including: cut-off FETs (Field Effect Transistors), 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.

Course Outcomes: On Completion of this course, the student will be able to

CO2: Design and develop the systems of electric and hybrid vehicles.

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UNIT-IV
MOTORS AND CONTROLLERS

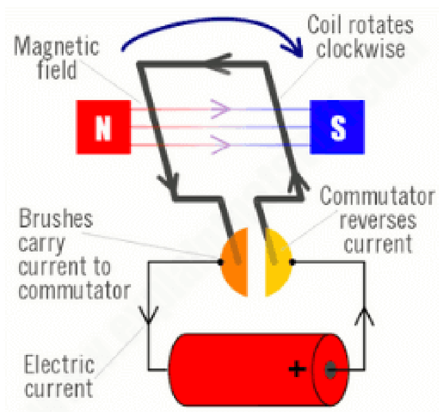
Objective

To select the suitable electric propulsion systems.

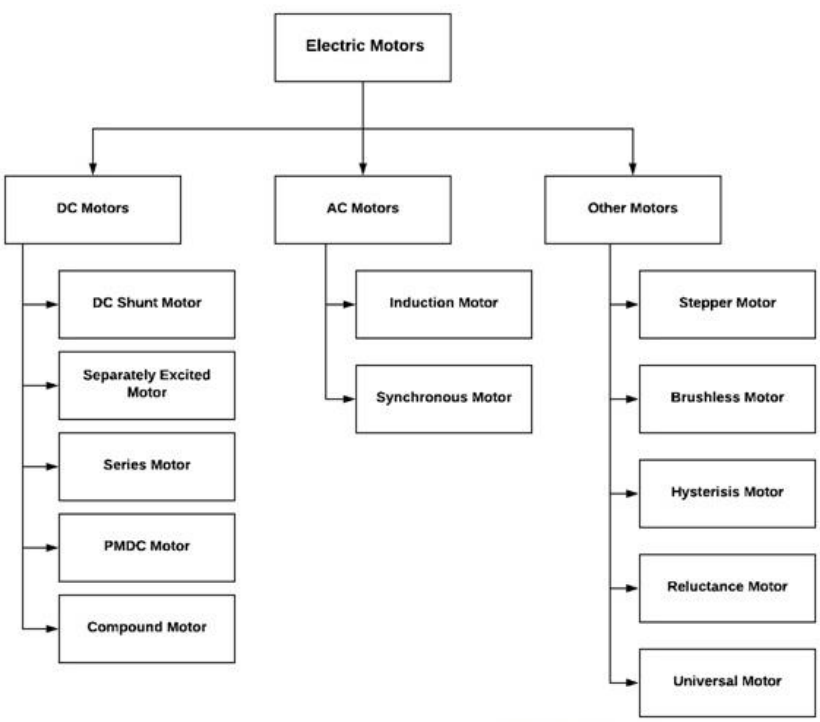
Motors

An electric motor is an electrical machine that converts electrical energy into mechanical energy. Most electric motors operate through the interaction between the motor's magnetic field and electric current in a wire winding to generate force in the form of torque applied on the motor's shaft. An electric generator is mechanically identical to an electric motor, but operates with a reversed flow of power, converting mechanical energy into electrical energy.

Electric motors can be powered by direct current (DC) sources, such as from batteries, or rectifiers, or by alternating current (AC) sources, such as a power grid, inverters or electrical generators.

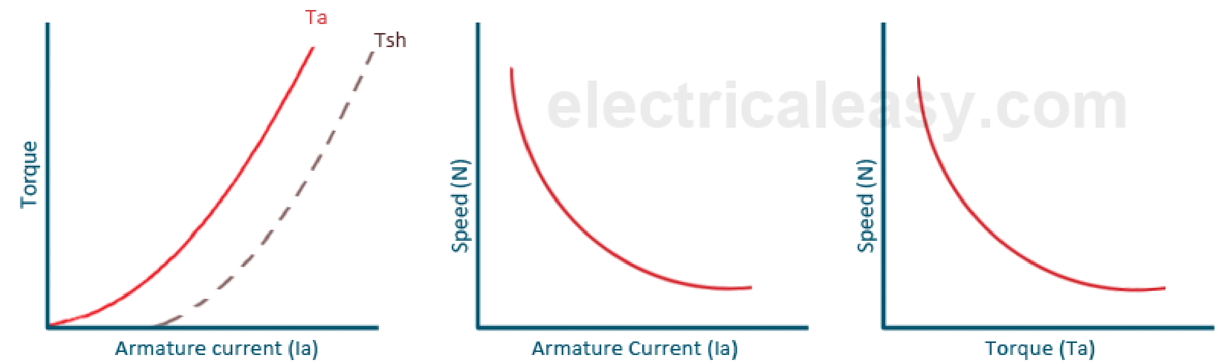


Types of Motors



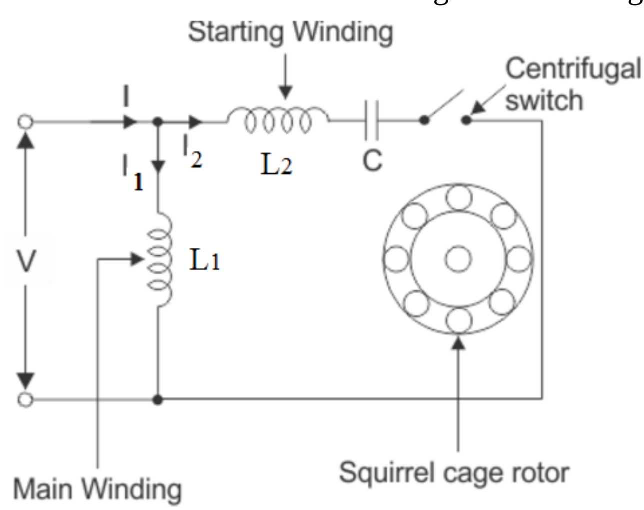
Characteristic of DC motors

Generally, three characteristic curves are considered important for DC motors which are, (i) Torque vs. armature current, (ii) Speed vs. armature current and (iii) Speed vs. torque



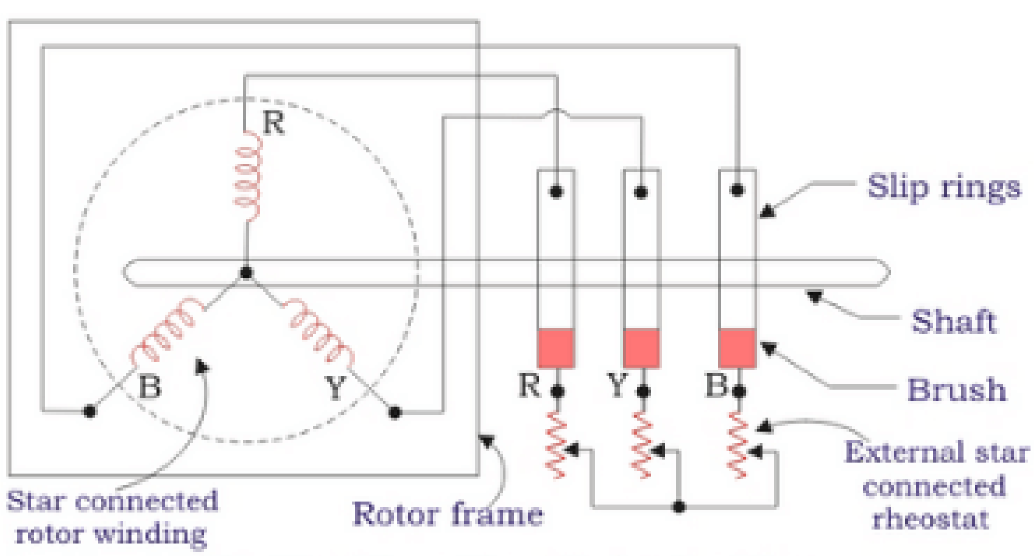
Single-phase AC induction motor

A single-phase AC induction motor is a brushless motor designed with a single stator coil.



Three-phase AC induction motor

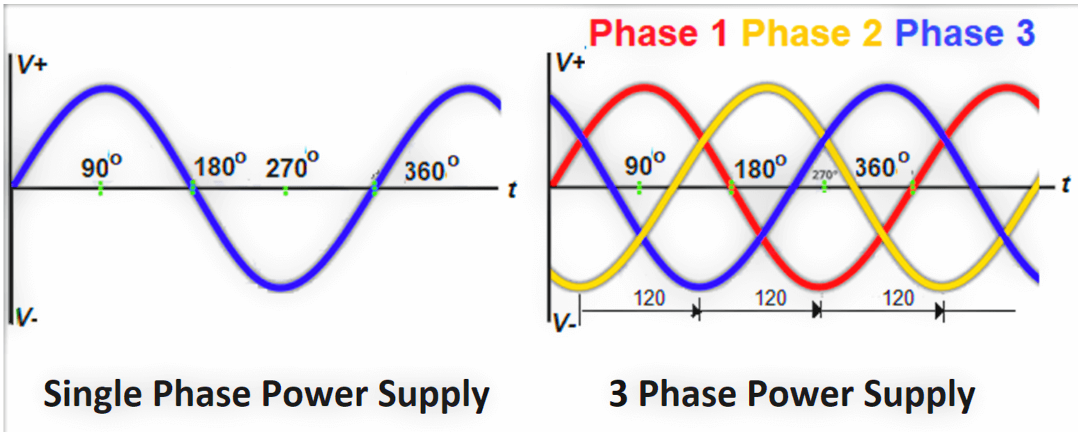
Three-phase motors are a type of AC motor that is a specific example of a polyphase motor. These motors can be either an induction motor (also called an asynchronous motor) or a synchronous motor. The motors consist of three main components – the stator, the rotor, and the enclosure.



Slip Ring Three Phase Induction Motor

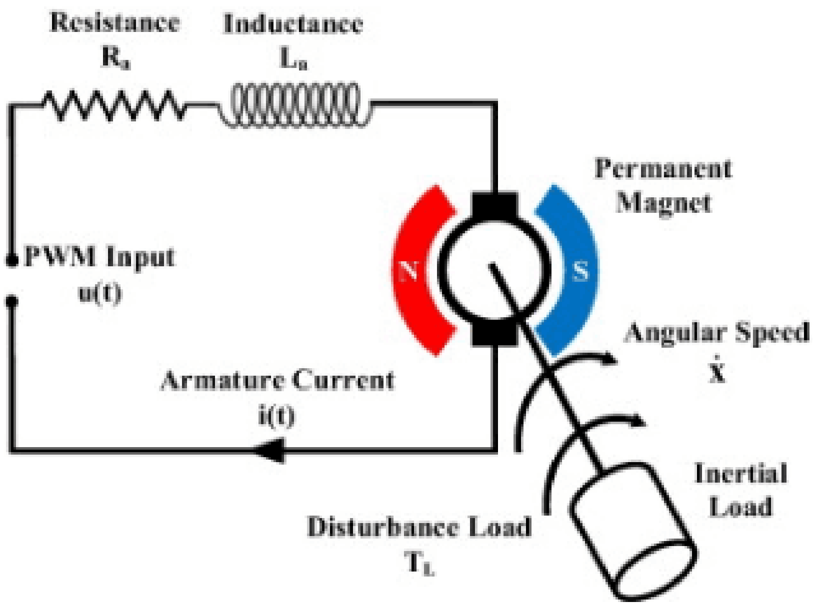
Comparison between single phase and 3 phase AC induction motor

The single-phase motor has two terminals, and it requires only two wires to power it up, and the three-phase motor has three terminals and requires three or four (including neutral) wires to operate. The power factor of a single-phase induction motor is low, compared to that of a three-phase induction motor.



Permanent magnet motor

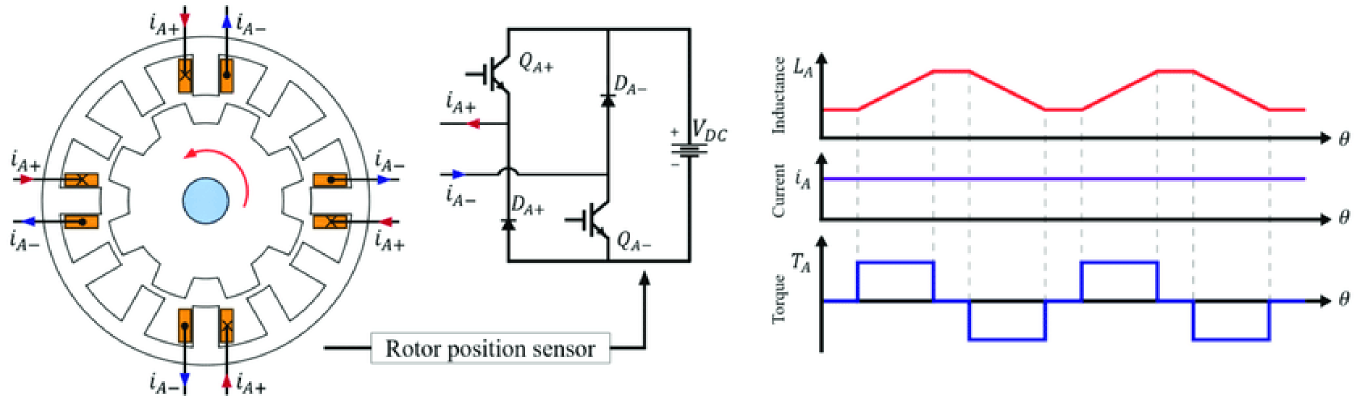
A permanent magnet motor is a type of electric motor that uses permanent magnets in addition to windings on its field, rather than windings only.



The fundamental operation of a permanent magnet motor is like most electric motors; the outer stator holds windings of coils fed by a power source, and the rotor freely rotates based on the forces imparted by the stator coils.

Switched reluctance motor (SRM)

The switched reluctance motor (SRM) is an electric motor that runs by reluctance torque. Unlike common brushed DC motor types, power is delivered to windings in the stator (case) rather than the rotor. This greatly simplifies mechanical design as power does not have to be delivered to a moving part, but it complicates the electrical design as some sort of switching system needs to be used to deliver power to the different windings. Electronic devices can precisely time the switching of currents, facilitating SRM configurations. Its main drawback is torque ripple.



The working principle of the switched reluctance motor is, it works on the principle of variable reluctance that means, the rotor of this motor constantly tries to align through the lowest reluctance lane. The formation of the rotary magnetic field can be done using the circuit of power electronics switching.

Benefits attributed to switched reluctance (also called variable-reluctance) motors include high motor-drive efficiency and reliability, low overall system cost, and increased performance.

Motor Drive

Motor drive means a system that includes a motor. An adjustable speed motor drive means a system that includes a motor that has multiple operating speeds. A variable speed motor drive is a system that includes a motor and is continuously variable in speed. If the motor is generating electrical energy rather than using it – this could be called a generator drive but is often still referred to as a motor drive.

There are three general categories of electric drives: DC motor drives, eddy current drives and AC motor drives. Each of these general types can be further divided into numerous variations.

By varying the frequency and voltage of the power supply to an electrical motor, drives can control its speed making it possible to enhance process control, reduce energy usage and generate energy efficiently or optimize the operation of various applications relying on electric motors.

Speed Controllers

Motor speed controllers are electronic devices that control motor speed. They take a signal for the needed speed and drive a motor to that speed. There are a variety of motor speed controllers available.

The main difference between a motor controller and a motor driver is, the motor controller is responsible for the controlling speed, torque, the direction of the motor whereas a motor driver is responsible to provide enough electrical power to the motor as per requirement

There are mainly there are three types of motor control circuits:

- Direct On Line Starter (DOL starter)
- Star Delta Starter.
- Auto Transformer Starter.

Torque vectoring

In simple terms, torque vectoring is a computer-controlled system that controls how much power your car's engine or motors send to each individual wheel. By controlling power more effectively, a car with torque vectoring will have more grip on slippery surfaces and can accelerate more quickly.

Torque vectoring technology is a vehicle's ability to vary torque in each wheel. Torque vectoring systems enable a car to transfer torque between a given wheel or axle based on cornering. This technology concept is designed to improve steering response and handling while also improving vehicle dynamics.

Torque vectoring normally works by piggybacking on the natural properties of a differential, which allow one wheel on an axle to go faster or slower than another. Mitsubishi defined the technology with its Active Yaw Control on the Lancer Evolution IV rear axle.

Regenerative Braking

Regenerative braking is a way of taking the wasted energy from the process of slowing down a car and using it to recharge the car's batteries. On a normal car, braking simply wastes energy - but with regenerative braking, some of the energy is able to be reused.

Regenerative braking harnesses the energy expended while slowing a vehicle to help recharge the batteries, tapping into the ability of an electric motor to turn into a generator.

This braking system still depends on uncontrollable variables. But, the regenerative braking system has a variety of benefits like the driving range can be extended, the efficiency of braking can be improved, decreases brake wear, etc.

Rectifier

A rectifier is an electrical device that converts alternating current (AC), which periodically reverses direction, to direct current (DC), which flows in only one direction. The reverse operation is performed by the inverter.

Ultimately, this induced alternating current electricity provides power for an AC load—for example, an electric vehicle's (EV) electric traction motor. A rectifier is a similar device to an inverter except that it does the opposite, converting AC power to DC power.

Inverters

The primary function of an inverter is to convert Direct Current (DC) power into standard, Alternating Current (AC). This is because, whereas AC is the power supplied to industry and homes by the main power grid or public utility, the batteries of alternating power systems store only DC power.

An inverter is a device that converts DC power to the AC power used in an electric vehicle motor. The inverter can change the speed at which the motor rotates by adjusting the frequency of the alternating current.

The inverter in an EV is also what's called a VFD – Variable Frequency Drive. The sine wave AC power can be generated in a wide range of different frequencies.

DC/DC converters

Unstable or improper voltage supplies can lead to characteristics degradation and even malfunction. To prevent this, a DC-DC converter is needed to convert and stabilize the voltage. A device that stabilizes the voltage using a DC-DC converter is referred to as a voltage regulator.

Once the initial specs of a DC-DC design are selected (e.g., input voltage range, output voltage, output current), the first step is to select a converter IC. The desired DC-DC topology will narrow this choice. If the input voltage is greater than the output voltage, choose a buck (i.e., step-down) topology.

Switching converters are prone to noise.

They are expensive.

Choppers are inadequate due to unsteady voltage and current supply.

Course Outcomes: On Completion of this course, the student will be able to

CO4: Identify the vehicle characteristics, operating modes, and performance parameters of the vehicle.

KSR COLLEGE OF ENGINEERING, (Autonomous) TIRUCHENGODE-637 215

DEPARTMENT OF AUTOMOBILE ENGINEERING

Year / Sem	:	**IV / VIII**
Subject Code & Name	:	**18AU811 – ELECTRIC AND HYBRID VEHICLES**
Faculty Name	:	**Dr. R. VENKATACHALAM**

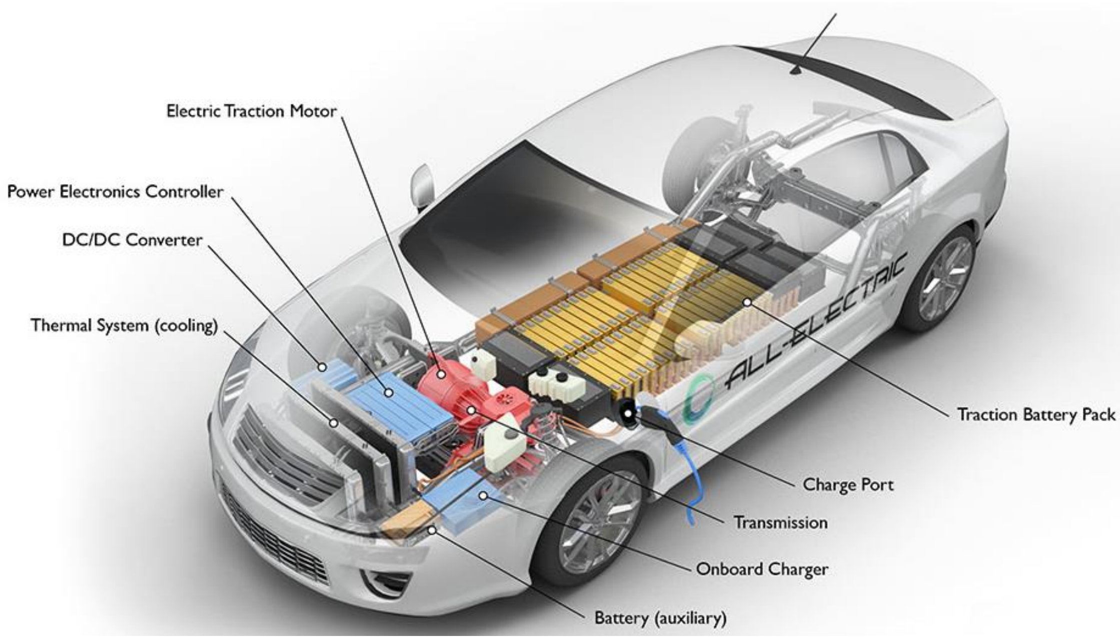
UNIT-V

DESIGN CONSIDERATIONS FOR ELECTRIC VEHICLES

Objective

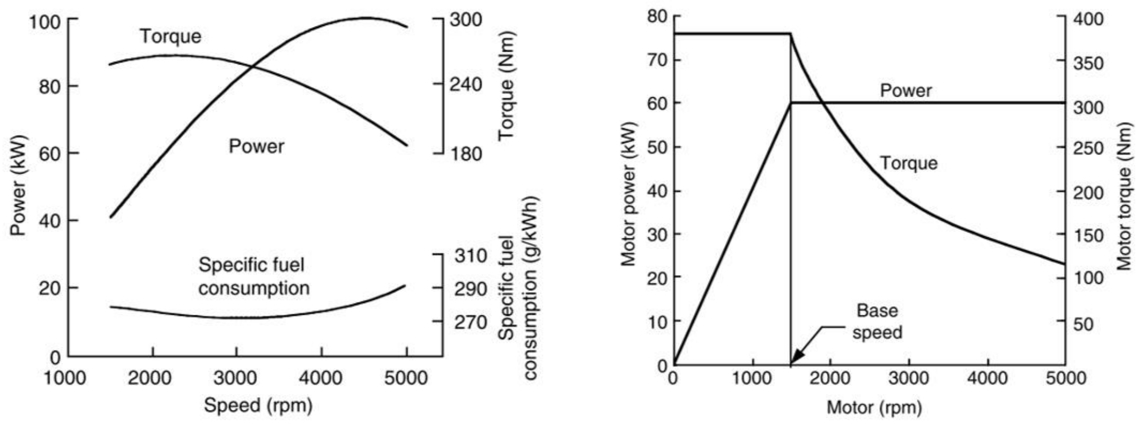
To infer the design consideration for electric vehicles.

Design requirement for electric vehicles

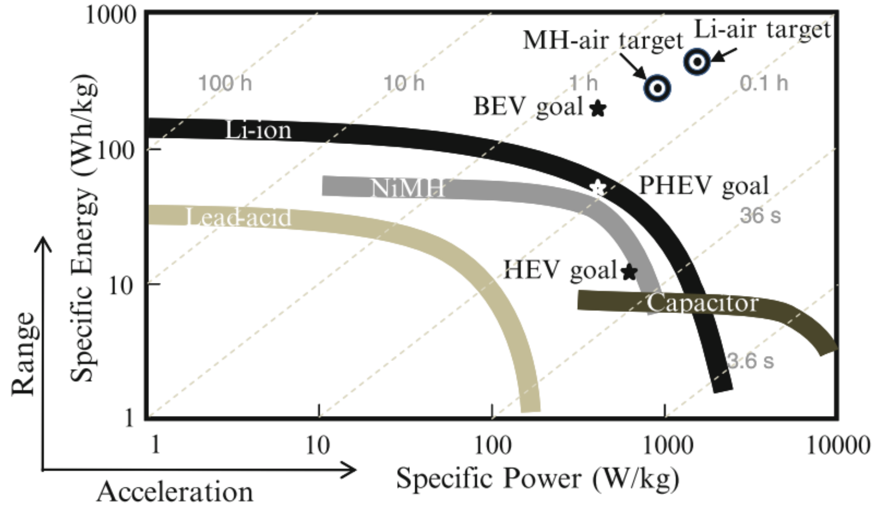


Factors that affect Electric Vehicle Range

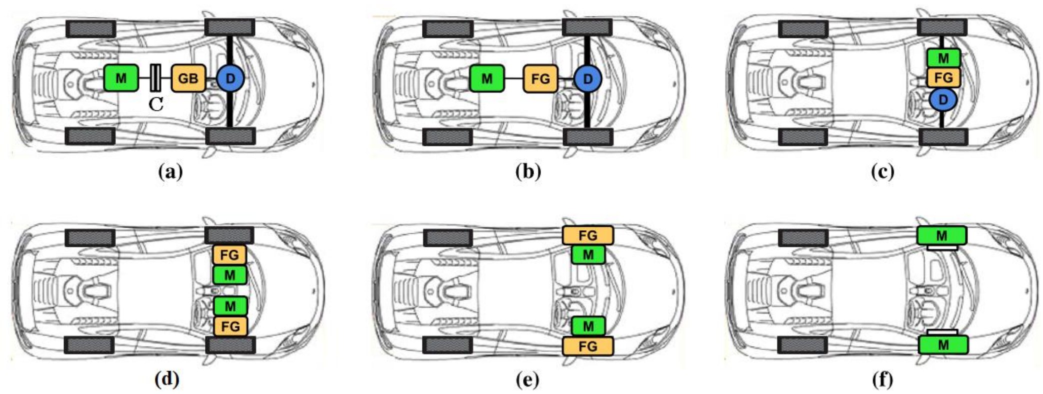
- Speed.
- Wind.
- Payload.
- Tire Traction.
- Cold Weather.
- HVAC.
- Battery Degradation.



Typical performance characteristics of gasoline engine (left) and electric motor (right)



Plot of a few electrochemical energy storage devices used in the propulsion application



C : Clutch, D : Differential, FG : Fixed Gearing, GB : Gear Box, M : Electric Motor

Six types of EV configurations

One-motor based EV powertrains

(a) Conventional type:

The EV propulsion system consists of a differential (D), a gearbox (GB), a clutch (C) and an electric motor (M). This configuration can be considered as a counterpart of an ICE vehicle with rear-engine-front-wheel drive, where the ICE is replaced by an electric motor.

(b) No transmission type: Rear-engine-Front-wheel (RF)

This configuration, with fixed gearing (FG) used instead of a clutch and gearbox, is quite similar as the conventional one.

(c) No transmission type: Front-engine-Front-wheel (FF)

The electric motor, fixed gearing and differential are placed together in the front, just like ICE vehicles with front-engine-front-wheel drives.

Two-motor based EV powertrains

(d) No differential type:

Two electric motors are employed for individual front wheel to eliminate a differential.

The two motors are connected to the front wheels through mechanical fixed gearing.

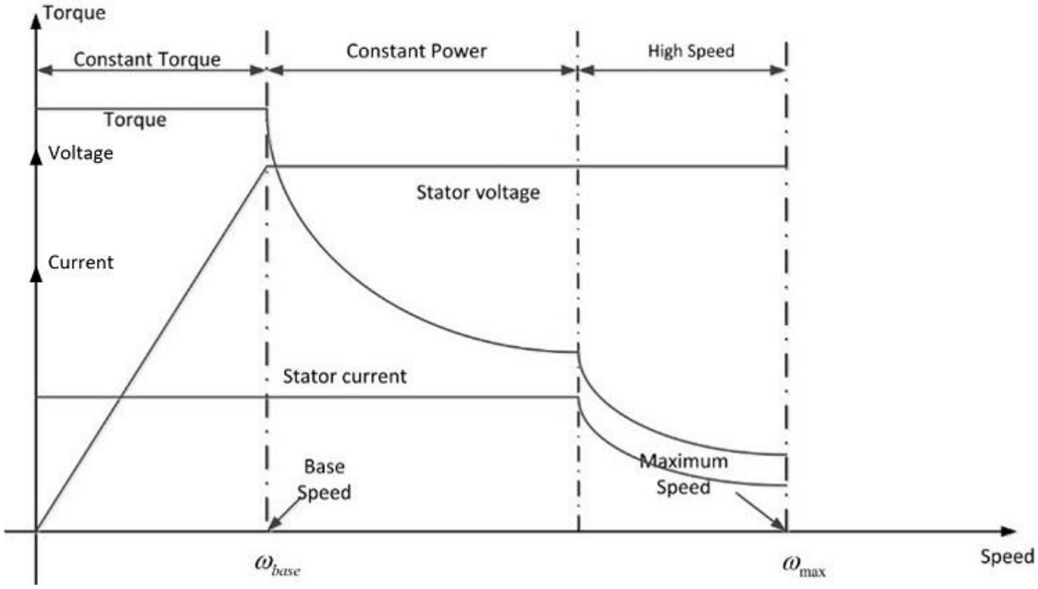
(e) In wheel type with fixed gear (FG):

This type is similar to the no-differential type in (d), except different location of the electric motors. Electric motors are embedded in wheels for the in-wheel type.

(f) In wheel type without fixed gear (FG):

Mechanical gearing is completely removed for this type.

The vehicle speed directly depends on the motor speed.



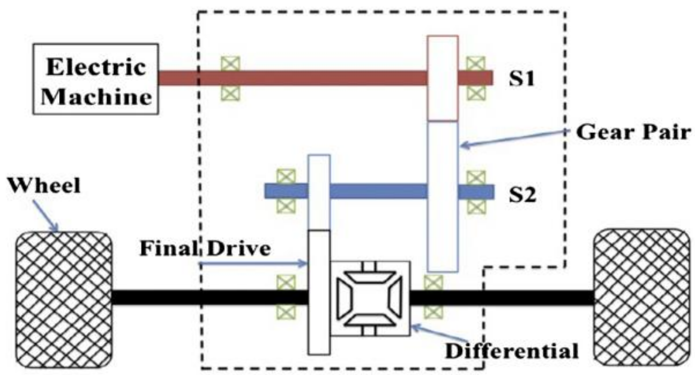
Typical torque speed curve of an electric traction motor

Evaluation of four electric machine types

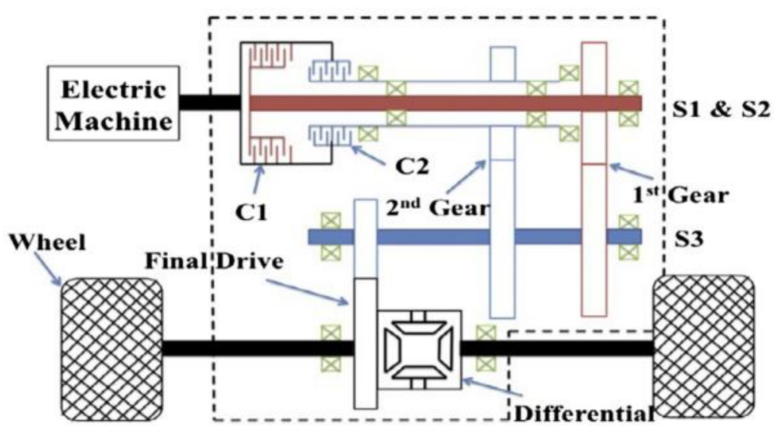
	DC	IM	PMSM	SRM
power density	⊖⊖	⊙	⊕⊕	⊙
efficiency	⊖	⊕	⊕⊕	⊕
costs	⊕	⊕⊕	⊖	⊕
reliability	⊖	⊕⊕	⊙	⊕
technical maturity	⊕	⊕	⊙	⊙
controlability, costs	⊕⊕	⊙	⊕	⊖

⊕⊕	very good
⊕	good
⊙	neutral
⊖	bad
⊖⊖	very bad

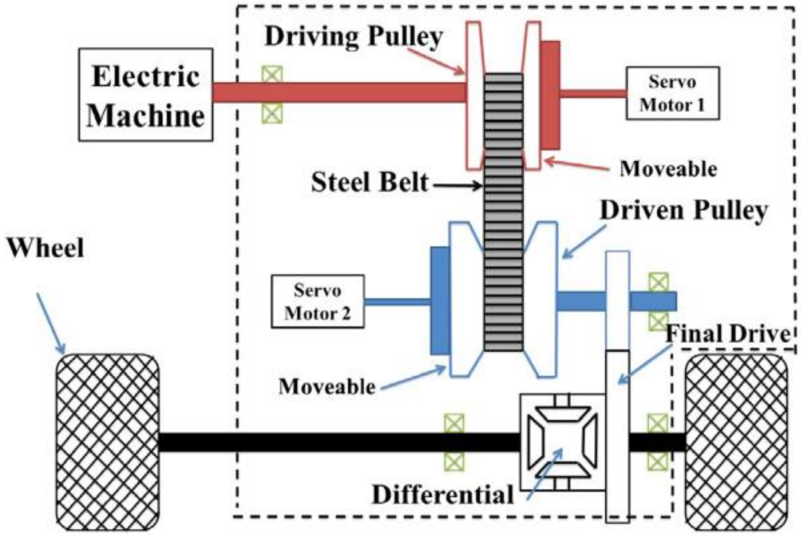
DC – direct current; IM – induction motor; PMSM – permanent magnet synchronous motor; SRM – switched reluctance motor



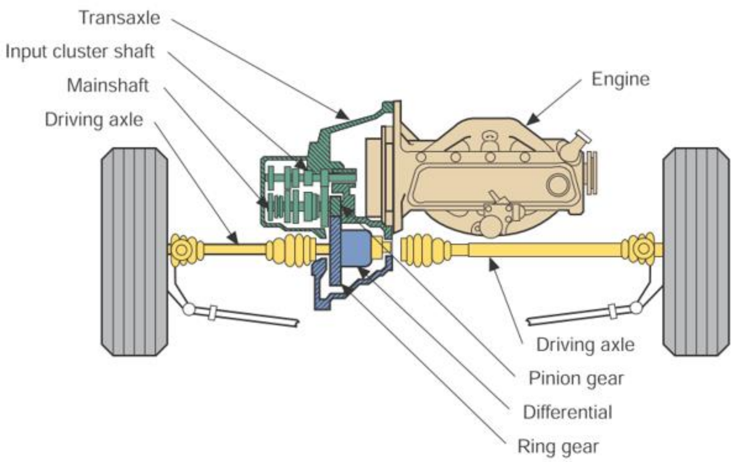
Single speed transmission in a PEV powertrain. S1, S2 – shafts

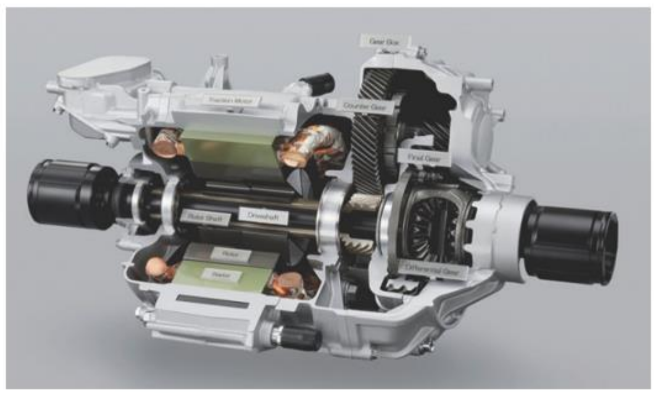


Two speed dual clutch transmission in PEV powertrain. S1, S2, S3 – shafts.C1, C2 – clutches

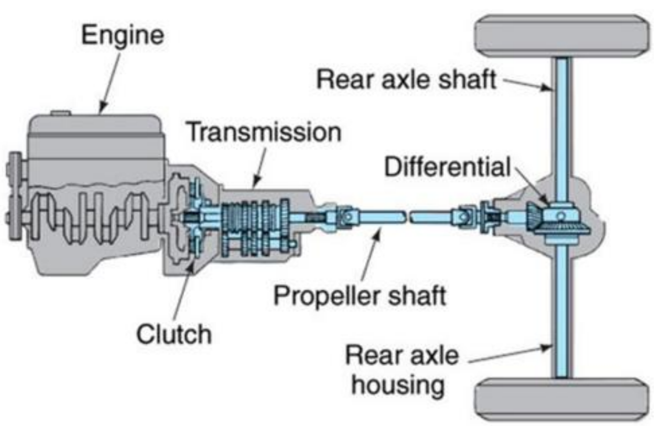


Continuously variable transmission with servo-electromechanical actuation system



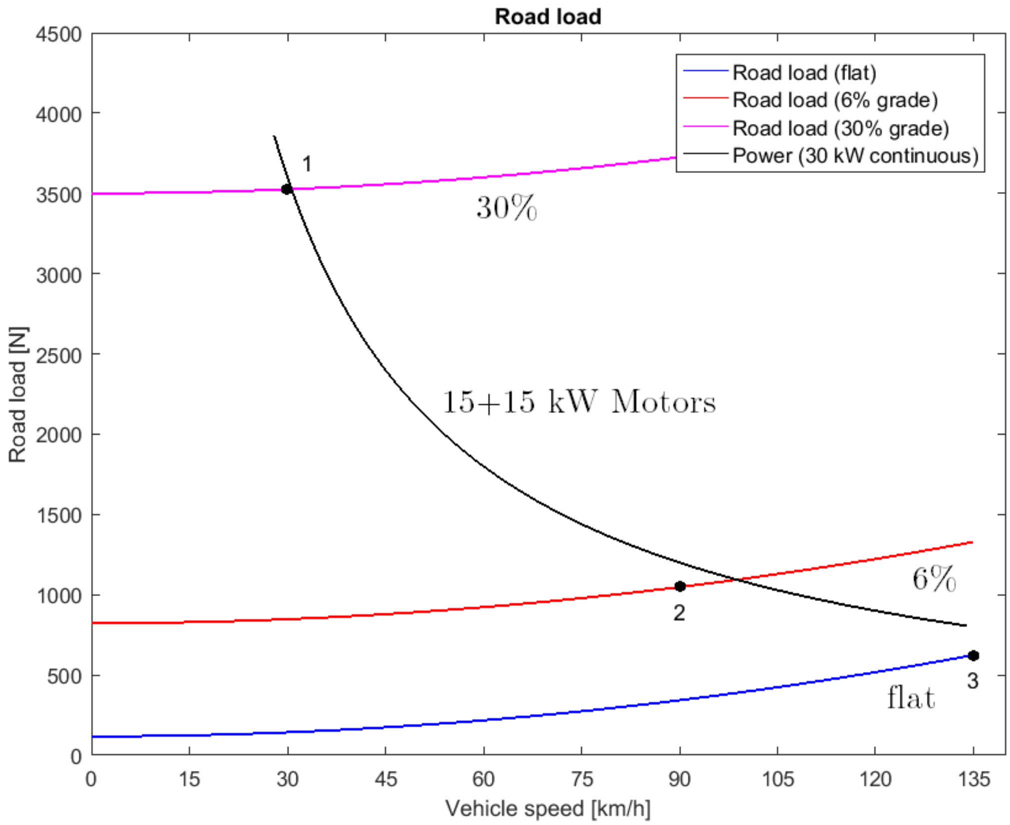


Typical front-wheel drive powertrain components: in an ICE vehicle (left) and in a PEV vehicle (right)



Rear-wheel drive powertrain components (left) and BMW rear differential (right)

Acceleration Performance



Road load as function of vehicle speed

Specifications for two ICE vehicles and the EV counterpart

Parameter	VW Up! (45 kW)	VW Up! (56 kW)	VW E-up!
Motor	Gasoline (3 cylinders)	Gasoline (3 cylinders)	Electric
Max. Power (kW / rpm)	45 / 5000 – 6000	56 / 6200	61
Max. Torque (Nm / rpm)	95 / 3000 – 4300	95 / 3000 – 4300	210
Transmission	5 speed	5 speed	1 speed
Tare weight (kg)	940	940	1229
Top speed (km/h)	162	172	130 (limited)
Acc. 0–100 km/h (s)	14,4	13,5	12,4
Consumption	4,9 l/100 km (urban)	4,9 l/100 km (urban)	11,7 kW/100 km
Autonomy (km)	650 (calculated)	650 (calculated)	160 (NEDC)
Price Portugal (€)	12 132	12 804	27 769
Price Germany (€)	10 425	11 900	26 900
Price Norway (€)	16 600	20 500	23 300

Power requirement for an electric vehicle

Most electric vehicles can cover up to 100 kilometres with 15 kWh. Their low energy loss makes means that they are not very energy intensive. While petrol or diesel engines convert a maximum of 35 % of this energy into driving force, an electric car reaches 90 % and more.

Mass of the vehicle

Rated range (NEDC):

500 km (85 kWh)

Tesla Model S

Component	Weight (kg)
Battery	**540**
Al space frame	**365**
Drivetrain	465
Electrical	100
Interior	**300**
Exterior	**90**
Miscellaneous	180
Total	2040

Rated range (NEDC):

300 km (33 kWh)

BMW i3

Component	Weight (Kg)
Battery	**230**
Life Module	**140**
Drivetrain	480
Electrical	80
Interior	**188**
Exterior	**57**
Miscellaneous	140
Total	1300

Various Resistances

Every vehicle, whether it's a car, truck, boat, airplane, helicopter or rocket, is affected by four opposing forces: Thrust, Lift, Drag and Weight.

Transmission Efficiency

Overall transmission efficiency Given that the transmission efficiency depends on the number of gears, in this paper, the transmission efficiency is considered to be 0.95 for single ratio and 0.92 for two gears.

Electric vehicle Chassis and Body design

Chassis design should be carried out in conjunction with other texts on chassis design, not to mention computer packages that specialise in this area. Nevertheless, a basic understanding of what the chassis should do and other parameters related to electric vehicle chassis is needed.

It is worth pausing to think precisely what the chassis/body does; ideally a chassis/body should fill the following criteria. It should:

- not vibrate, particularly at frequencies and harmonics of rotating parts;
- be aerodynamic;
- be resistant to impact;
- crumple evenly in an accident, minimising forces on driver/passengers;
- be strong enough to fix components to easily;
- be impact and roll resistant;
- be aesthetically pleasing;
- be corrosion-proof.

Chassis/body design requires optimisation of conflicting requirements such as cost and strength, or performance and energy efficiency. There are important differences when designing electric vehicles compared to their IC equivalents. For example, extra weight is not so important with an internal combustion vehicle, where a little more power can be cheaply added to compensate for a slightly heavier chassis. The same is true for aerodynamic drag, where a slight increase in drag can be similarly compensated for. Savings in weight as well as increases in efficiency contribute directly to the size of the batteries and these are both heavy and expensive.

Electric Vehicle Recharging and Refuelling Systems

There are three categories or types of charging: Trickle Charge, AC Charge and DC Charge. The slowest method of charging your EV at home, using a standard (three-prong) 220V plug. It is only recommended in urgent cases, with caution and consultation with electricity providers.

If you're the proud owner of a hybrid car, you can fuel it like you would have fuelled your old-fashioned gasoline model. Hybrid models utilize an internal combustion engine along with an electric motor and battery, which means that part of the power does have to come from fuel.

Performance of electrical vehicles

An EV directly converts electricity into movement. This makes it far more efficient than a conventional car, which has to burn fuel (creating heat) and then convert that heat into motion.

EVs have several advantages over conventional vehicles: Energy efficient. EVs convert over 77% of the electrical energy from the grid to power at the wheels. Conventional gasoline vehicles only convert about 12%–30% of the energy stored in gasoline to power at the wheels.

Course Outcomes: On Completion of this course, the student will be able to

CO5: Explain the different subsystems of electric and hybrid vehicles.