1. Electric & Hybrid Electric Vehicles.

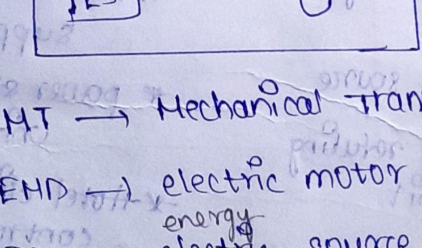
* Configuration of electrical vehicle.
* performance of electric vehicle.
* Tractive effect traction motor characteristics.
* Tractive effect & transmission requirements.
* vehicle performance.
* Tractive effect in normal driving.
* Energy consumtion
* Hybrid electric drive train.
* Architecture of hybrid electric drive train.
* series hybrid electric drive train
* parallel hybrid electric drive train.

Electric link (—)

Mechanical link (or) Transmission link (=)

control link (- - - -)

Robert
1996 year →.



→ primary electric vehicle.

MT → Mechanical Transmission (MT)

EMD → electric motor drive

ES → ~~electric~~ energy source.

Advantages of Electric vehicle:

* cost less
* Independent of petrol
* pollution low.
* Absence of emission.
* High efficiency.

* Explain the performance of Electric vehicle.
* Explain different configurations of electric vehicle.

SIPS
Break
accelerator

* MEV Types

-) Electric populsion

-) Battery. (energy subsystem)

-) Auxillary.

* Electric vehicle types:

engine + battery -) EV

engine + fuel -) Normal

-) Battery electric vehicle

-) Hybrid electric vehicle

-) plug in hybrid electric vehicle

-) Fuel cell electric vehicle.

* Electric vehicle (EV): motion / movement

- Any vehicle which is propul (or) by electricity is called electric vehicle.

* MEV (Modern electric vehicle)

MEV

- Electric propulsion
  - * Vehicle controller
  - * electronic power converter — supply the power
    - -) AC to DC, DC to AC
  - * electric motor
  - * mechanical Transmission
- Battery (energy source subsystem) — used to power backup regenerative purpose
  - * energy mangement unit
  - * Energy source
  - * energy refuling unit
- Auxillary. — provide necessary power at different volts
  - * Auxillary power supply
  - * power steering unit
  - * Hotel climate control unit — To reduce high temperature

=> Single source Battery is used

=> More source ultra capacitor is used.

↓

super capacitor. fuel cell

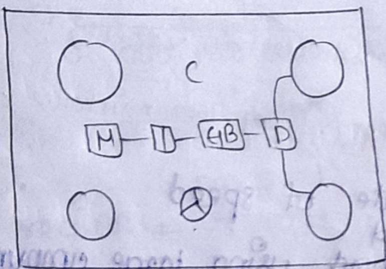
=> Auxillary supply voltage to the whole MEV.

motor ~~04~~ 04/23 → converts electric to mechanical
gearbox → ↑ or ↓ the speed torque inversely proportional to speed
clutch → used to disconnect or connect power supply
~~Dif~~ fixed gear → constant.
torque - twisting of force.
gear ratio → $\frac{G_1}{G_2} = \frac{G_2}{G_3} = \frac{G_3}{G_4} = G_K$.
Differential — mechanical vehicle.
→ enables the wheels when the vehicle runs with closed.
~~torque~~. curve.

configurations:
→ motor, gearbox, clutch, Differential.
→ motor, gearbox, Differential } No clutch.
→ motor, fixed gear with wheels. }
→ motor, fixed gear without wheels.
→ motor, fixed gear, fixedgear, motor.

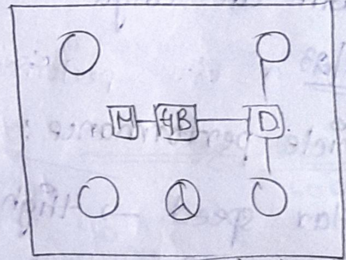
case (i) :-

(a)



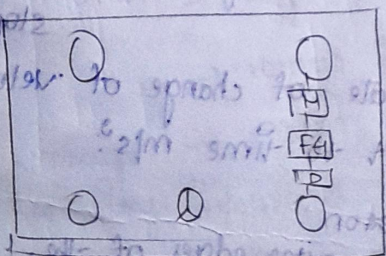
-AU

(b)



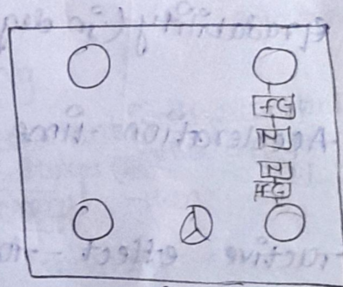
Removal of clutch

(c)



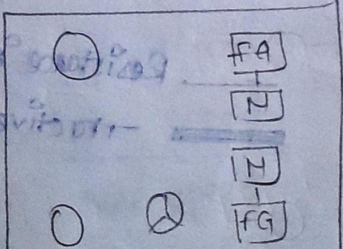
Replacing the GB with FG

(d)



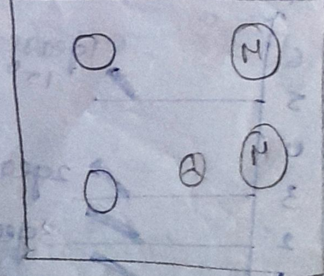
FG, M with wheels

(e)



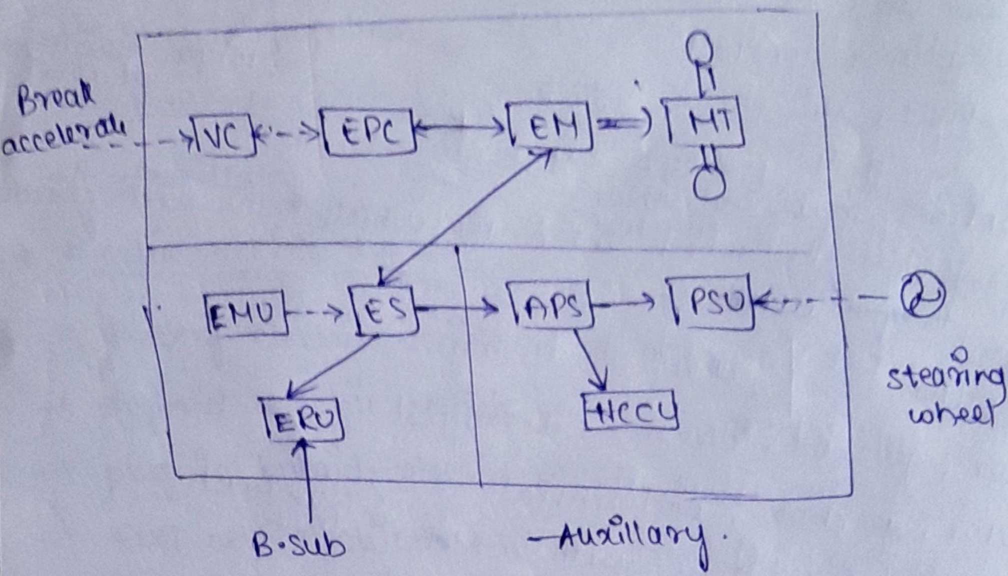
FG, M without wheels.

(f)



only motor

General configuration (or) concept configuration.



The ability to climb is gradability which is moved with an angle.

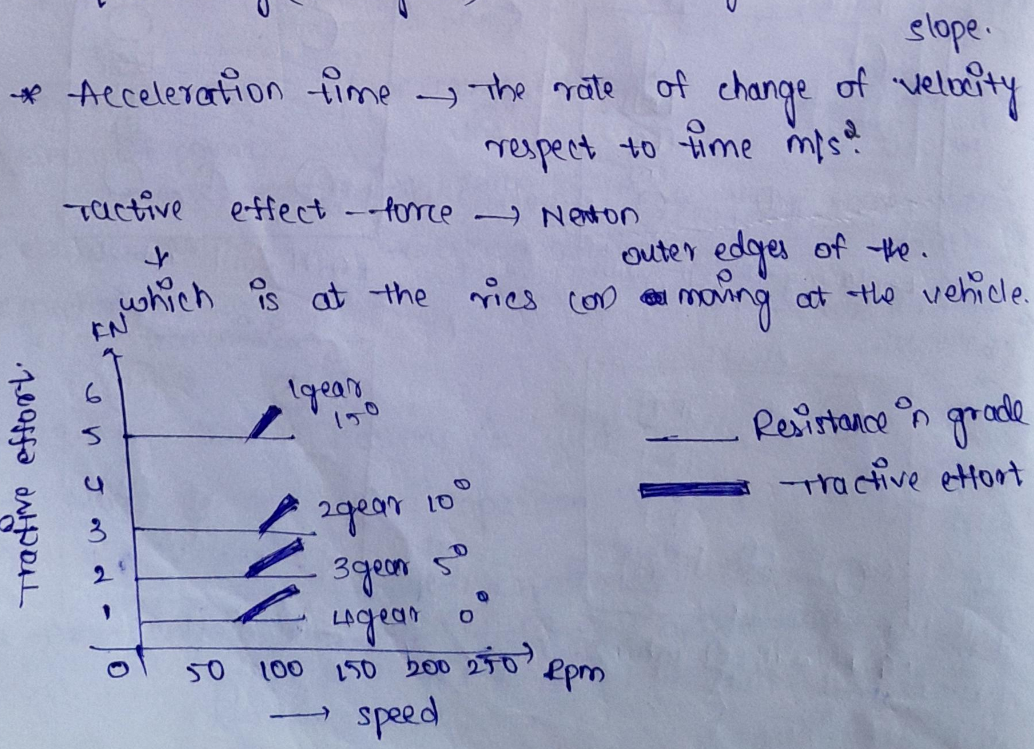
08/09/23

performance of veh electric vehicle.

Vehicle performance : can be formed by the resistance curve.

* Max speed → Highest rate of speed
* Max crusing speed → max speed without using large amount of effort.
* Gradability (in degrees) → the ability to claim the hill or slope.
* Acceleration time → the rate of change of velocity with respect to time m/s^2.

Tractive effect -- force → Neton
which is at the rics (or) outer edges of the moving at the vehicle.



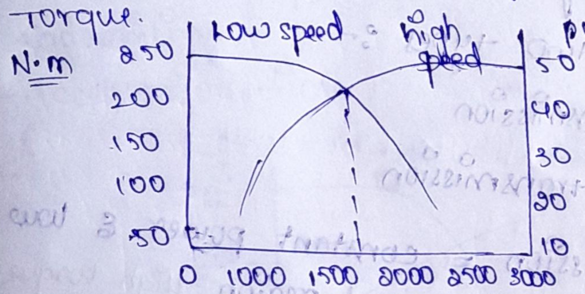
* General layout of electric vehicle (or) Explain conceptual configuration of electric vehicle.

18/09/23

Traction motor characteristics: | Translation speed.

* speed
  power
  Torque.

* It has 2 regions → Low
  → High



speed (rpm)
↳ rotations per min
(Low speed)

$E = \frac{P\phi N}{60A}$

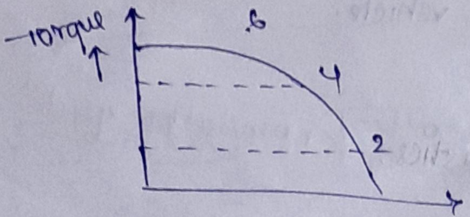
* Low region ⇒ Torque is constant
  power will be varying.
* High region ⇒ High speed.
  → Torque is varying
  → power will be constant [voltage constant flux changes] weakens — After the Base speed.
  Torque also changes
* As ~~velocity~~ voltage increases speed increase then it reaches to source voltage then flux constant.
  ↳ Before the Base speed.

* 'x' → speed ratio → Traction speed characteristics

$\rightarrow \frac{\text{Max. speed}}{\text{Base speed}}$

* Explain the traction motor characteristics of electrical vehical.

* the graph of speed and torque near 60 KW



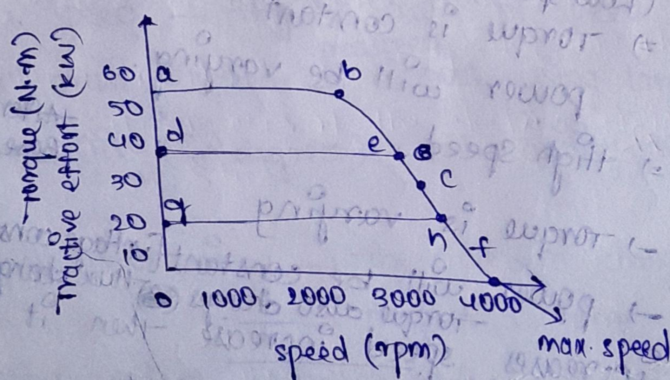
14/09/23

Tractive Effort & Transmission Requirement:

* The force which is at the outer edge of or erics of the moving vehicle or moving wheels. (KW)
* Transmission is of two types :-
    1) Single gear transmission
    2) Multi gear transmission

=> Single gear transmission = constant power & low speed region High torque.

=> Multi gear transmission = High speed region.



a-b-c → first gear transmission

d-e-f → second gear transmission

g-h-f → third gear transmission

force → $f_t = \frac{\eta_t \, i_g \, i_0 \, T_M}{r_d}$ f_t = Tractive force.

i_g - gear transmission ratio

i_0 - gear transmission at final drive

η_t - efficiency

TM - maximum torque

rd : radius.

velocity.
~~voltage~~ $V = \frac{\pi N_m r_d}{30 i_g i_o}$ m/s

Nm = maximum speed.

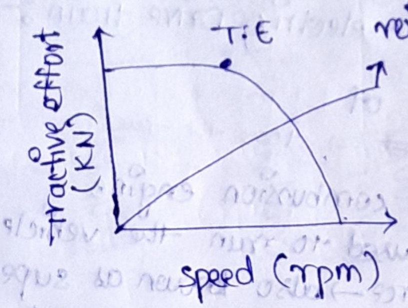
Vehicle Performance:

→ Max speed → can be found ~~formed~~ by the resistance curve.

→ Max cruising speed

→ Gradability.

→ Acceleration time



* Resistance curve is the combination of the rolling resistance and aero dynamic drag.

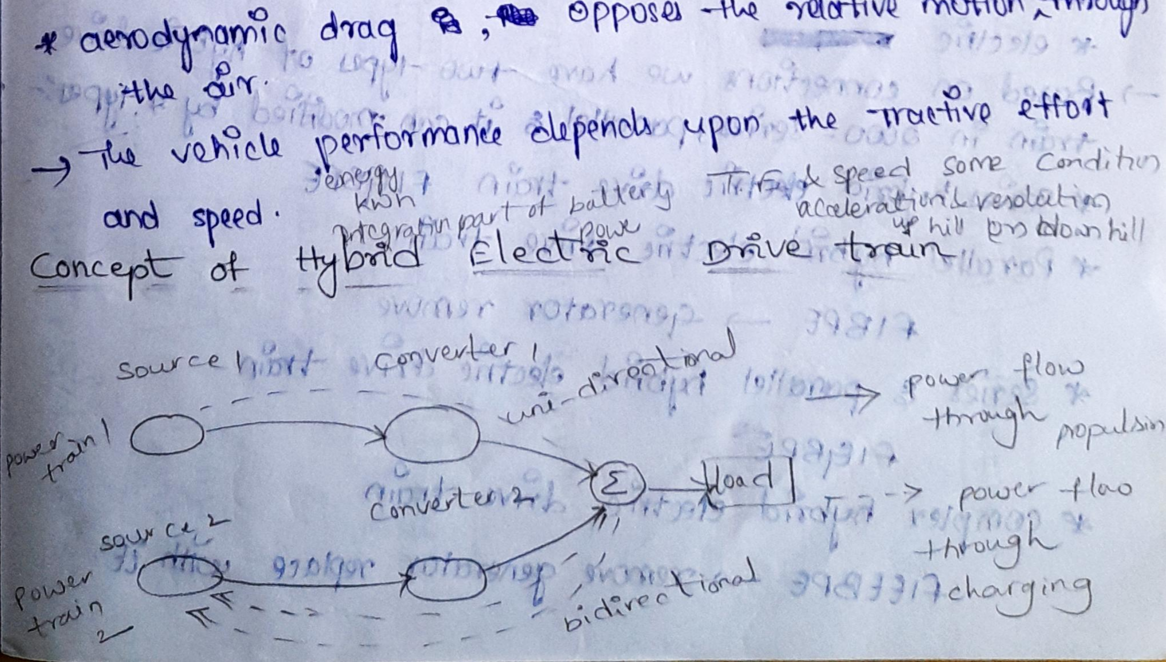
* Rolling Resistance which opposes the rolling of the wheel which causes the effort. It is also called as rolling friction (or) rolling drag.

* aerodynamic drag : opposes the relative motion of the object through the air.

→ The vehicle performance depends upon the tractive effort and speed.

energy kwh integration part of battery power — T.E & speed some condition acceleration & resolution up hill (or) down hill

Concept of Hybrid Electric Drive train



* ① → delivers – power to load
* ② → " – "
* ① Pove 1 & ② – delivers power to load. at the same time
* ② → obtains power from ① & it delivers to load
* ① → " " ② & " "
* ② → obtain power from ① & load at the same time
* ① → obtain " " ② & " "

①x delivers power from ②

② " " ① & load at the same time

Architecture of hybrid electric Drive train:-

- The architecture consist of
  * fuel tank → ~~propult tank~~ petrol → store the fuel
  * IC Engine → Internal combustion engine. It can used to run the vehicle.
  * Battery → energy source → also known as super or ultra capacitor (or) fly wheel
  * power converter.
  * Motor: It can convert the electrical energy into mechanical energy
- → It consists of 3 links:
  * Hydralic – – – – → represents mechanical function
  * Mechanical ══
  * electric ▬▬
- → Based on connections we have two types of hybrid drive train in 2000 - series, parallel & it can modified by 4 types:-
  * series hybrid electric drive train FIGBPE
  * Parallel hybrid electric drive train

    FIBPE → Generator remove
  * series & parallel hybrid electric drive train

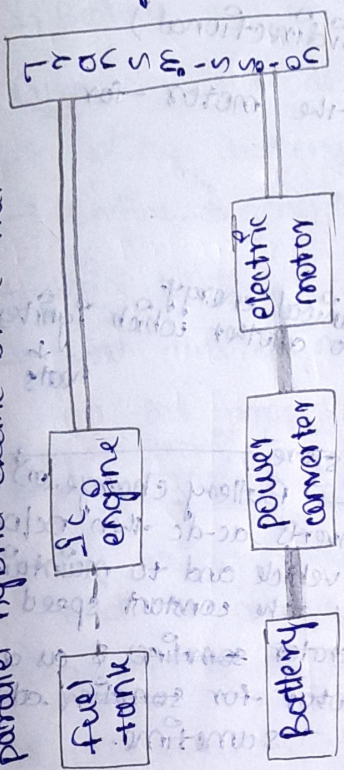
    FIGBPE
  * complex hybrid electric drive train

    FIEEBPE → remove generator replace with EE.

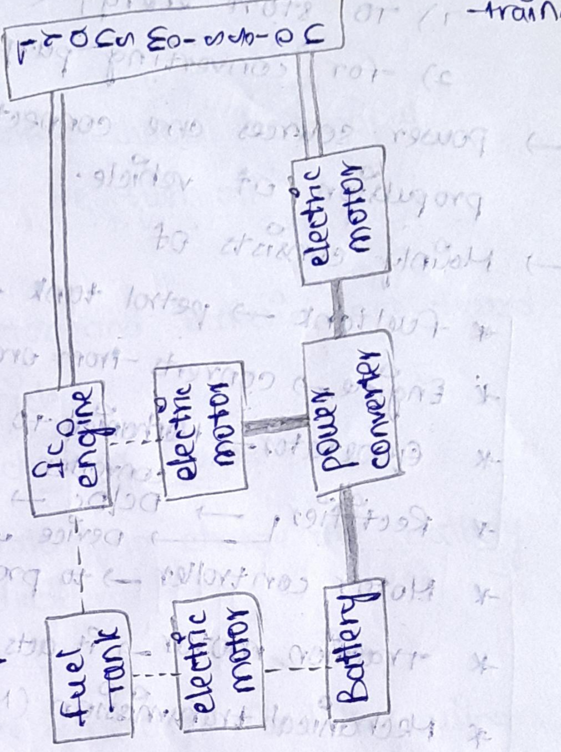
#1 Explain the concept of Hybrid electric drive train ?

#) wt is series electric hybrid drive train and draw the general configuration of series hybride electric drive train.

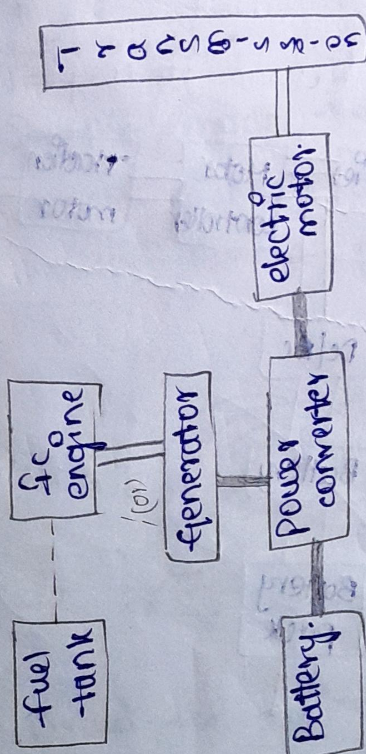
parallel hybrid electric Drive train



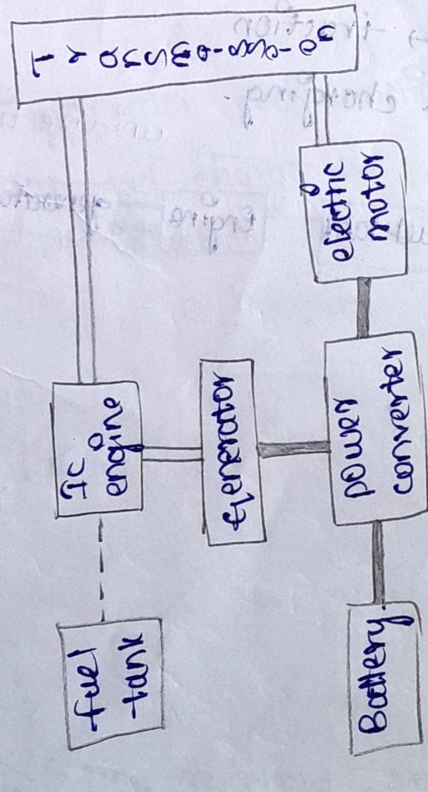
complex hybrid electric Drive train



series hybrid electric Drive train



parallel series hybrid electric Drive train



Series ele hybrid electric drive train :

→ Two power sources :
1) To store energy (uni directional)
2) for converting purposes. (Bidirectional)

→ power sources are connected to the motor for propulsion of vehicle.

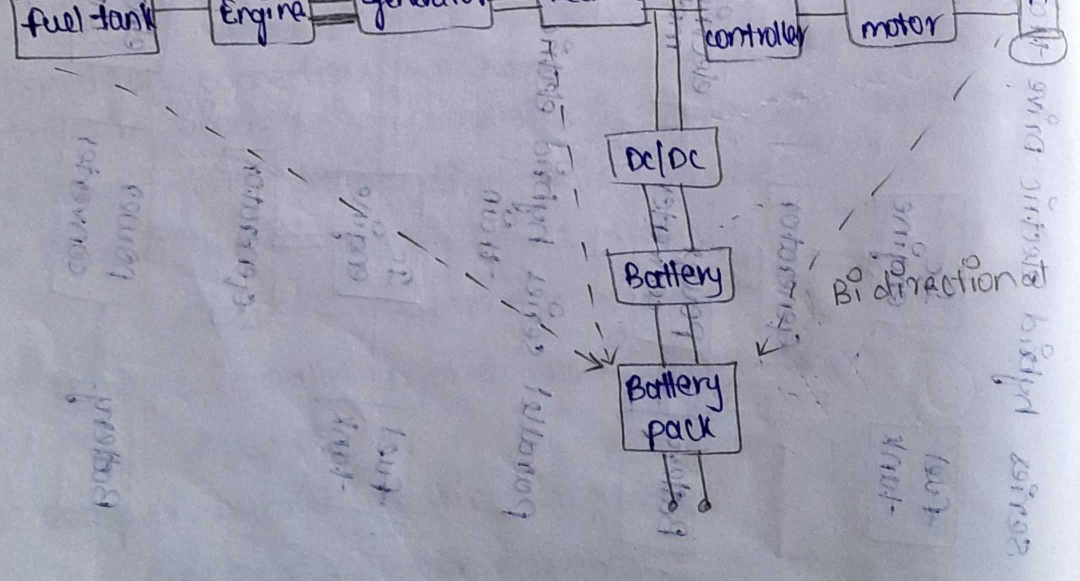
→ Mainly consists of

- * fueltank → petrol tank - to store
- * Engine → converts from one energy to another which ignites & heats (mechanical energy)
- * Generator → Mechanical to electrical
- * Rectifier → DC/DC (converter) → Battery (energy store) → Battery charge (or) pack
  → Device which converts ac-dc then DC/DC.
- * Motor controller → to protect the vehicle and to maintain the constant speed
- * Traction motor → it acts as generator & as a motor for at the same time.
- * Mechanical transmission (M)

Inverter → DC to AC

→ traction

--→ charging.



* Pure engine Mode :
  - The vehicle will propul by using the engine.

→ Battery will be turn off.

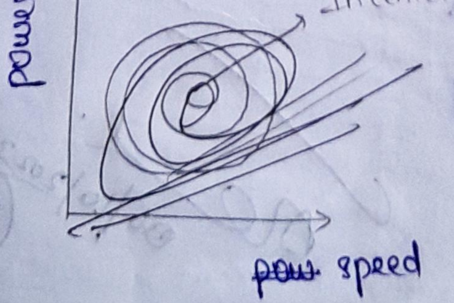
* Pure electric Mode :
  Using battery the vehicle should be propul
→ Engine ~~&~~ generator should be turn off.

* Hybrid Mode ;
→ Both the engine generator and batteries are turned on for propul the vehicle.

* ~~Energy~~ Engine/Electric Traction & Battery charging Mode :
→ By using engine generator to charge the battery and to propul the vehicle

* Regenerative Mode :
→ By turn off the engine generator and by using the traction motor which acts as generator will charge the Battery to propul the vehicle

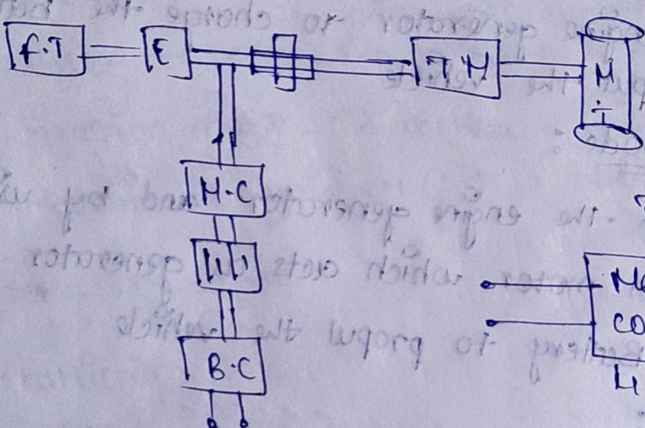
* Hybrid Mode ;
→ In this mode, the engine generator and traction motor will act as generator and charge the battery for propulsion of vehicle.

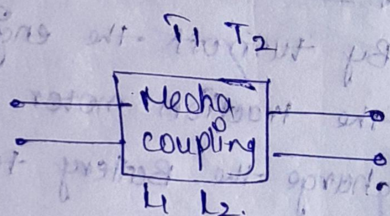


* Draw the parallel.
* Wt is aerodynamic drag, Rolling resistance, resistance curve with suitable example.

Parallel hybrid electric drive train :-

* It consists of
  - → Fuel Tank
  - → Motor controller
  - → Traction motor
  - → Mechanical Transmission
  - → Engine
  - → clutch
  - → Battery
  - → Battery charge } Battery pack.





used to couple the E & E.M

Transmission 1 :- single gear

Transmission 2 :- Multi gear

⟶ Traction

- - -> charging

06/10/2023

unit - ① Imp

1. Explain vehicle performance of E.V ?
2. Explain different configurations of EV or conceptual configuration ?
3. General layout of E.V ?
4. Explain traction motor characteristics of E.V ?
5. Explain the concept of hybrid electric drive train ?
6. what is series hybrid electric drive train and draw the general concept configuration of series hybrid electric drive train?
7. Draw the configuration of parallel hybrid electric drive train & explain ?
8. what is aerodynamic drag, Rolling resistance, resistance curve ?

26/09/23

2. Energy Storage for EV & HEV

* Energy Storage Requirements.
* Battery parameters
* types of batteries
* Modeling of batteries
* fuel cell operation and its principle.
* types of fuel cells.
* Modeling of PEM FC.
* supercapacitor

charging
electrical energy to potential chemical en...
Discharging
potential chemical energy to electrical energy.

Energy Storage Requirements:

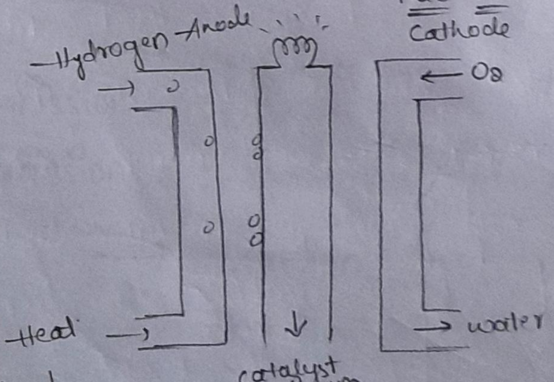
~~Battery performance~~:

29/09/23

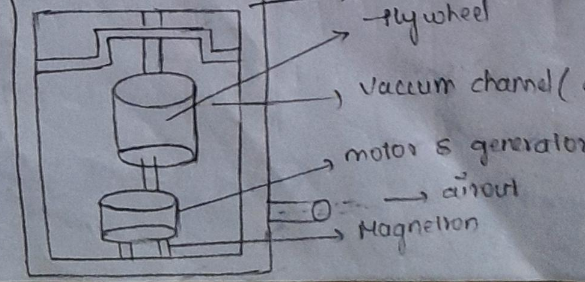
* ~~Battery~~ :-

* Energy storage requirements :
 1) Battery storage → Based Energy system (electrical to chemical) → Longer duration
 2) flywheel based energy system
 3) fuel cell based energy system
 4) Ultracapacitor (or) supercapacitor. based energy system
    * store energy & deliver energy to the vehicle
    * High power
    * used for shorter duration
 5) Hybrid energy system.

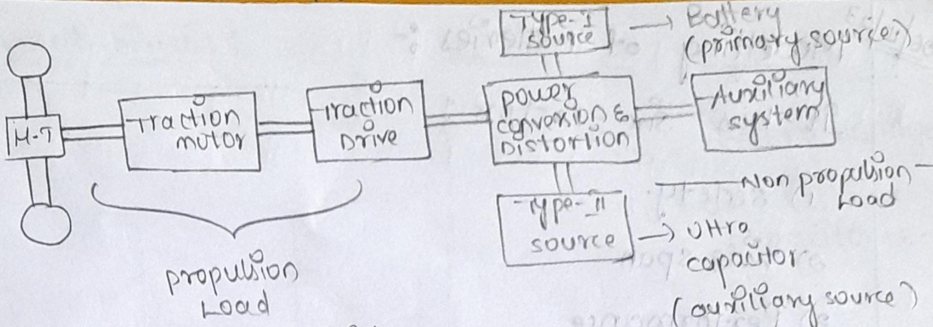
Fuel cell



Flywheel



→ kinetic energy is less
→ large rotations per min



Battery type :- Lead acid
Lithium ion
Nickel metal

Battery parameters :

* **Energy stored :**

The energy stored in a battery depends on its voltage and the charge stored (joules).

* **Specific energy :**

The ~~en~~ specific energy is the amount of electrical energy stores for every kg ~~ab~~ wh/kg.
(wh = watt hour)

* **Energy density :**

The energy density is the amount electrical energy stores per cubic meter of battery volume j/m³.

* **state of charge :**

The SOC of a cell denotes the capacity that is the currently available as a function of rated capacity (0% to 100%)

* **Depth of discharge :**

The DOD is the fraction of battery capacity that can be used for the battery.

* **Life cycle :**

The cycle life of batteries is the no.of charge and discharge cycles that a battery can complete before losing performance.

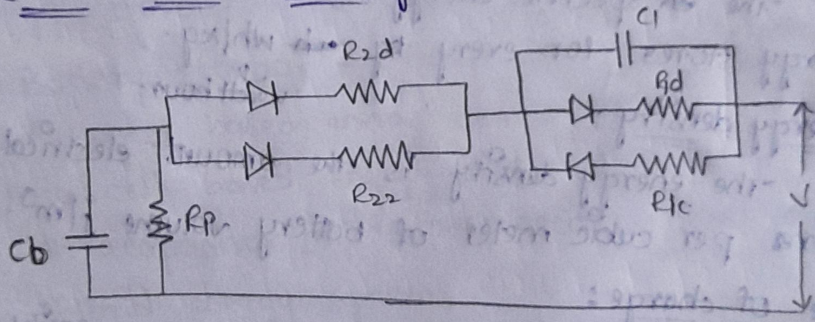
06/10/23 Modelling of batteries :-

It has six - factors :

1) safety.
2) Life span
3) Performance
4) Specific powers → maximum power
5) specific energy
6) charge time.

* there are two types of modelling:
    1) circuit based modelling.
    2) chemistry based modelling.

1) circuit based modelling:



Cb = battery capacitance

Rp = insulation resistance

Rx = internal resistance for charge.

R2d = Internal resistance for discharge.

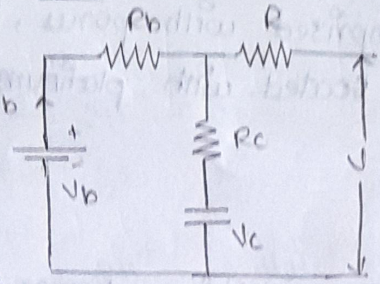
R1c = Overvoltage resistance for charge

C1 = over voltage capacitance.

* for designing purposes and controlling purposes.

* forward and Reverse.

equivalent circuit :



Vb = battery voltage.
Vc = over voltage capacitance.

* Square algorithm and temperature compensation formula,

$$B_E = k_1 \exp[k_2[V_m - V_{oc}]]^{k_3}$$

BE = Battery elements
Vm = Mean voltage
Voc = open circuit voltage.

* Battery capacitance,

$$C_b = k_i C_b \exp[k_1(V_m - V_{oc})]^{k_3}$$

constant voltage is used $V_{oc} = 14V$.

* the temperature effect on resistor compensated,

$$T_c = \left[\frac{R}{R_{ref}}\right] \left[\frac{T_{ref} - T}{T_{ref}}\right]$$

<u>fuel cell</u> :

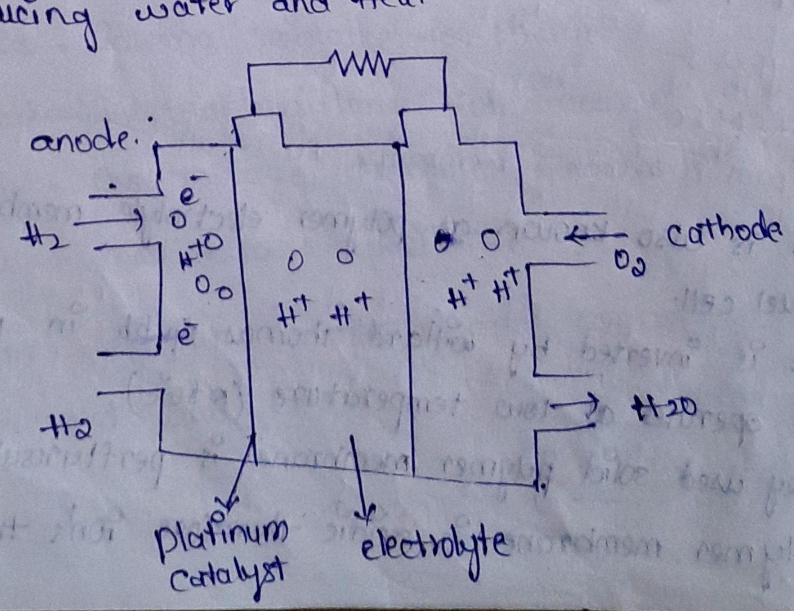
* It is a electrochemical cell
* Types :-
  → PEMFC
  → (proton exchange membrane fuel cell)
* It is also known as polymer electrolyte membranes fuel cell.
* It is inverted by willard thomas Grubb in 1950's
* It operates at low temperature (≈80°c)
* they used solid polymer membrane is perflurosulfanic acids
* polymer membrane is acidic therefore ion's transported

as hydrogen ions or protons.

* Each electrode is comprised with porus, high surface area material which coated with platinum or platinum alloy.

Working :

* It uses a water based acidic polymer membrane as it electrolyte with platinum based electrode. The proton's pass through the membrane to the cathode side of the cell which the electrode travel in an external circuit generating the electrical output of the cell.
* Hytrogen take place at anode and oxygen take place at cathode.
* At the anode the platinum catalyst causes the Hydrogen split into two hydrogen ion's or proton's and to negative charged electrons.
* Polymer membrane allow only two Hydrogen ion's or proton and reach the cathode.
* Electron travels to external circuit to produce the current.
* This proton combine with oxygen at the cathode producing water and Heat.



Expression

Anode:

$H_2 \rightarrow 2H^+ + 2e^-$

cathode:

$\frac{1}{2} O_2 + 2H^+ \longrightarrow H_2O$

$\frac{1}{2} O_2 + 2H^+ + 2e^- \longrightarrow H_2O$

Advantage:

* they have short response time.
* they have faster cool off time and faster heat.
* They have purity of Hydrogen
* Lower operational costs.
* They operate wide range of power input.

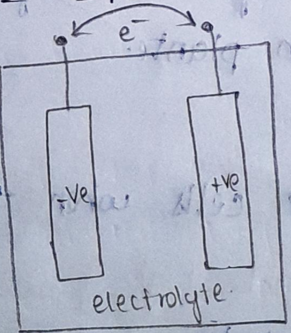
Disadvantages:

* They can easily damaged.
* They are sensitive to dust and impurities.

Applications:

* Portable fuell cell application
* Transportation fuel cell application
* stationary fuel cell application.

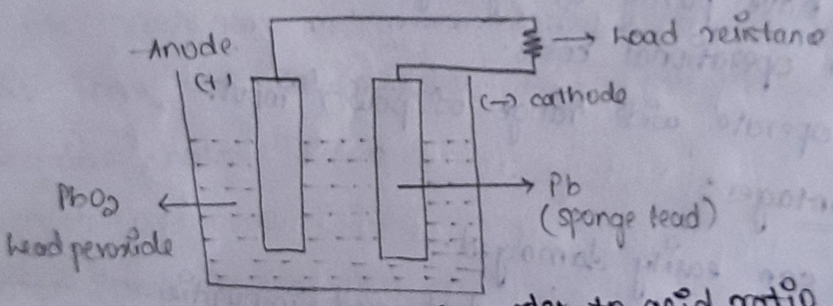
Battery and its operation:-



* In each every battery oxidation and reduction takes place.
* A battery is a device which converts electrical energy to chemical energy during charging and converts chemical energy to electrical energy during discharging.
* There are two types of batteries:
  1) primary batteries: only for one use and not rechargeble.
  2) Secondary batteries: rechargeble battery.

Lead-acid battery:

Invented by Gaston plante in 1859



H_2SO_4 uses water to acid ratio 3:1

* It is a rechargable battery that uses lead and sulphuric area to function.
* It is an example of secondary cells.
* Also known as lead storage battery.
* It was invented by french physician in 1859.
* It was first ever rechargable battery the lead acid battery was Gaston plante.

Secondary cells:

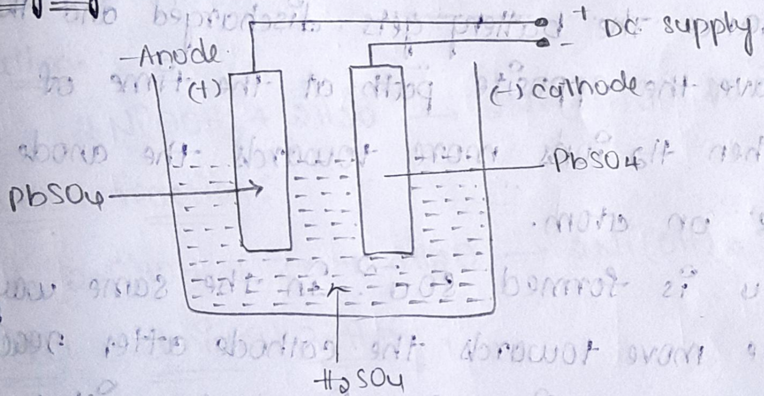
There are rechargable cells when the charge gets over.

Ex: Battery used in inverter.

Construction :-

* It consists of two electrodes submerged in an electrolyte of sulphuric acid.
* The +ve electrode is made up of gains of metallic lead peroxide while the -ve electrode is attached to a grid of metallic lead.
* There are 3 types of lead acid battery.
  1) Flooded acid
  2) Gelled acid
  3) Advanced AGM (Absorbed Glass mat)

Charging :



* During charging the cathode and anode are connected to DC supply. The +ve H_2 ions move in the direction of cathode and gain $2e^-$ and forms as H_2 atom.
* It undergoes as a chemical reactions with lead sulphate and forms lead of sulphuric acid.

Anode :

$$PbSO_4 + 2H_2O + SO_4 \longrightarrow PbO_2 + 2H_2SO_4$$

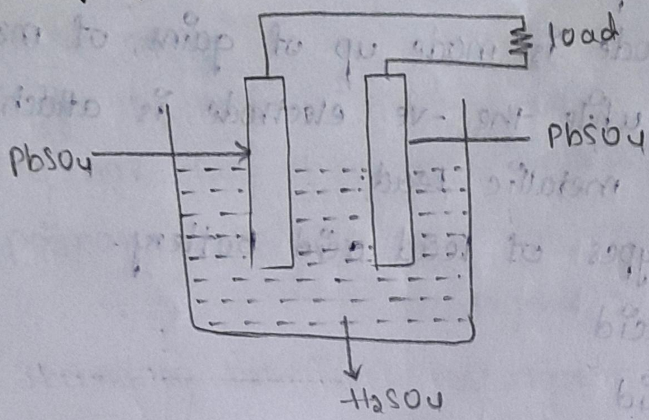
Leadoxide

Oxidation
↓ add of O_2
Reduction
↓
loss of O_2.

cathode:

$PbSO_4 + 2H \longrightarrow Pb + H_2SO_4$

Discharging:



Disadvantages

→ Low specific energy, poor weight-to energy ratio

→ Lead is heavier compare to alternative elements

→ It has limited life cycle

→ there are transportation restrictions on flooded type.

when a battery is completely discharged then the anode & cathode are PbO_2 & Pb. when these connected using resistance. The battery gets discharged and the electrons have the opposite path at the time of charging. Then H_2 ions more towards the anode and become on atom.

Thus $PbSO_4$ is formed SO_4^{-2}. In the same way. the sulphate move towards the cathode after reaching the ion is formed into SO_4. It reacts with lead cathode and forms lead sulphate.

Anode:

$PbO_2 + 2H \longrightarrow PbO + H_2O$ reduction

lead oxide

cathode:

$Pb + SO_4 \longrightarrow PbSO_4$ oxidation

lead sulphate

Advantages

→ cheap, easily rechargeable, high power output capability, powerful

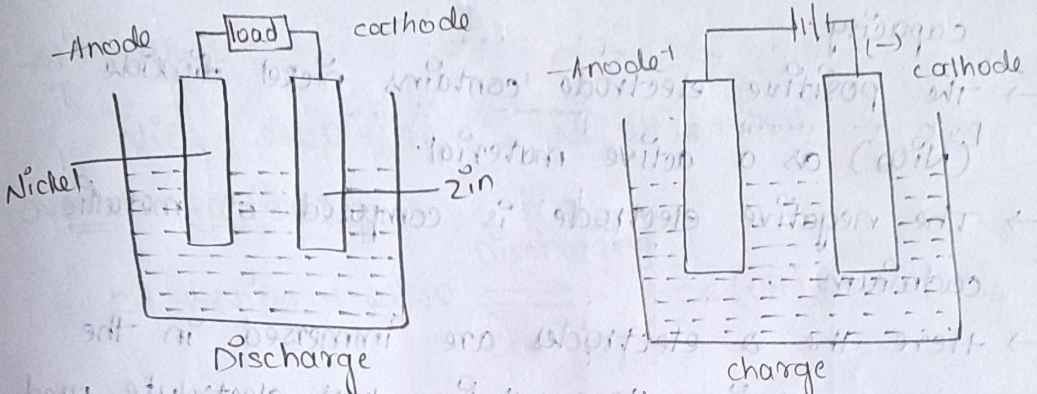
→ Does not require maintenance

→ Available in all shapes and sizes

→ offers best power and energy.

Nickel-Zinc Battery:

Nickel Zinc Battery is a combination of nickel electrode and zinc electrode.



Anode:

$$Zn + 2OH^- \longrightarrow Zn(OH)_2 + 2e^-$$

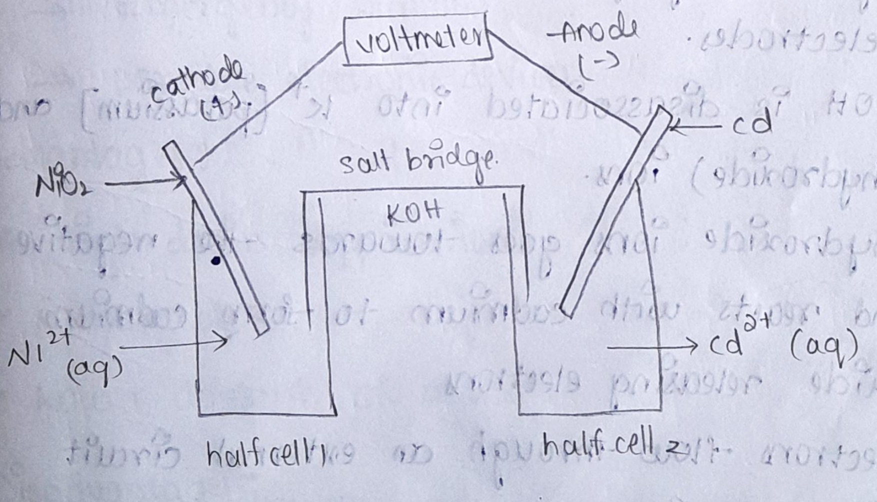
cathode:

$$2NiOOH + 2H_2O \longrightarrow 2Ni(OH)_2 + 2OH^-$$

overall reaction:

$$2NiOOH + Zn + 2H_2O \longrightarrow 2Ni(OH)_2 + Zn(OH)_2$$

Nickel cadmium Battery:



* The nickel cadmium battery is a type of rechargable battery abbrevated as Ni-cd battery or Nicad battery.

* Nickel cadmium battery offers.
→ Good cycle life
→ And performance at low temperature with a capacity.
→ The positive electrode contains nickel dioxide (NiO_2) as a active material.
→ The negative electrode is composed of metallic cadmium.
→ Here the 2 electrodes are immersed in the aqueous solution. Here alkaline KOH electrolyte used as salt bridge in between two electrode.
→ Here the electrolyte is not involved in the electro chemical reaction. Hence the concentration of electrolyte does not change when the changing and discharging of battery.

<u>Working</u>:
→ During discharging the load is connected across the two electrodes.
→ the KOH is disassociated into K^+ [potassium] and OH^- (hydroxide) ions.
→ The hydroxide ions goes towards the negative ion and reacts with cadmium to form cadmium hydroxide releasing electrons
→ the electrons flow through an external circuit producing electric current and reach +ve electrode.
→ At +ve electrode nickel dioxide (NiO_2) combines with water and absorb. The electron to produce nickel hydroxide and hydroxide ions.

Reactions :-

At anode :

$$Cd + 2OH^- \longrightarrow Cd(OH)_2 + 2e^-$$

At cathode :

$$NiO_2 + 2H_2O + 2e^- \longrightarrow Ni(OH)_2 + 2OH^-$$

overall reaction:

$$Cd + NiO_2 + 2H_2O \underset{charging}{\overset{Discharging}{\rightleftharpoons}} Cd(OH)_2 + Ni(OH)_2$$

During charging the reactions are inverse.

* When the cell is fully charged the normal voltage is 1.5V
* While discharging the voltage is 1.1V.
* Ni-Cd battery are used in:
  → portable power only
  → Flash Lights
  → Emergency Lighting
  → portable electronic devices.

Advantages:

* High drain Applications
* Rechargeble
* Lower amount of waste.

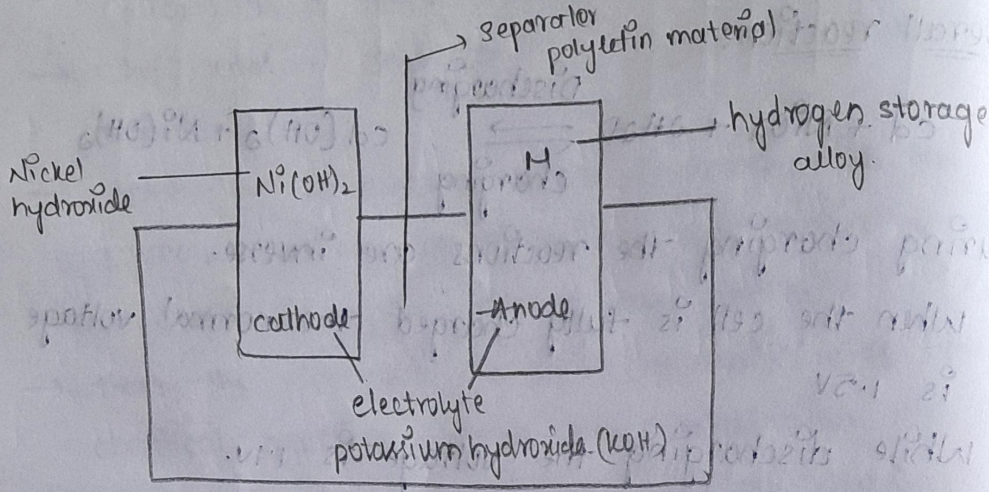
Disadvantages:

* Higher self discharge
* Loss charge over time even when not in use
* Memory effect.

* Environmentally unfriendly.
* cadmium is extremely toxic.

Nickel - Metal hydride :

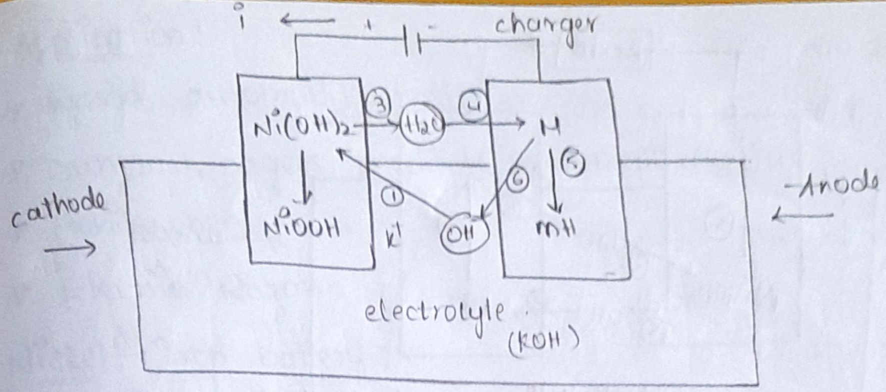
* It is a type of rechargeable battery.
* which is commonly used in Hybrid electric vehicle.



* consider a simplified cell a cathode is made from nickel hydroxide and anode is made from hydrogen storage alloy.
* The electrolyte is an aqueous solution of potassium ion and hydroxide (KOH).
* The separate is made from polyelefin material.
* In this charging of cell there is 2 types.
  1) charging
  2) Discharging.

charging :

* During the charging of the cell the cathode is $Ni(OH)_2$ and anode is [m].
* When a charger is acrossly connected to electrodes the (current 'i' flows into the cathode)



* The electrolyte is KOH which is splits into +ve potassium ion and -ve hydroxide ion.
* At cathode the hydroxide ion reacts with $Ni(OH)_2$ in order to produce nickel oxihydroxide (NiOOH) giving away the water and also electron are produce which flows through the external circuit and reaches the anode.
* At anode metal reacts with water in order to form metalhydride giving away hydroxide.

Chemical Reaction

Anode:

$$M + H_2O + e^- \longrightarrow MH + OH^-$$

cathode:

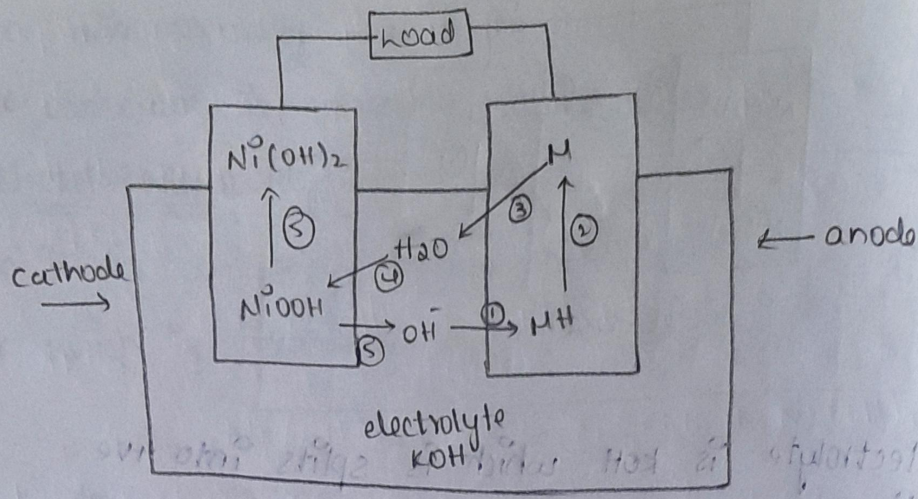
$$Ni(OH)_2 + OH^- \longrightarrow NiOOH + H_2O + e^-$$

overall:

$$Ni(OH)_2 + M \longrightarrow NiOOH + MH$$

Discharging:

* At anode the hydroxide ion reacts with metal hydride and it order to form metal giving away water and electron are produced.



* The electron flows through the external circuit and light of the load and reach the cathode.
* At cathode water reacts with NiOOH to form nickel hydroxide giving away the hydroxide ions.

Reactions

Anode:

$$MH + OH^- \longrightarrow M + H_2O + e^-$$

cathode:

$$NiOOH + H_2O + e^- \longrightarrow Ni(OH)_2 + OH^-$$

overall:

$$NiOOH + MH \longrightarrow Ni(OH)_2 + M$$

Advantages:
* High power density
* High energy density
* Rechargeable
* No toxi material (like Nicd, cd is a heavy metal)
* Less effect on memory

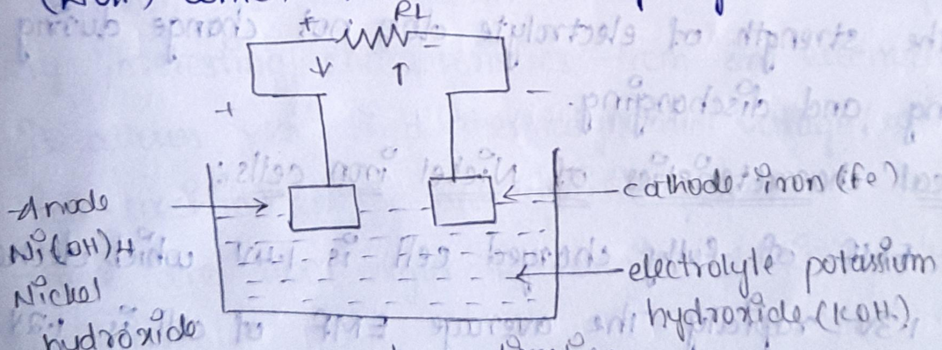
Disadvantages:
* fast recharge
* Driveless current compared to Nicd.

-Application:

* Hydrid automobile batteries
* cameras, pagers medical instruments
* Mobile phones
* Electric Razors

Nickel - Iron battery:

* Nickel - iron battery also known as edison battery.
* Nickel-iron battery is abbrevated as Ni-Fe battery.
* Nickel-iron battery is very strong battery.
* It has 2 plates.
* The active material of the positive plate is $Ni(OH)_4$ and negative plate is of iron (Fe).
* The electrolyte is a solution of potassium hydroxide (KOH) with a small addition of Lithium hydrate (LiOH) which increases the capacity of the cell.



→ shows direction of flow of electrons

Working:

During Discharging:

When the battery discharge the potassium hydroxide (KOH) is disassociated into potassium (K^+) and hydroxyl (OH^-) ions. The hydroxyl ions go to cathode and potassium ion goes to the anode.

* The following chemical reaction takes place during discharging are:

At cathode:

$$Fe + 2OH^- \longrightarrow Fe(OH)_2$$

At anode:

$$Ni(OH)_4 + 2K \longrightarrow 2KOH + Ni(OH)_2$$

During charging:

when the battery is put on charging the hydroxyl (OH^-) ions moves to anode and potassium ions moves to cathode. The following reactions are

At anode:

$$Ni(OH)_2 + 2OH \longrightarrow Ni(OH)_4$$

At cathode:

$$Fe(OH)_2 + 2K \longrightarrow Fe + 2KOH$$

The strength of electrolyte does not change during charging and discharging.

Electrical characteristics of Nickel iron cells:

* The EMF of fully charged cell is 1.4V which decreases to 1.3V rapidly. The average EMF of cell is 1.2V and reduce to 1.0V when fully discharged.
* The internal resistance of this cell is quite high nearly 5 times to that of lead acid cell.
* Average life span of Ni-Fe battery is more than 20 years.

Advantages:

* It has high power density compared with lead acid

battery.

* It has capability of with standing 2000 deep discharge
* Spilling of electrolyte (KOH) is not harmful where as in the case of lead acid battery is harmful.
* Weigh is less than the lead acid battery.

Disadvantages:

* cost is high compared to lead acid battery.
* This batteries are complex due to need to maintain the water level and the safe disposing of hydrogen.
* These batteries also suffer from low temperature.

Applications :-

* It is used for rail road, signaling, forklift, and stand by power.

* **Lithium Based Batteries:**

Lithium is the highest of all metals and prevents very interesting characteristics from an electrochemical.

* It allows very high thermodynamic voltage, which has high specific energy and specific power.
* There are two major technologies of Lithium based batteries
  1) Lithium polymer Battery
  2) Lithium ion Battery.

1) **Lithium polymer Battery:**

* It can be abbreviated as Li-P, LiPo, Li-poly.
* It is a rechargable battery of lithium ion technology using a polymer electrolyte instead of a liquid electrolyte.

* this electrolyte has high conductivity gel like polymer which has improved safety and flexibility in design.

Working:

* It works on the principle of intercalation and deintercalation of lithium metal and a transition metal intercalation oxide (MyO_z)
* To prevent the electrodes from touching each other directly a microporous separator is in between which allows only the ions and not the electrolyte particles to migrate from one side to other.
* this MyO_z posses a layered structure from which lithium ions can be inserted from where they can be removed by discharge and charge.
* The general electrochemical reactions are,

$$x\,Li + MyO_2 \rightarrow Li_x\,MyO_z$$

* On discharge, lithium ions formed at -ve electrode migrate through the electrolyte and are inserted into the crystal structure of the electrode.
* On charge, the process is reversed.

  lithium foil $\longrightarrow$ -ve electrode

  vanadium oxide (V_6O_{13}) $\longrightarrow$ +ve electrode

* $Li|SPE|V_6O_{13}$ cell is the most attractive one within the family of Li-polymer. It has nomial voltage of 3V. specific energy of 155 w/kg. specific power of 315 w/kg.

Advantages:

* very low self discharging rate.
* capability of fabrication in variety of shapes and sizes.
* Safety designs.

Drawbacks:

* Low temperature performance due to the temperature dependence on ionic conductivity.

Applications:

* Drones
* Personal electronics
* Electric vehicles.

AR 10/10/2023 (1)

1) What are the types Batteries
Explain any two batteries in detail.
2) What is fuel cell and what are the types of fuel cells.
3) Discuss polymer electrolyte membrane in fuel cell with neat diagram. (PEMFC | proton exchange)
4) What are the battery models used in EV and explain.
5) What are battery parameters and discuss.

Unit-3

Electric propulsion

* E.V consideration:-
  Motor drives & speed control
  Induction motor drive
  Permanent magnet motor drive
  Switched reluctance motor drive for E.V
  Configurations and speed control of drives

* Machines working on the principle of Law of Conservation of energy.

There are two types of motors
1. AC motor
2. DC Motor

* In AC motor there are two types

* Generator

There are two types of Generators according to their Excitation
1. Seperately Excitated
2. self Excited

Law of Conservation of energy:-

The Energy can be neither be calculated nor destroyed but it converts one form of energy to another form.

Series
~~Shunt~~ parallel
Compound — Long shunt / short shunt

Speed control (formula)

$$E_g = \frac{P\phi N Z}{60} \times A$$

$$N = \frac{E_g \times 60}{P\phi_z} \times A$$

where N is directly proportional to E_g and A and inversely proportional to $P\phi_z$ ($N \propto \frac{1}{P\phi_z}$)

where ϕ = flux

N = speed in rpm

E_g = Generated EMF

P = no. of poles

Z = no. of conductor

A = no. of parallel paths

* $N = \frac{120f}{P}$

where $N \propto F$ & $N \propto \frac{1}{P}$

→ E_b → back emf in motor

→ two drives → Commutator → motor → excited connection

→ Commutator less

↓

Induction motor

Switch reluctance

* KCL :- Sum of current coming to junction is equal to sum of currents leaving from the junction

* KVL :- Sum of voltage drops in the closed loop

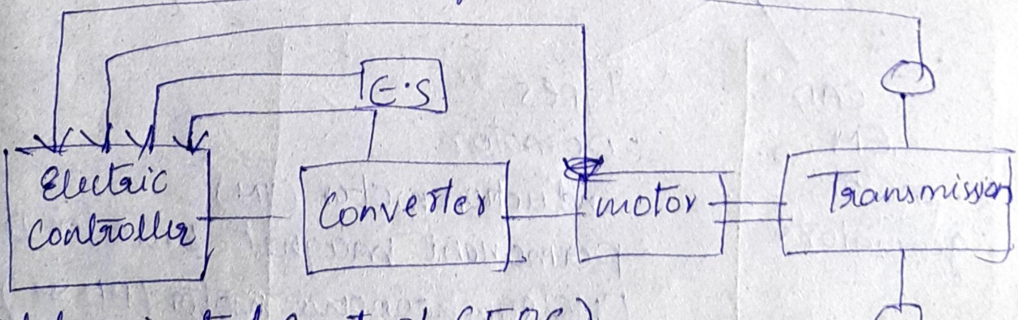
* chopper device acts as a switch also called as DC to DC converter
* four Quadrants four modes of operation
* Two control strategies → current limit control
  → Time ratio control
* Electric propulsion mainly consists of electric controller, power converter, electric motor, energy storage.
* Electric Controller :-

  classified into two types:
  1. Software
  2. Hardware

Software:—

It consist of

1) VVVF - Variable voltage and variable frequency



2) field oriented control (FOC)
3) STC - sensitive time control
4) Voltage Source Converter (VSC)
5) Neural Network control (NNC)
6) faizy Control
7) Current Source converter (CSC)

Hardware :-

1) micro processor
2) Microcontroller
3) Digital signal processor

* Power converters :-

Classified into two types :

1) Device
2) Topology

Devices :-

IGPT , MOSFET , GTO , MCT , BJT , Control Thyristor

IGPT → Insulated gate bipolar transistor

GTO → Gate turn off Thyristor

Topology :-

choper → Converters DC to DC

* Electric motor :-

CAD
EM
motors
generators

Types
DC motor
Induction motor (IM)
permanent magnet brushless DC
PMS synchronous motor (PMSM)
PM hybrid motor (PMHM)
Switched reluctance motor (SRC)

Energy storage or Energy sources :-

Battery , fly wheels , fuel cell , Super capacitor

Motor drives :-

Classified into 2 types :

1. Commutator

2. Commutator less

Commutator :- convert AC to DC

Self excitor Seperately excited DC motor

Commutator less :-

Induction motor , Switched reluctance motor , PMBLDC motor , PMHM

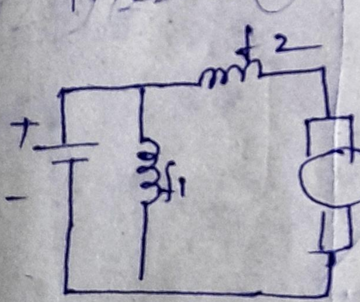
* The coil which carries current is called armature

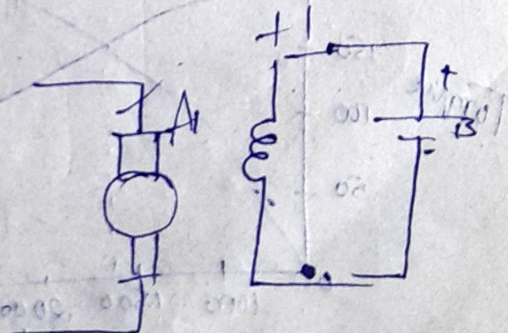
Working principle :-

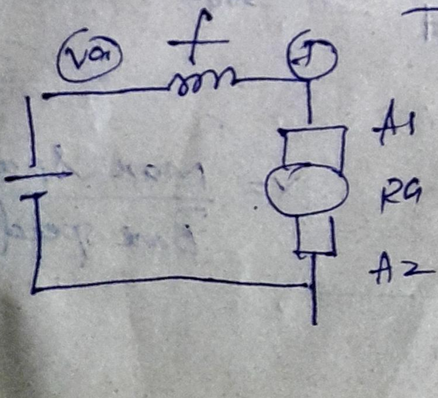
$F \propto BIL$

$F = BIL$

$T = BIL\cos\alpha$ – angle b/w coil & mag field





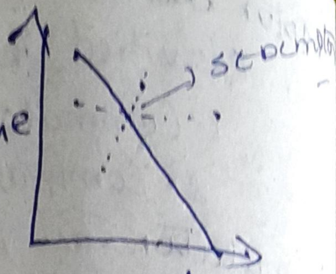


$V_a = E + I_a R_a$

$E = k\phi\omega_m$

$V_a = k\phi\omega_m + I_a R_a$

$T = k\phi I_a$



$I_a = \frac{V_a - k\phi\omega_m}{R_a}$

flux $\phi = k_f I_a$

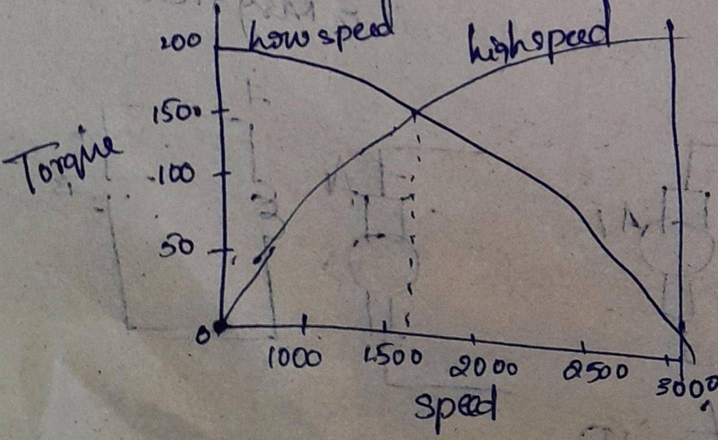
$T = k(k_f I_a) I_a$

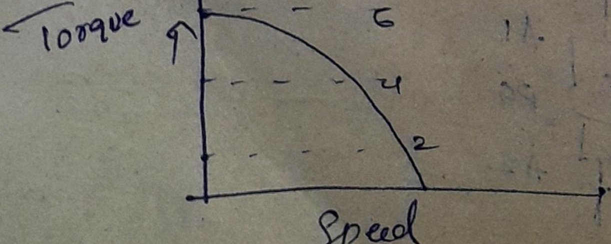
$T = k k_f I_a^2$

$= k k_f \left(\frac{V_a - k\phi\omega_m}{R_a} \right)^2$

$= \frac{k k_f}{R_a^2} (V_a - k\phi\omega_m)^2$

k & k_f - Constant





$x = \frac{\text{Max Speed}}{\text{Base speed}}$

* Speed is inversely proportional to torque

$$\text{speed} \propto \frac{1}{\text{Torque}}$$

* Torque constant at low speed
* Power constant at high speed

* Choper :-

* Choper acts as switch to turn ON and turn OFF the device.
* It converts DC into AC

Advantages:-

* High efficiency
* Small size
* reduces losses

* It is defined as the ratio of turn ON & turn OFF

$$\delta = \frac{T_{ON}}{T} \text{ sec}$$

* Control strategies of choper on time limit or time ratio control, current limit control.

$$f \propto \frac{1}{T}$$

frequency is inversely proportional to time

* Variable freq is high speed also high (or) increases
* Variable freq is high time decreases.

1. Dc motor drives:-

Dc motor drives have been widely used in applications requiring adjustable speed, good speed regulation, and frequent starting, braking and reversing. Various Dc motor drives have been widely applied to different electric traction applications because of their technological maturity and control simplicity.

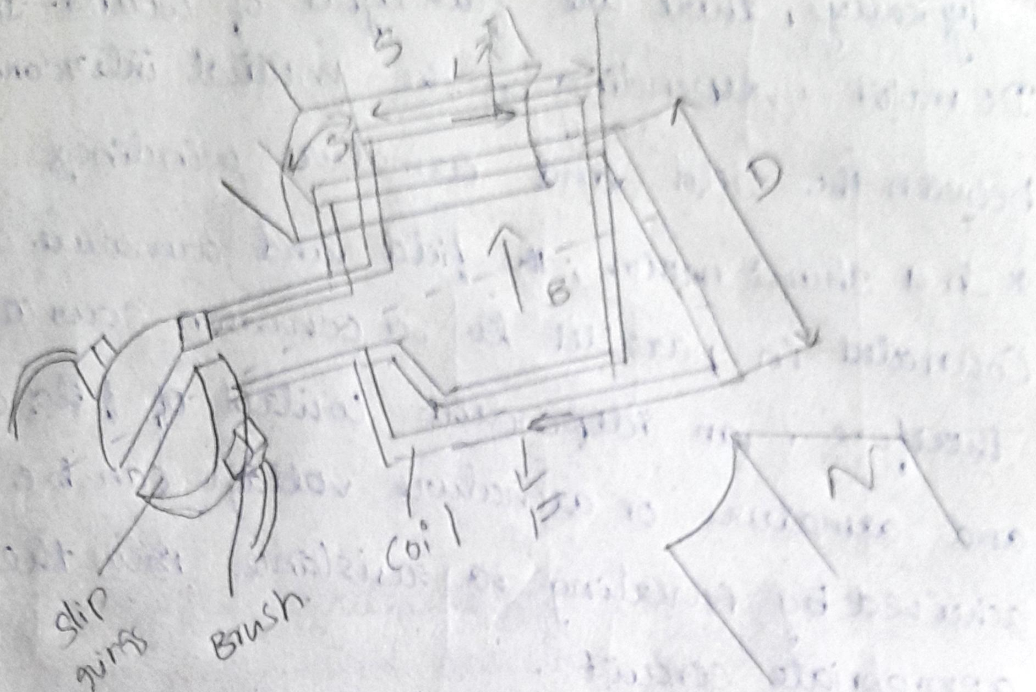
Principle of operation and performance:-

The operation principle of a Dc motor is straight forward. When a wire carrying electric current is placed in a magnetic field, a magnetic force acting on the wire is produced. The force is perpendicular to the wire and the magnetic field as shown in fig. The magnetic force is proportional to the wire length, magnitude of the electric current, and the density of the magnetic field; that is

$$F = BIL$$

When the wire is shaped into a coil, the magnetic forces acting on both sides produce a torque, which is expressed as

$$T = BIL \cos\alpha,$$



where α is the angle between the coil plane and magnetic field as shown in . The magnetic field may be produced by a set of windings or permanent magnets . The former is called wound - field DC motor and the latter is called the PM DC motor . In order to obtain continuous and maximum torque , slip rings and brushes are used to conduct each coil at the position of α = 0

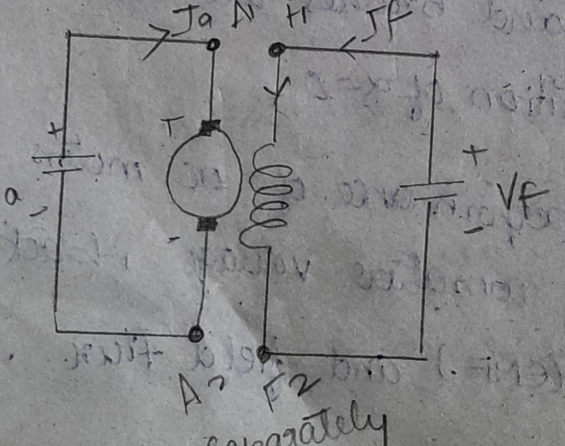
practically , the performance of DC motors can be described by the armature voltage , back electromotive force (EMF) and field flux .

Typically, there are four types of wound-field DC motor, depending on the mutual interconnection between the field and armature windings.

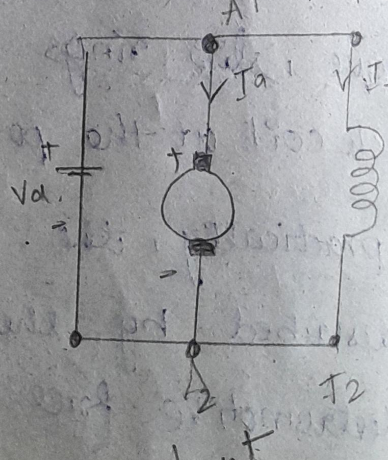
* In a shunt motor, the field and armature are connected in parallel to a common source. Therefore, an independent control of field current and armature or armature voltage can be achieved by inserting a resistance into the appropriate circuit.

* In case of series motor, the field current is the same as the armature current; therefore, field flux is a function of armature current.

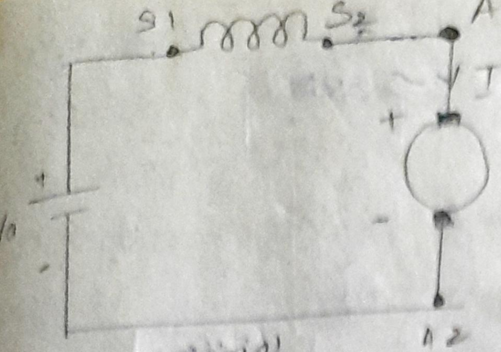
* In a cumulative compound motor, the magnet motive force (mmf) of a series field is a function of the armature current and is in the same direction as the mmf of the shunt field?



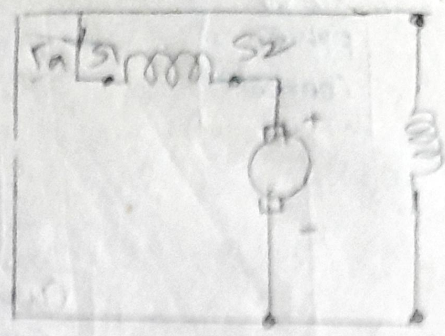
Separately



Shunt



Series



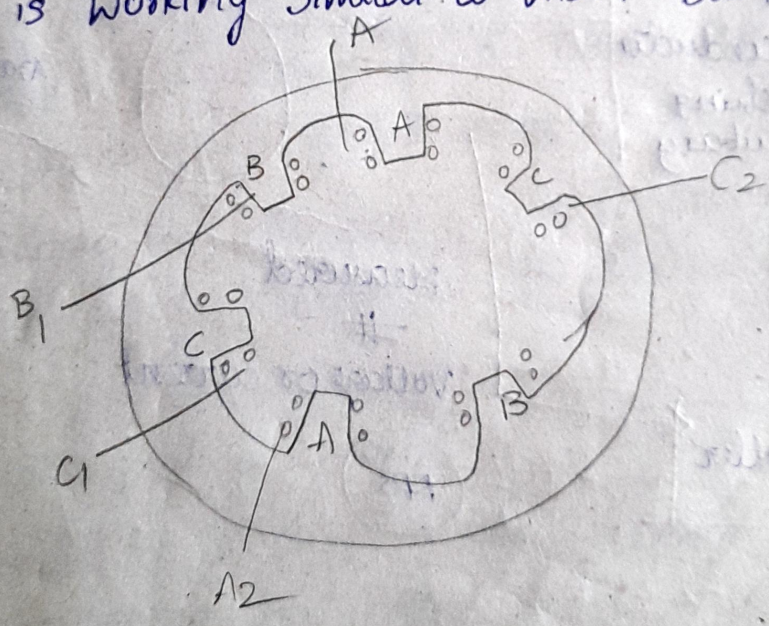
Cumulative Compound

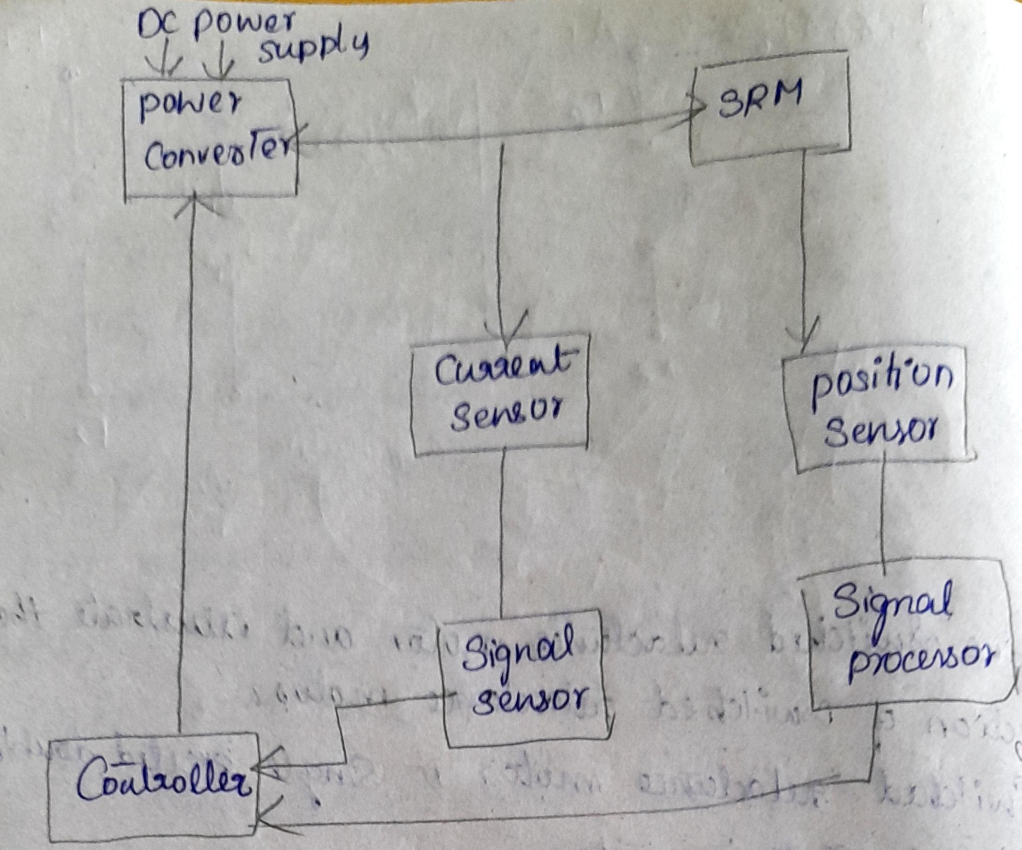
2. Define Switched reluctance motor and illustrate the Construction of Switched reluctance motor?

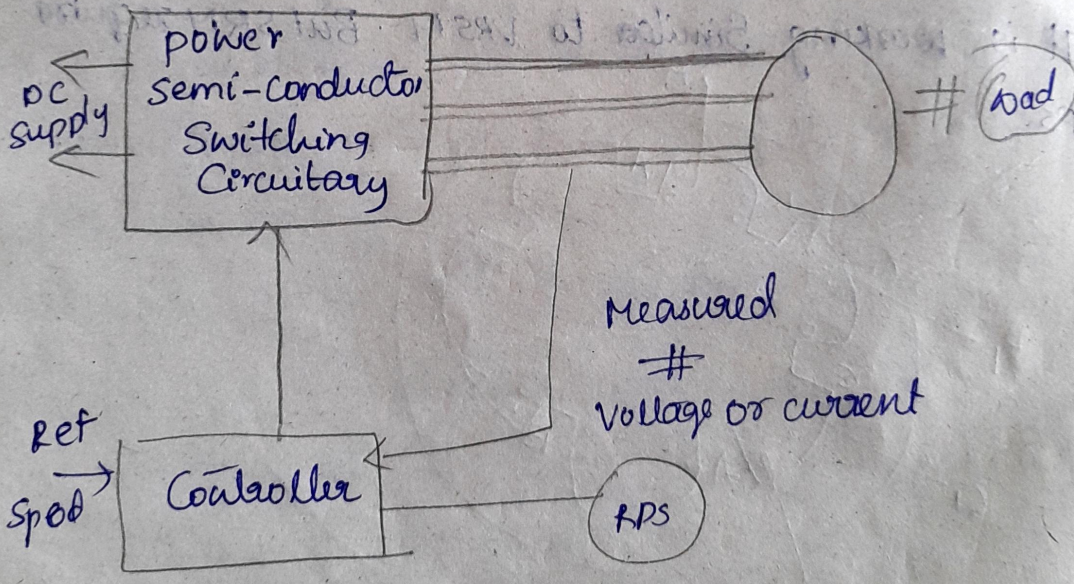
A) * Switched reluctance motor is Single excited double salient pole Electric motor

* It is an electromagnetic electro dynamic equipment

* It is working Similar to VRSM. But SRM requires RPS




DC power supply
power Converter
SRM
Current Sensor
position Sensor
Signal sensor
Signal processor
Controller


DC supply
power semi-conductor Switching Circuitary
load
Measured
Voltage or current
Ref Sped
Controller
RPS

STATOR:-

* Stator is made up of Silicon steel stampings with inward projected poles
* All poles carry fixed coils on stator windings field coils of opposite poles connected in series mmfs are additive they are called phase windings & it is Connected to the terminal of the motor.

ROTOR:-

* Rotor is made up of silicon steel Samplings with outward projected poles
* It Carries rps Turning OFF & ON operation of the Various devices of the power semi conductor switching circuitary are influenced by signals obtained from rotor positioned sensor.
* No. of poles of rotor different from no. of stator poles
* Different Configuration of SRM with stator & rotor poles ratio can be given as 1) 6:4 2) 8:6 3) 10:4 4) 12:8.
* DC Supply given to power semi conductor switching Circuitary which is Connected to Various phase windings of SRM.

RPS (Rotor position sensor):-

* Mounted on the shaft of SRM provide Signal to Controller about the position of the rotor w.r to reference axis
* Controller collects the informations & also reference Speed Signal & Suitability turns ON & OFF the concern

power Semi-conductor devices of switching ckt such that the desired phase windings connected to DC supply.

* The current signal is also feedback to the controller ckt to limit the motor current within permission limits.

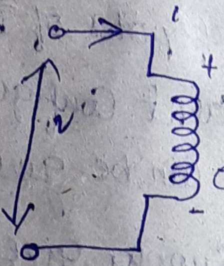
3) Derive the torque equation of switched reluctance motor?

A) * Consider an inductance whose inductance is a function of "θ" or position since we are using switching inductance that also called switched reluctance of motor.

* Based on variable reluctance principle $\psi = 4$

According to faradays law

flux linkage $\psi = Li$



$$e = -\frac{d\psi}{dt}$$

$$= -\frac{d(Li)}{dt}$$

$$= -L\frac{di}{dt} - i\frac{dL}{dt}$$

$$= -L\frac{di}{dt} - i\frac{dL}{d\theta}\frac{d\theta}{dt} \quad \left[\because \omega = \frac{d\theta}{dt}\right]$$

$$= -L\frac{di}{dt} - i\omega\frac{dL}{d\theta}$$

Magnitude of $e = L\frac{di}{dt} + 4\, i\omega\frac{dL}{d\theta}$ — ①

* Power developed $ei = Li\frac{di}{dt} + wi^2\frac{dL}{d\theta}$

ie power received from supply is

$$ei = Li\frac{di}{dt} + i^2 w\frac{dL}{d\theta} \rightarrow (2)$$

* Energy stored in magnetic field given by $\frac{1}{2}Li^2$
* Power due to variation of magnetic field is

$$\frac{dw_e}{dt} = \frac{1}{2}L\,2i\frac{di}{dt} + \frac{1}{2}i^2\frac{dL}{dt}$$

$$= Li\frac{di}{dt} + \frac{1}{2}i^2\frac{dL}{d\theta}\cdot\frac{d\theta}{dt} \quad \left[\because w = \frac{d\theta}{dt}\right)$$

$$\frac{dw_e}{dt} = Li\frac{di}{dt} + \frac{1}{2}i^2 w\frac{dL}{d\theta} \rightarrow (3)$$

* Mechanical power developed by given by equation (2) & (3)

P_m = Power received from supply - power due to change in magnetic field

$$P_m = Li\frac{di}{dt} + i^2 w\frac{dL}{d\theta} - Li\frac{di}{dt} + \frac{1}{2}i^2 w\frac{dL}{d\theta}$$

$$P_m = \frac{1}{2}i^2 w\frac{dL}{d\theta} \rightarrow (4)$$

Torque is developed

$$T = \frac{P_m}{w}$$

$$T = \frac{\frac{1}{2}i^2 w\frac{dL}{d\theta}}{w} \Rightarrow T = \frac{1}{2}i^2\frac{dL}{d\theta} \rightarrow (5)$$

* Positive value of $\frac{dL}{d\theta}$ Corresponds to motoring ac
* Negative value of $\frac{dL}{d\theta}$ Corresponds to generating a

* Torque depends on torque of current, hence it is independent of the direction of current
* Flux linkage current, torque waveform is shown in fig.

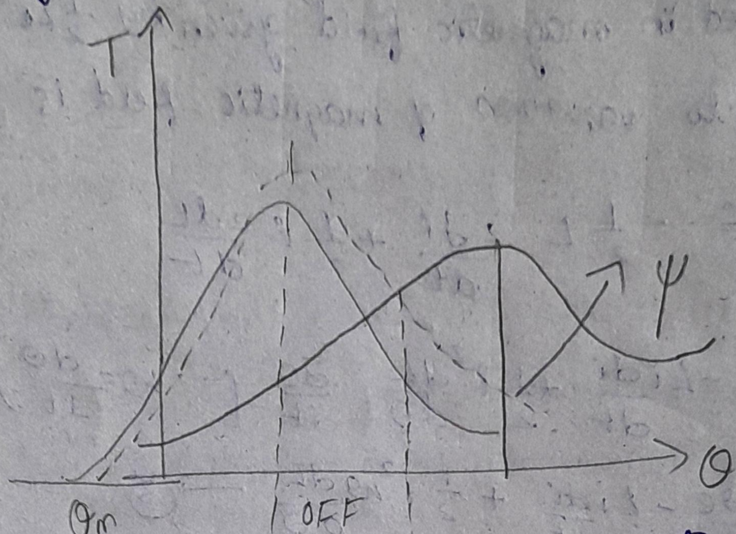


fig: Stator phase switches on at θon, switched off at θOFF.

3) What are the control strategies of chopper and Explain with neat sketch?

A) * The chopper allows a variable DC voltage to be obtained from a fixed voltage DC source
* The switch's can be controlled in various ways for varying the duty ratio δ
* The control technologies can be divided into the following categories

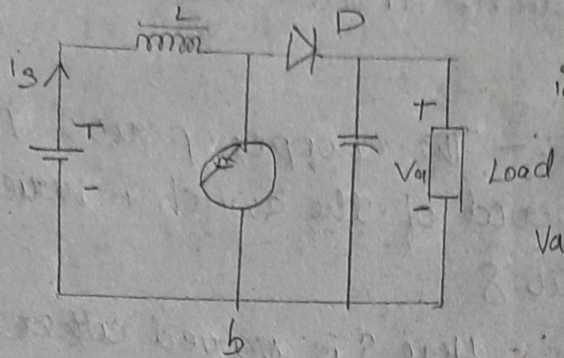
1. Time ratio control (TRC)
2. Current limit control (CLC)

* In TRC, also known as pulse width control, the ratio of on time to chopper period is controlled. Then the TRC further can be divided into the following categories

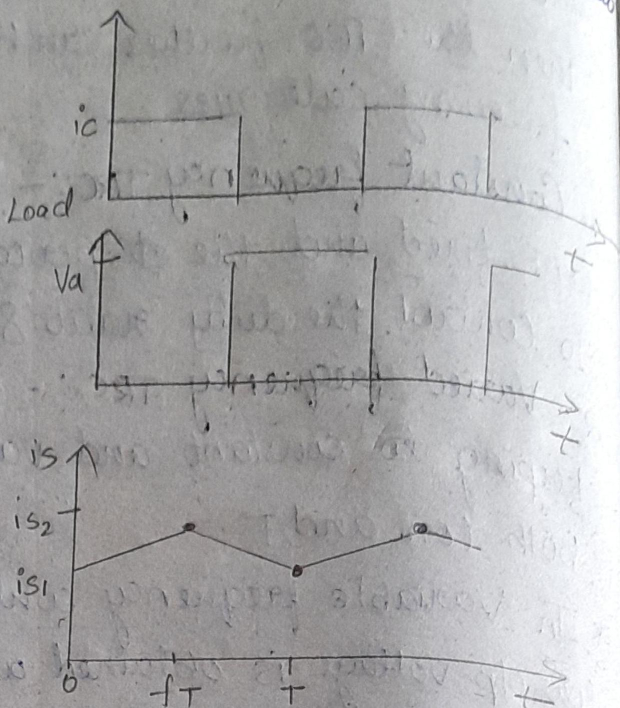
1. Constant frequency TRC :- The chopper period T is kept fixed and the on period of the switch is varied to control the duty ratio δ.
2. Varied frequency TRC :- Here δ is varied either by keeping ton constant and varying T or by varying both ton and T.

* In variable frequency control with constant on time low o/p voltage is obtained at very low value of chopper frequencies
* The operation of chopper of low frequencies adversly affects the motor performance.
* further more operation of a chopper with variable frequencies makes the design of an input filter very difficult.
* Thus the variable frequency control is rarely used
* In current limit control also known as point by point δ is controlled indirectly by controlling the load current b/w certain specified maximum and minimum values.
* When the load current reaches a specified maximum value the switch disconnects the load from the source and re-connects it when current reaches a specified min value

* for a DC motor load this type of control is in effect a variable frequency variable on time control



a)



b) wave forms

* The Source current is not continuous but flows in pulses. The pulsed current makes the peak input power demand high and may cause fluctuation in the source voltage.
* The Source current wave form can be resolved into DC and AC harmonics
* The fundamental AC harmonic frequency is same as chopper frequency
* The load terminal voltage is not perfect direct voltage. In addition to a direct component it has harmonics of the chopping frequency and its multiples. The load current also has an AC ripple
* for understanding the setup operation, capacitors is assumed to be large enough to maintain a

constant voltage Va across the load.

* The average voltage across the terminal b is given

$$V_{ab} = \frac{1}{T}\int_0^T V_{ab}\,dt = V_a(1-\delta)$$

average voltage across the inductance is

$$V_L = \frac{1}{T}\int_0^T \left(L\frac{di}{dt}\right)dt = \frac{1}{T}\int_{i_{01}}^{i_{02}} L\,di = 0$$

$$V = V_a(1-\delta) \quad \therefore \quad V_a = \frac{V}{(1-\delta)}$$

* It is also used in regenerative breaking of DC motor drives.

5) Compare permanent magnet Brushless DC motor & SR motor ?

PMBDC (or) BLDC	SRM
1. <u>Working</u> <u>principle</u>:- BLDC operates on the principle of permanent magnet on the rotor interacting with stator's electromagnets using electronic commutation to switch the current direction.	* SRM operates based on the reluctance torque produced by aligning the rotor poles with the energized stator poles. It does not have permanent magnets on the rotor.
* Typically BLDC has a rotor with permanent magnets making it a synchronous motor	* Rotor lacks permanent magnets and relies on the reluctance torque generated due to magnetic reluctance b/w stator and rotor.
<u>Control</u> <u>Complexity</u>:- Generally BLDC requires more complex electronic control system for precise commutation involving sensors or sensorless methods.	* SRM control systems compared to BLC motor. They are often praised for their robustness and reliability.

PMBDC (or) BLDC	SRM
Torque characteristics :- BLDC have smooth torque delivery due to the presence of permanent, providing good efficiency across a wide range of speeds.	SRM have tends to have more variable torque characteristics with torque peaks at specific operating points.
Applications :- BLDC Commonly used in various applications such as electric vechiles, robotics and household applicancy where smooth and efficient torque control is crucial	SRM can be used in industrial and high power applications where simplicity of and robustness are valued.
* BLDC offers high efficiency across a wide range of operating conditions.	* SRM has competitive efficiency when it can be operated in specific operating regions.

15. What is the need of power drives in motors? Explain the working principle of the power drive system used in switched reluctance motor with relevant sketch.

A) The power drive in motor control of speed, direction, acceleration, deceleration, torque and in some applications, position of the motor shaft.

Switched Reluctance Motor Drives:-

The Switched reluctance motor (SRM) drive is considered to be an attractive candidate for variable speed motor drives due to its low cost, rugged structure, reliable converter topology, high efficiency over a wide speed range, and simplicity in control. These drives are suitable for EVs, electric traction applications, automotive applications, aircraft starter/generator systems, mining drives, washing machine, door actuators

Working Principle:-

* 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 done using the circuit of power electronic switches

Switched reluctance motor Construction :-

* The construction of the switched reluctance motor is shown below

* This motor includes 6-stator poles as well as 4 rotor poles.

* The design of the stator can be done using silicon steel stampings inside projected poles

* The poles in the stator are either an odd number or even number.

* Most of the electric motor have an even number of poles within the stator which have field coils

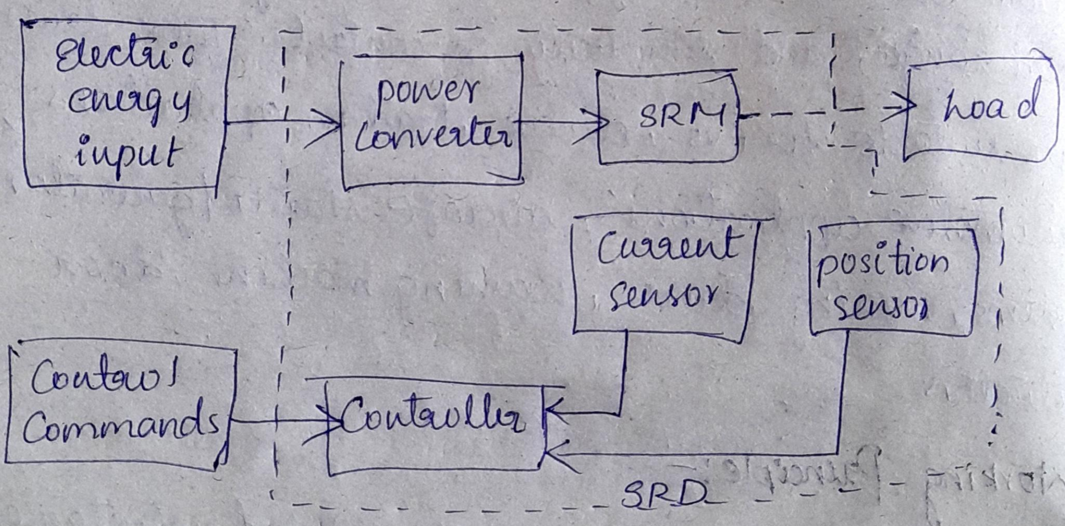
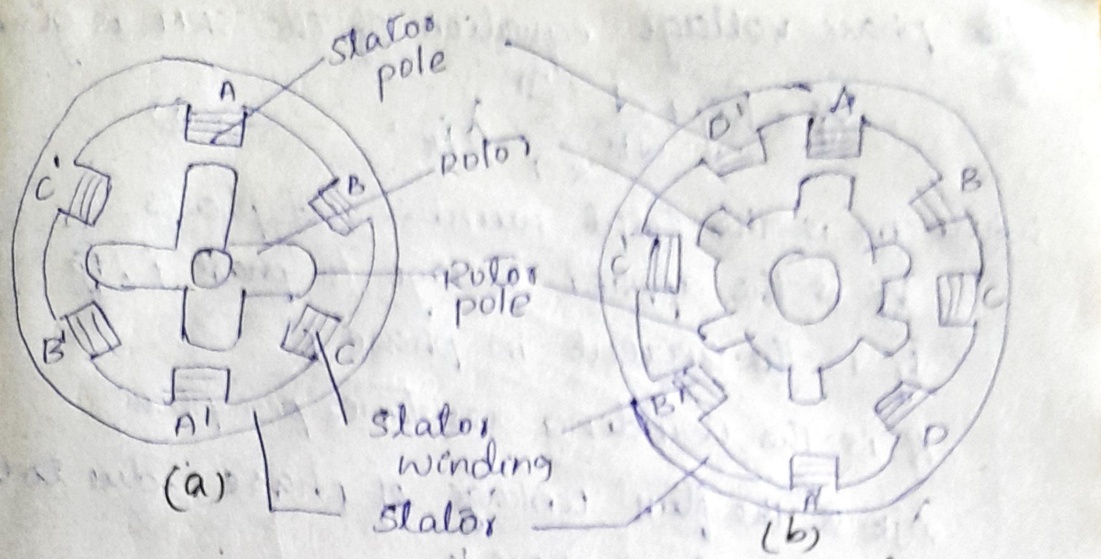


fig: SRM drivesystem



Cross section of common SRM configuration

a) 6/4 SRM b) 8/6 SRM

* When the poles are opposite then the field coils will be connected in series

* Due to its double saliency structure, the reluctance of the flux path for a phase winding varies with the rotor position.

* Also, due to the SRM is commonly designed for high degree saturation at high phase current, the reluctance of the flux path also varies with the phase current.

* As a result, the stator flux linkage, phase bulk inductance, and phase incremental inductance, and phase incremental inductance all vary with the rotor position and phase current

The phase voltage equation of the SRM is given by

$$V_j = Ri_j + \frac{d}{dt}\sum_{k=1}^{m} \lambda_{jk}, \longrightarrow ①$$

where m is the total number of phases,

V_j is the applied voltage to phase j,

i_j is the current in phase j

R is the winding resistance per phase.

λ_{jk} is the flux linkage of phase j due to the current of phase k,

t is the time

* The phase flux linkage λ_{jk} is given by

$$\lambda_{jk} = L_{jk}(i_k, \theta, \theta)\, i_k, \longrightarrow ②$$

where L_{jk} is the mutual inductance between phase k and phase j.

* Mutual inductance between phases is usually small compared to the bulk inductance and is neglected in equations.

Substituting eq ② into eq ①,

$$V_j = Ri_j + \frac{d}{dt}\sum_{k=1}^{m} \lambda_{jk}$$

$$= Ri_j + \sum_{k=1}^{m}\left\{\frac{\partial \lambda_{jk}}{\partial i_k}\frac{di_k}{dt} + \frac{\partial \lambda_{jk}}{\partial \theta}\frac{d\theta}{dt}\right\}$$

$$= Ri_j + \sum_{k=1}^{m}\left\{\frac{\partial (L_{jk} i_k)}{\partial i_k}\frac{di_k}{dt} + \frac{\partial (L_{jk} i_k)}{\partial \theta}\,\omega\right\}$$

$$= Ri_j + \sum_{k=1}^{m} \left\{ \left(L_{jk} + i_k \frac{\partial L_{jk}}{\partial i_k} \right) \frac{di_k}{dt} + i_k \frac{\partial L_{jk}}{\partial \theta} \omega \right\}.$$

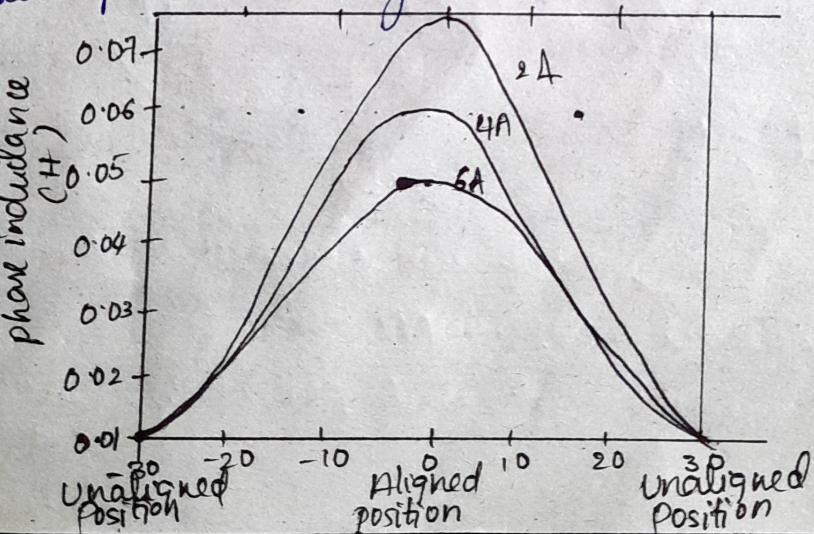
When only one phase is energized in the operation

$$V_j = Ri_j + \left(L_{jj} + i_j \frac{\partial L_{jj}}{\partial i_j} \right) \frac{di_j}{dt} + i_j \frac{\partial L_{jj}}{\partial \theta} \omega \quad \text{--- (3)}$$

* The eq (3) term is equation of the back EMF
* The phase incremental inductance is defined as the derivative of the phase flux linkage against the phanse current as

$$l_{jj} = \frac{\partial \lambda_{jj}}{\partial i_j} = L_{jj} + i_j \frac{\partial L_{jj}}{\partial i_j},$$

* Torque production :-
* Torque in SRM is produced by the tendency of the rotor to get into alignment with the excited stator poles.
* The analytical expression of the torque can be derived using the derivative of the coenergy against the rotor position at a given current.



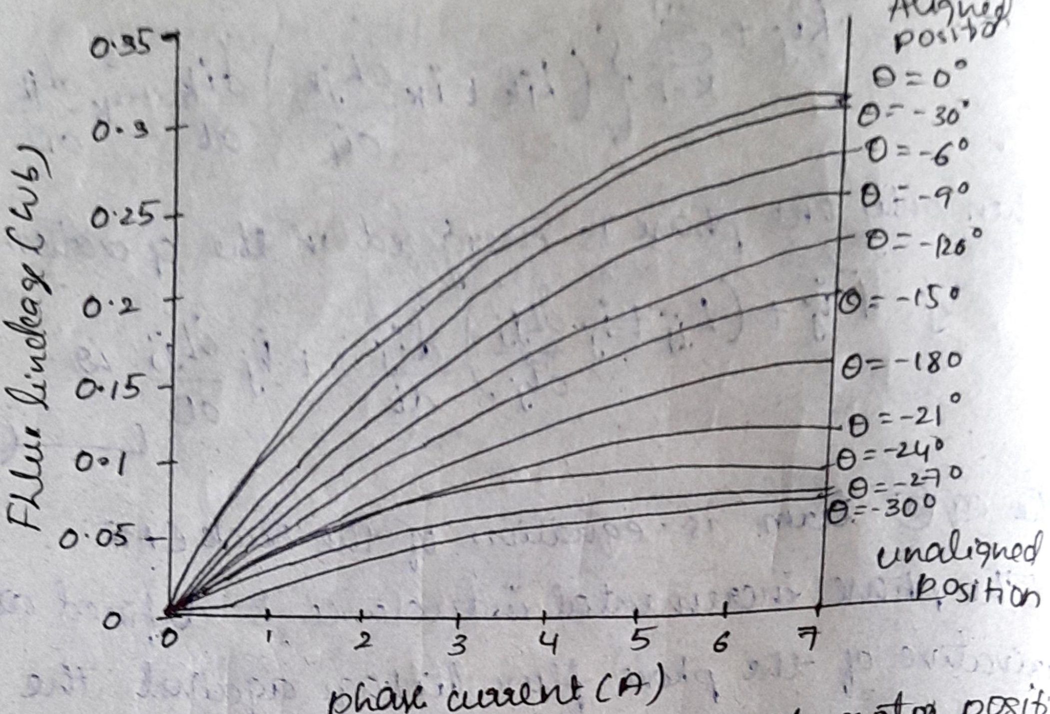


fig: variation of phase flux linkage with rotor position and phase current

16) Explain the working principle and components involved in the control system process of typical BLDC motor with relavent schematic sketch

A) Basic Principles of BLDC motor drives :-

* The BLDC motor drive consists mainly of the brush-less DC machine, a DSP-based controller, and a power electronics-based power converter.

* Position sensors H_1, H_2 and H_3 sense the position of the machine rotor.

* The rotor position information is fed to the DSP-based controller, which, in turn, supplies gating signals to the power converter by turning on and turning off the proper stator pole windings of the machine.

* In this way, the torque and speed of the machine are controlled.

* BLDC Machine construction an:

* BLDC machines can be categorized by the position of the rotor permanent magnet, the way in which the magnets are mounted on the rotor.

* The magnets can either be surface-mounted or interior-mounted.

* Each permanent magnet is mounted on the surface of the rotor.

* It is easy to build; and specially skewed poles are easily magnetized on this surface-mounted type to minimize cogging torque.
* But there is a possibility that it will fly apart during high-speed operations.

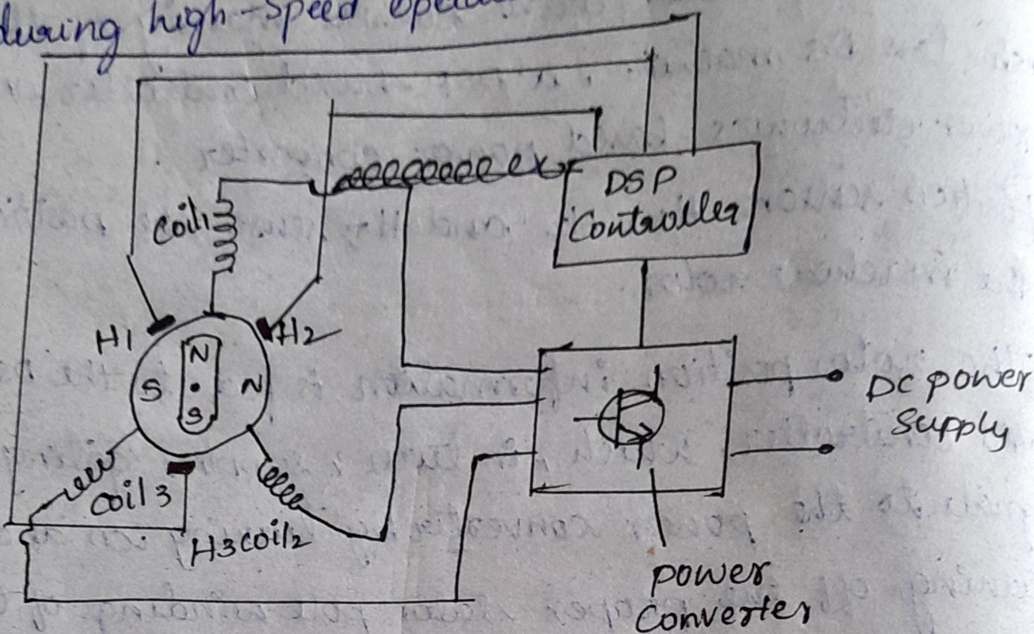
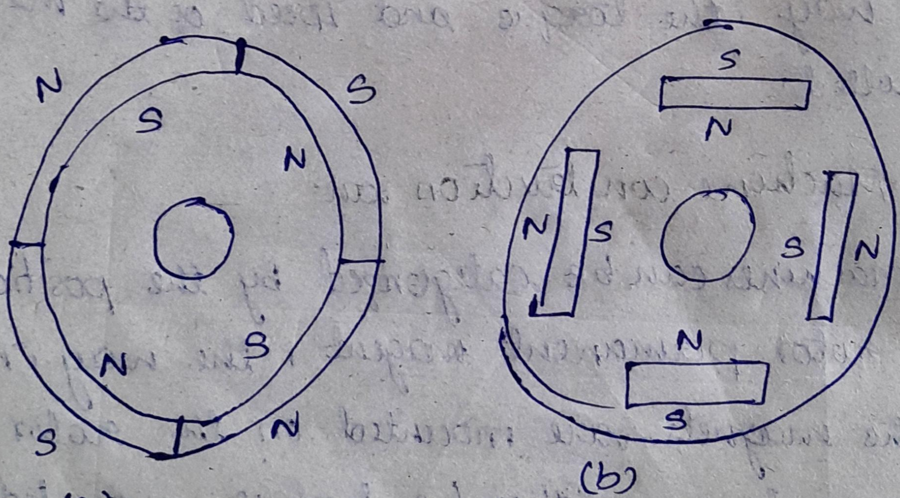


fig: BLDC motor



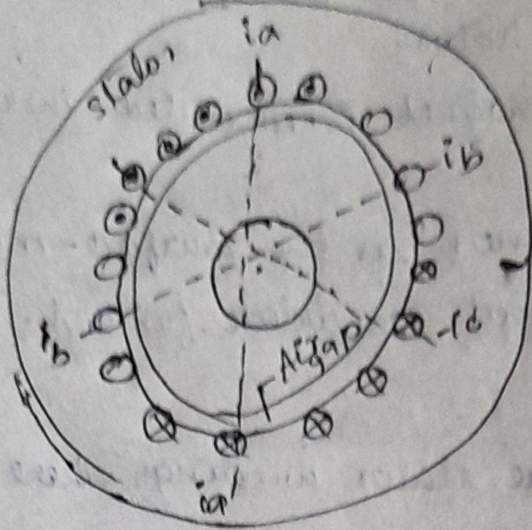
Cross sectional view of the permanent magnet rotor: a) surface mounted PM rotor &
b) interior-mounted PM rotor

* The above figure shows the interior - mounted permanent magnet rotor.
* Each permanent magnet is mounted inside the rotor.
* It is not as common as the surface - mounted type but it is a good candidate for high - speed operations.

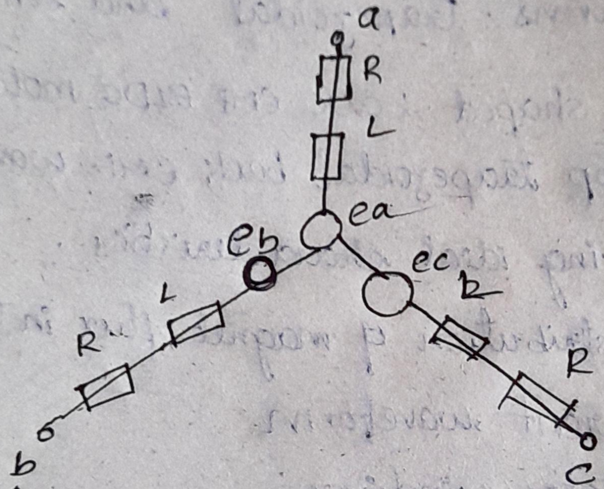
* In this case of the stator windings, there are two major classes of BLDC motor drives, both of which can be characterized by the shapes of their respective back EMF waveforms: trapezoidal and sinusiodal.

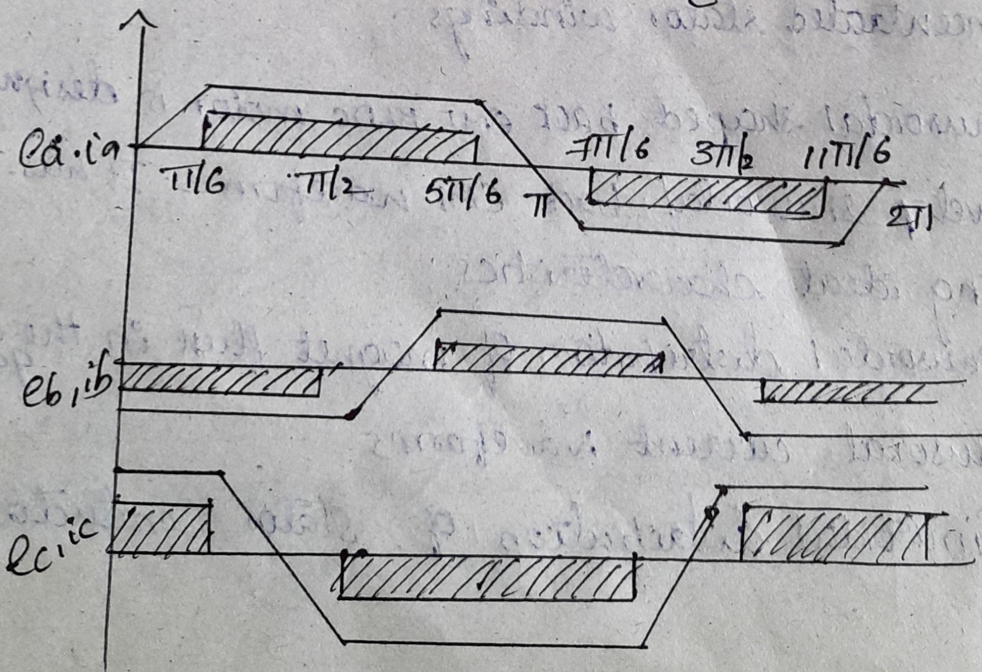
* The trapezoidal - shaped back EMF BLDC motor is designed to develop trapezoidal back EMF waveforms
* It has the following ideal characteristics:
  1. Rectangular distribution of magnet flux in the airga
  2. Rectangular current waveform
  3. Concentrated stator windings.

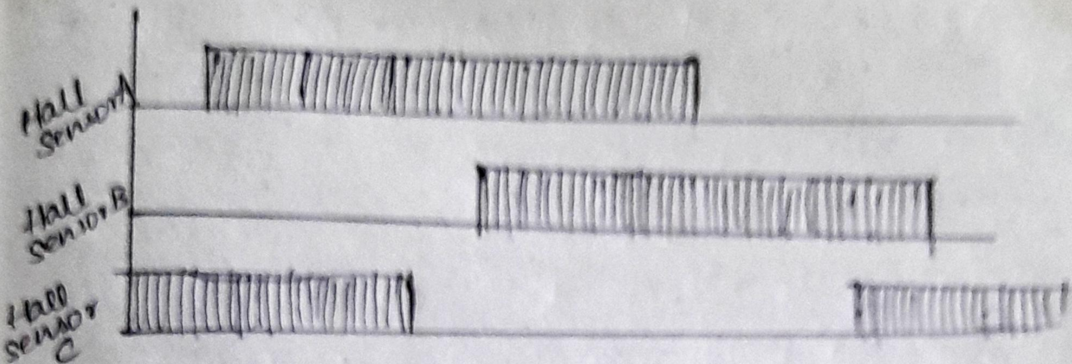
* A Sinusoidal shaped back EMF BLDC motor is designed to develop sinusoidal back EMF waveforms. It has the following ideal characteristics:
  1. Sinusoidal distribution of magnet flux in the air gap
  2. Sinusoial current waveforms
  3. Sinusoidal distribution of stator Conductors



winding configuration of the trapezoidal-shaped back EMF BLDC







phase current : ia , ib , ic

Back EMF : ea , eb , ec

Hall sensor Signal .

* The most fundamental aspect of the sinusoidal-shap back EMF motor is that the back EMF generated in each phase winding by the rotation of the magnet should a sinusoidal wave function of rotor angle .

unit-III

① Explain the motor drive, principle operation with neat sketch or dc motor question ?

(AC) → induction motor. switched electron

② Defined switched reluctance motor illustrate the construction of switched reluctance of motor

③ what are the control strategies of chopper and explain with neat sketch ?

④ Derive the torque equation of a switched reluctance of a motor ?.

⑤ compare permanent magnet . brushless DC motor and switched reluctance motor ?

Unit - 4

Design of Electric & Hybrid Electric vehicles

- Series Hybrid Electric Drive Train Design: operating patterns, control strategies, sizing of major components, power rating of engine/generator, & design of PPS parallel Hybrid Electric Drive Train Design: control strategies of parallel hybrid drive train, design of engine power capacity, design of electric motor drive capacity, transmission design, & energy storage design.

Series Hybrid Electric Drive Train Design:-

operation pattern:-

* In series hybrid electric drive train, the engine/generator system is mechanically decoupled from the driven wheel.
* The speed & torque of the engine are independent of vehicle speed & traction torque & can be controlled at any operating point on it speed - torque plane.
* However, it heavily depends on the operating modes & control strategies of the drive train.

operating modes are:-

* **Hybrid traction mode:-**

when a large amount of power is demanded, that is the driver depresses the accelerator pedal deeply, both engine/generator & peaking power source supply their powers to the electric motor drive

$$P_{demand} = P_{e/g} + P_{pps}$$

where

P_{demand} = power demanded by the driver

$P_{e/g}$ = engine/generator power

P_{pps} = pps power.

Peak power source - Alone Traction Mode :-

In this operating mode, the peak power source alone supplies its power to meet the power demand that is,

$$P_{demand} = P_{pps}$$

Engine/ Generator - Alone Traction Mode :-

In this operating mode, the engine/ generator alone supplies its power to meet the power demand that is,

$$P_{demand} = P_{elg}$$

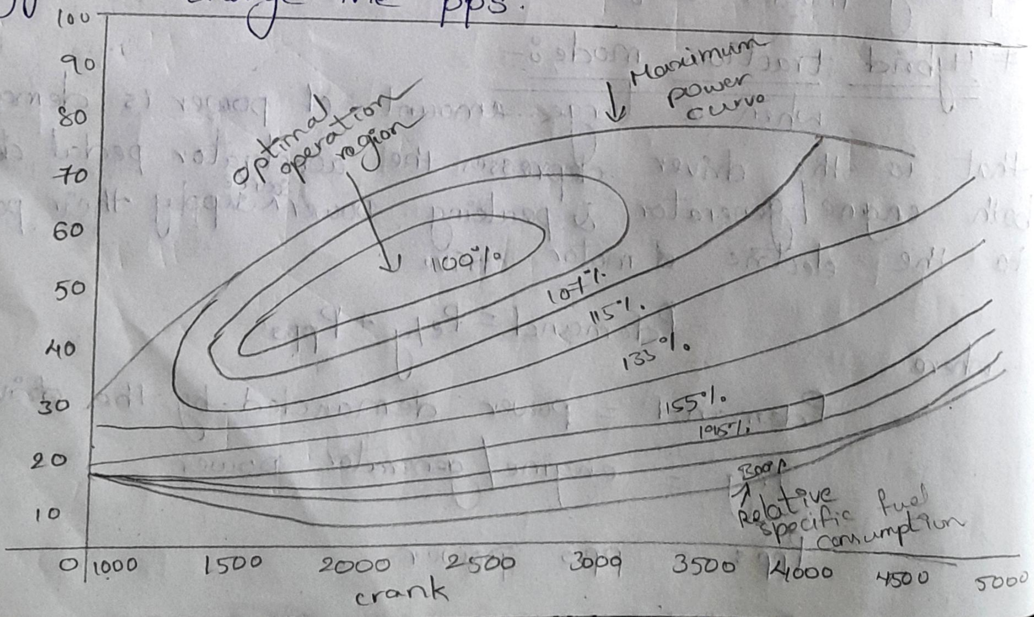
PPS charging from the Engine/ Generator :-

When the energy in the pps decreases to a bottom line, the pps must be charged. This can be done by regenerative braking (or) by the engine/generator. In this case, the engine power is divided into two parts : one is used to propel the vehicle & the other is used to charge the pps. That is,

$$P_{demand} = P_{elg} - P_{pps}$$

Regenerative Braking Mode :-

When the vehicle is braking, the traction motor can be used as a generator, converting part of the kinetic energy of the vehicle mass into electric energy to charge the pps.

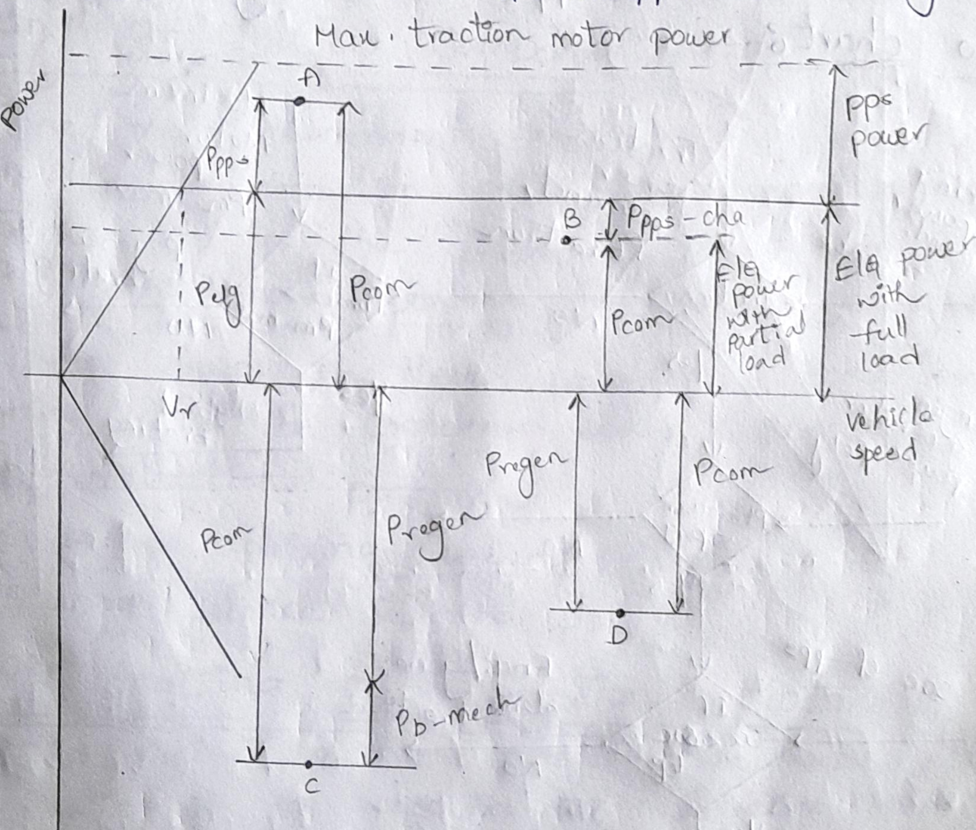


Control strategies :-

* A control strategy is a control rule that is present in the vehicle controller & commands the operating of each component.
* obviously, the performance of the drive train relies mainly on the control quality, in which the control strategy plays a crucial role.
* There are two typical control strategies :-
  # Maximum state-of-charge of peaking power source (Max. soc-of-pps)
  # Engine turn-on & turn-off (engine-on-off) control strategies

Max. soc-of-pps control strategy :-

* The target of this control strategy is to meet the power demand commanded by the driver & at the same time, maintain the soc of the pps at its high level



A - Hybrid traction mode

Pcom - Commanded power

Ppps - power of the peaking power source

Pelg - power of engine/generator.

B - Engine/generator - alone traction mode (or) pps charging mode

$P_{pps-cha}$ - pps charging power

C - Hybrid braking mode

P_{regen} - Renerative braking power

P_{b-mech} - Mechanical braking power

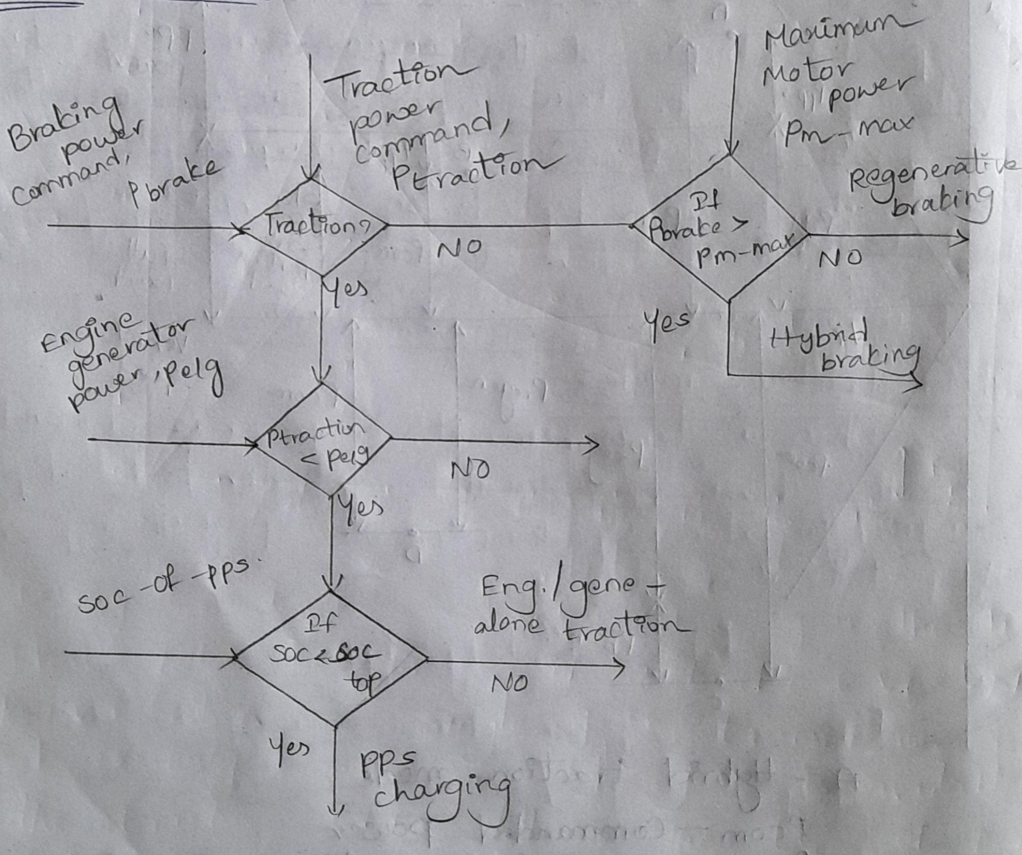
D - Regerative braking mode.

* The Max. soc-of-pps control in which points A, B, C & D represents the power demands that the driver commands in either traction Motor (or) braking mode.
* In this case, two operating modes may be used, depending on the soc level of pps.

Thermostat Control strategy (Engine-on-off)

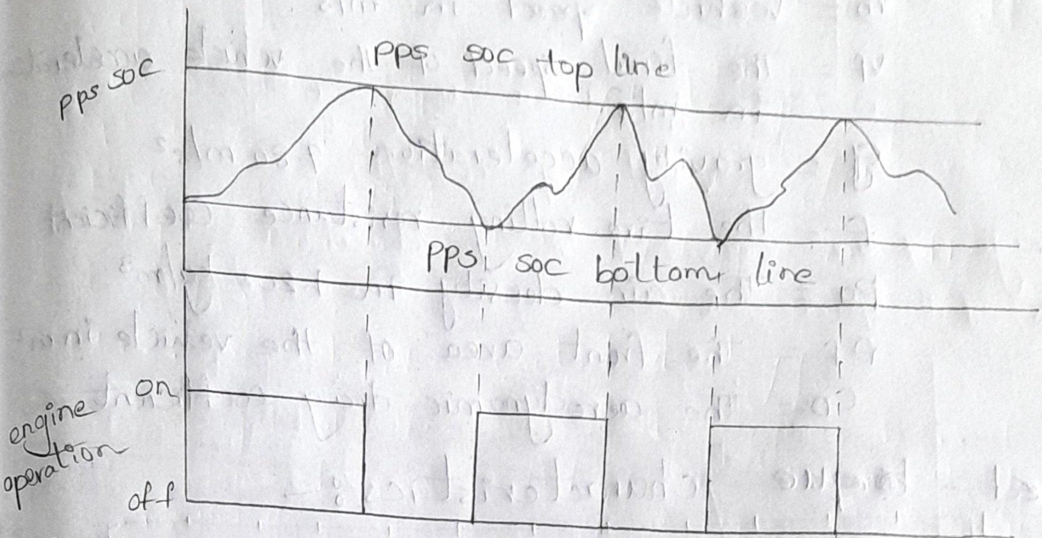
* The Max. soc-of-pps control strategy emphasizes maintaining the soc of the pps at a high level.

Flow chart:-



* However, in some driving conditions such as long time driving with a low load on a highway at constant speed, the PPS can be easily charged to its full level & the engine/generator is forced to operate with a power output smaller than its optimum.

Illustration of thermostat control:—



Sizing of Major Components:—

* The major components in a series hybrid drive train include traction motor, engine/generator, & PPS.
* The design of the power rating of these components is the first & most important step in the whole system design.
* In the design of these parameters, some design constraints must be considered, which includes
  - ↳ acceleration performance
  - ↳ Highway driving & urban driving
  - ↳ energy balance in the PPS.

Power rating of Traction Motor:—

* It is similar to the pure electric vehicle, the power rating of the electric motor drive in series HEV is completely determined by vehicle acceleration performance requirements, motor characteristics & transmission characteristics.
* At the beginning of the design, the power rating of

of the motor drive can be estimated, according to the acceleration performance.

$$P_t = \frac{\delta M_v}{2t_a}(V_f^2 + V_b^2) + \frac{2}{3} M_v g f_r V_f + \frac{1}{5} \rho_a C_D A_f V_f^3.$$

where M_v = Total vehicle mass in kg.

t_f = The expected acceleration time in sec

V_b = vehicle speed in m/s.

V_f = The final speed of the vehicle acceleration in m/s.

g = gravity acceleration 9.80 m/s²

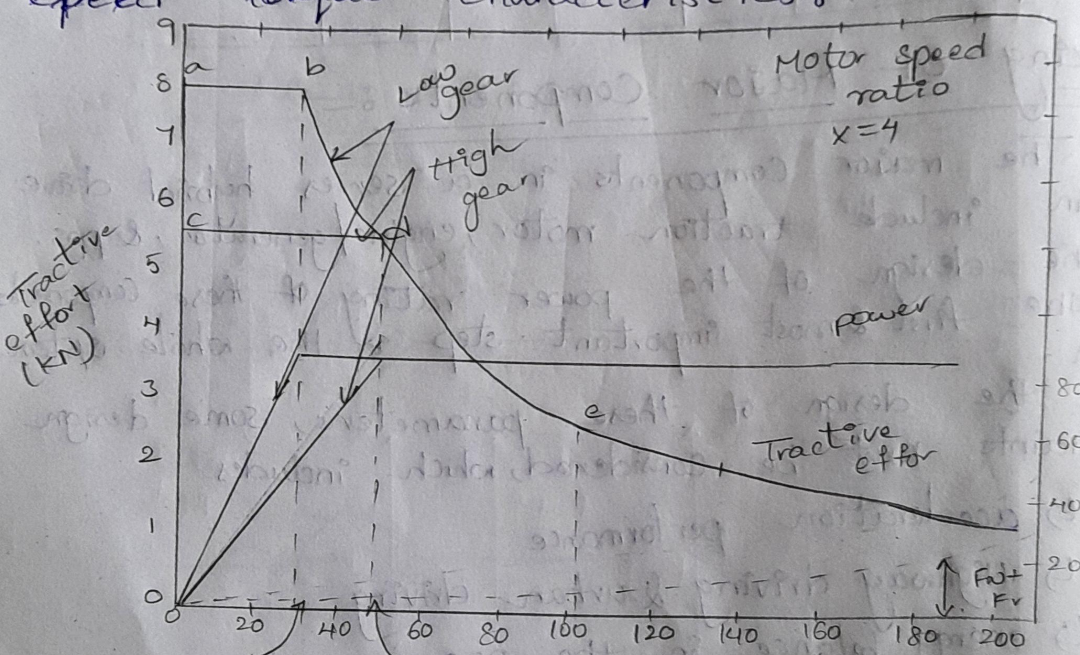
f = the tire rolling resistance coefficient

ρ_a = The air density in 1.202 kg/m³.

A_f = The front area of the vehicle in m²

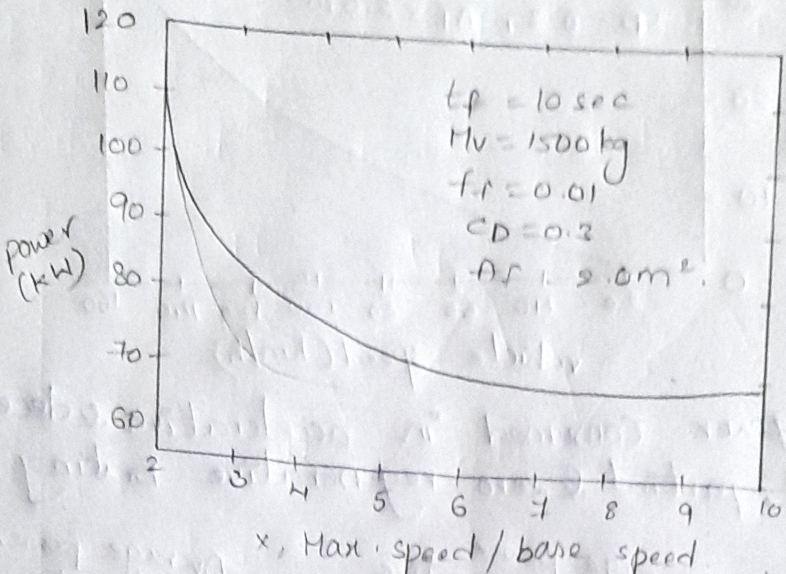
C_D = The aerodynamic drag coefficient

Speed - torque characteristics :-



During acceleration starting low gear, the tractive effort follows the trace of a-b-d-e & $V_t = V_{b1}$. However when a single gear transmission is used that is, only when a high gear is available, the tractive effor follows the trace of c-d-e & $V_b = V_{b2}$.

Power rating of the traction power vs speed ratio of drive train :-



Power Rating Design of the Engine/Generator

* The engine/generator in a series hybrid drive train is used to supply steady-state power in order to prevent the pps from being discharged completely.
* In the design of the engine/generator, two driving conditions should be considered :-
  ↳ driving for a long time with constant speed, such as highway driving b/w cities & driving with a frequent stop-go driving pattern, such as driving in cities.

At constant speed & on a flat road, the power output from the power source can be expressed as

$$P_{e/g} = \frac{V}{1000\,\eta_t \eta_m}\left(M_v g f_r + \frac{1}{2}\rho_a C_D A_f V^2\right) (kW)$$

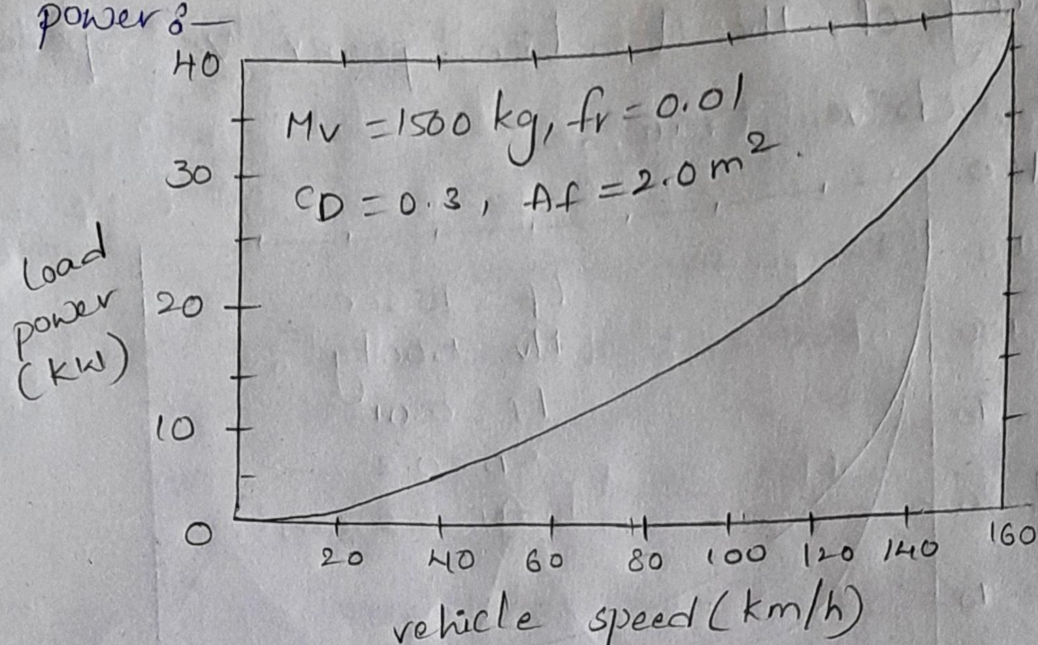
where :- η_t & η_m = The efficiency of transmission & traction motor, respectively.

The average load power can be expressed as;

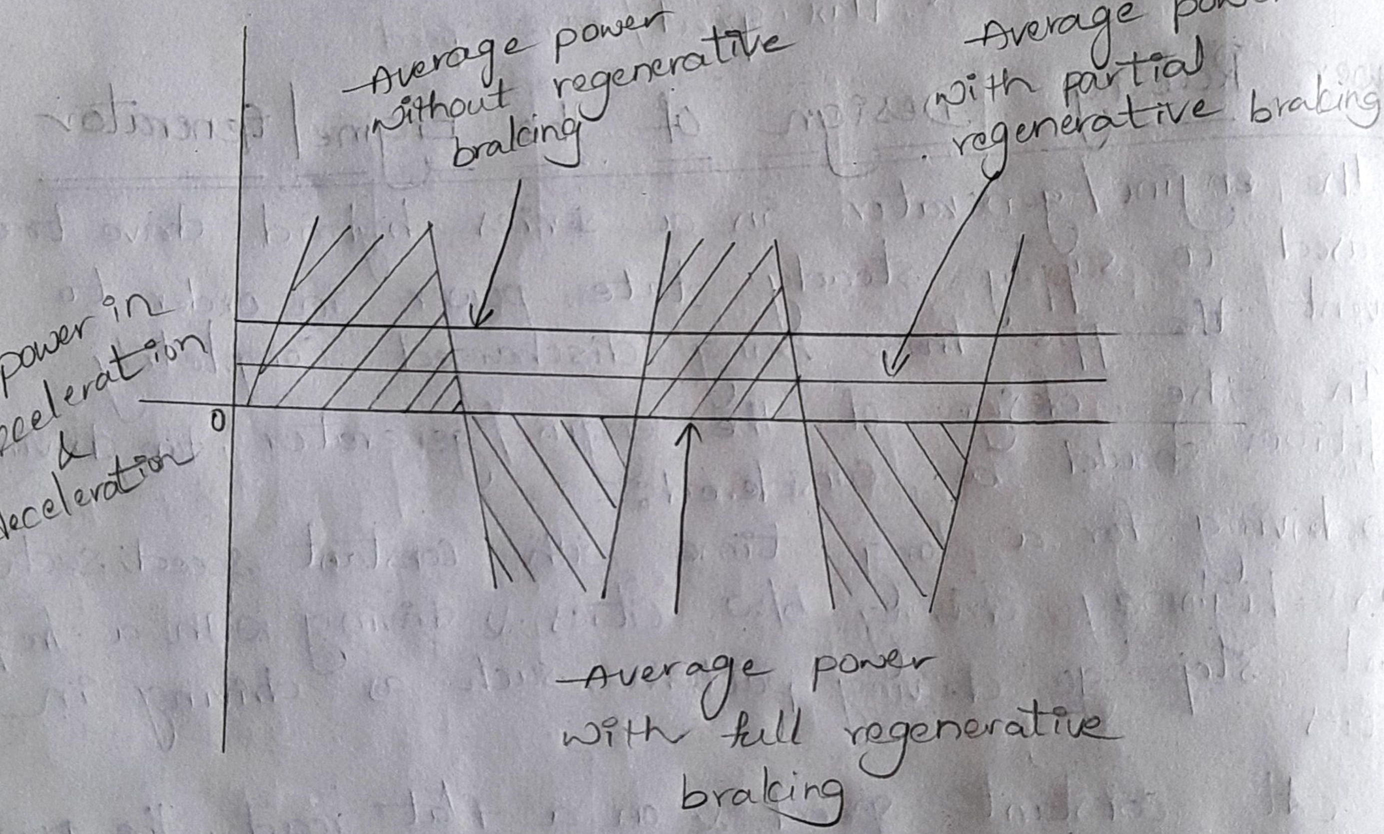
$$P_{ave} = \frac{1}{T}\int_0^T \left(M_v g f_r + \frac{1}{2}\rho_a C_D A_f V^2\right) V\,dt + \frac{1}{T}\int_0^T \delta M_v \frac{dV}{dt}\,dt$$

δ = vehicle mass factor, dV/dt = acceleration of the vehicle.

Load power :-



Average power consumed in acceleration & deceleration with full, partial & zero regenerative braking

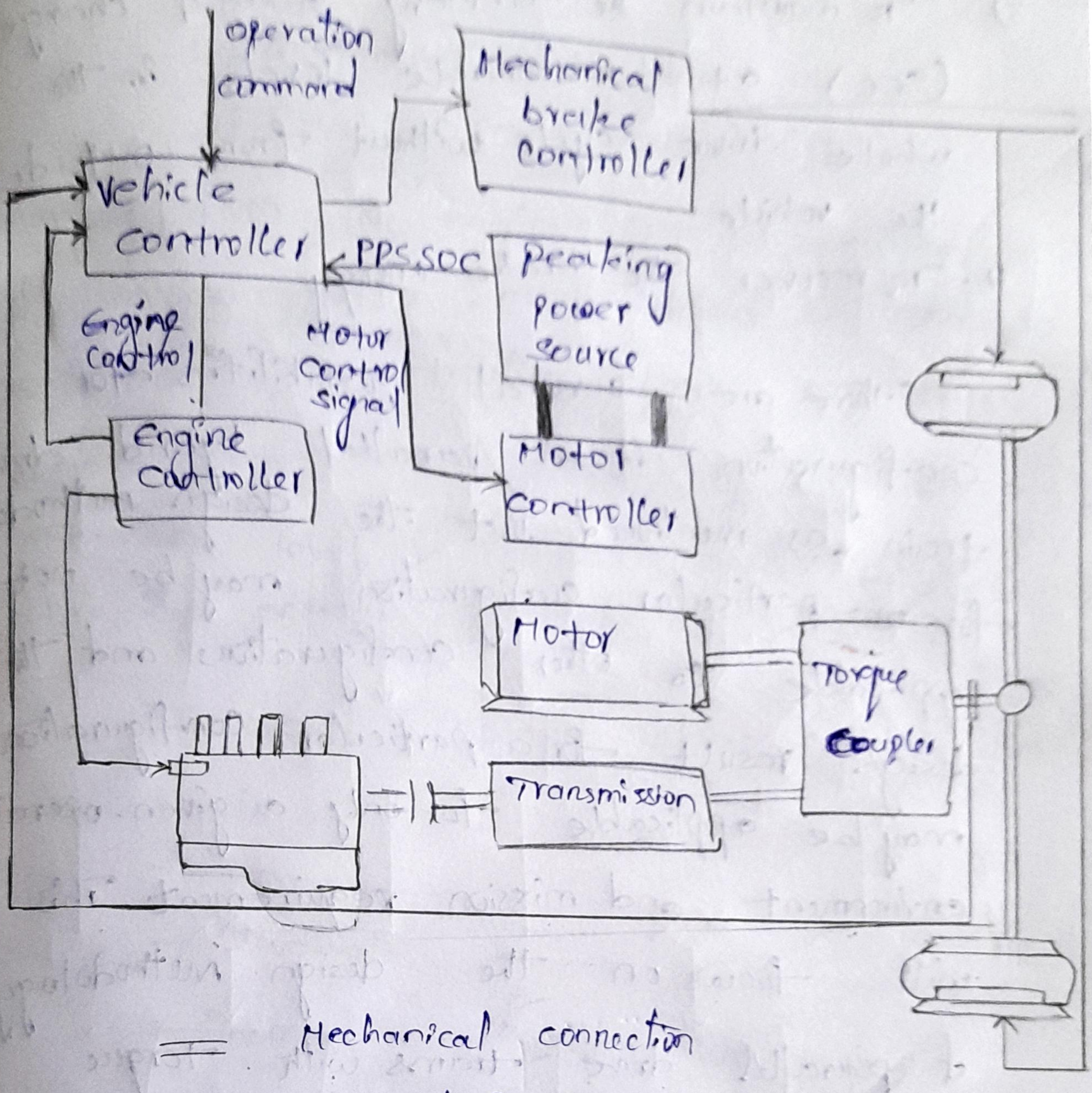


21/12/23

unit-IV

Design of PPS parallel hybrid electric drive train design:-

Block diagram



═ Mechanical connection

▬ Electrical power

→ Signals.

The design objectives are:-

1) To satisfy the performance requirements (gradeability, accleration and maximum crusing speed)
2. To achieve high overall efficiency
3) To maintain the battery state of charge (SOC) at reasonable levels in the whole drive cycle without from outside the vehicle
4. To recover the brake energy

There are several possibilities for configuration in a parallel hybrid drive train, as mentioned. But the design methodology for one particular configuration may be not applicable to other configurations and the design result for a particular configuration may be applicable for only a given operation environment and mission requirement. This will focus on the design methodology of parallel drive trains with torque coupling, which operate on the electrically peaking principle: that is, the engine supplies its power to meet the base load and the electrical traction supplies the power to meet the peaking load requirement

Control Strategies of parallel Hybrid Drive train

The available operation modes in a parallel hybrid drive train. mainly include (1) engine alone traction 2) electric alone traction

3) Hybrid traction

4) Regenerative braking

5) Peaking power Source (PPS)

charging from the engine. During operation. the proper operation modes should be used so as to meet the traction torque requirements achieve high overall efficiency. maintain a reasonable level of PPS SOC. and recover braking energy as much as possible

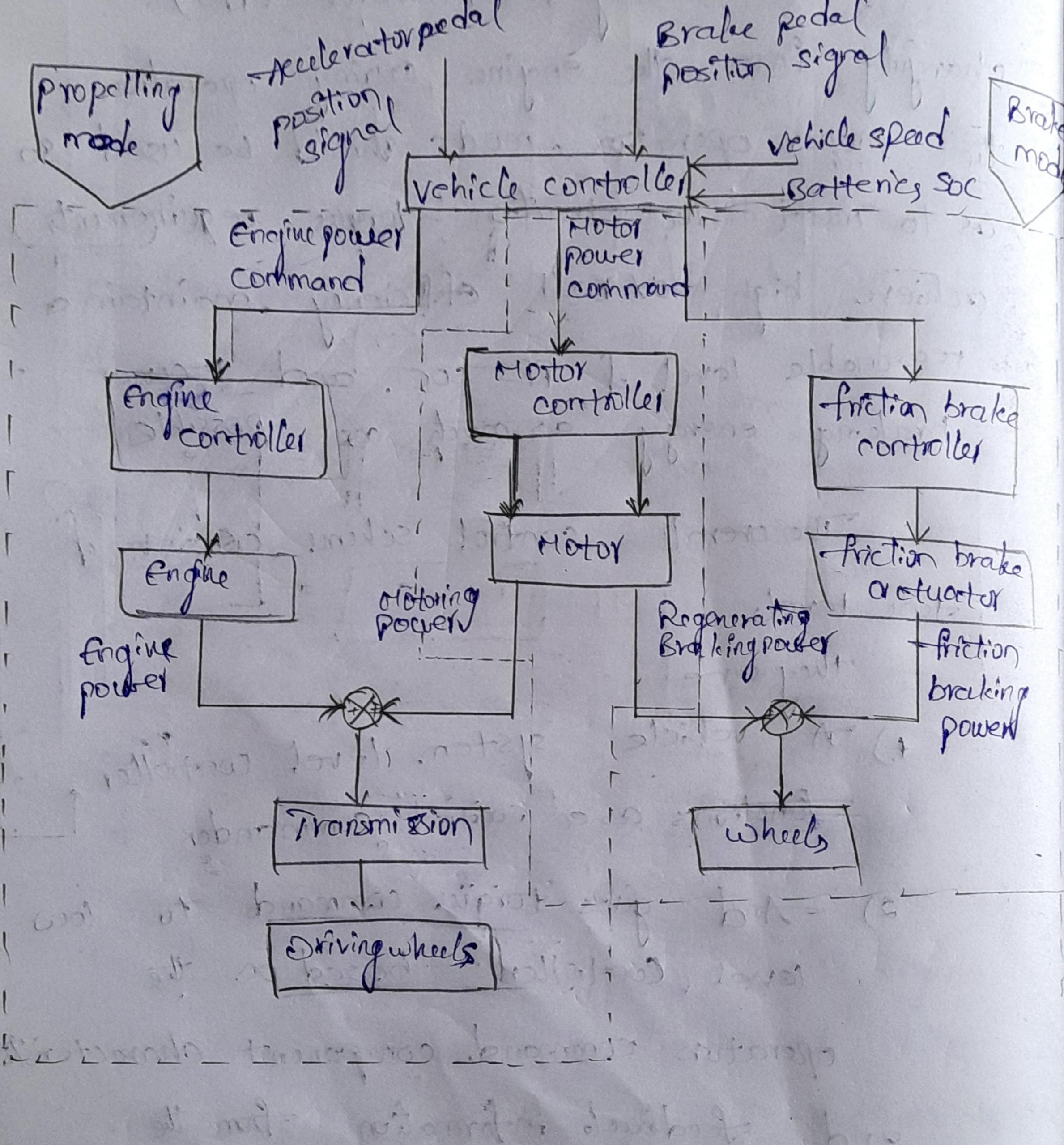
The overall control scheme consists of two levels

they are

1) A vehicle system level controller functions as a control commander

2) And gives torque commands to low level controllers based on the operators command. component characteristics and feedback information from the components

The low level controllers such as the engine controller, motor controller, and transmission controller in a multigear transmission, control the corresponding components to make them operate properly



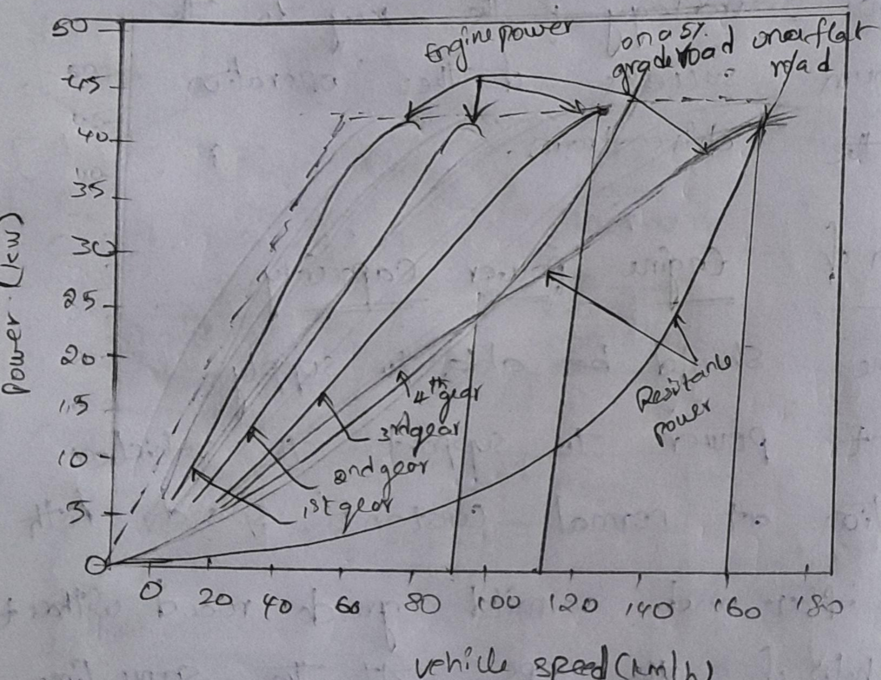
The vehicle controller plays a central role in the operation of the drive train. The vehicle controller should fulfill various operation modes according to the drive condition and the data collected from components and the driver's command, should give the correct control command to each component controller. Hence the preset control strategy is the key to the optimum success of the operation of the drive train.

Design of Engine power Capacity

The engine should be able to supply sufficient power to support the vehicle operation at normal constant speeds both on a flat and a mild grade road without the help of the PPS. At the same time the engine should be able to produce an average power that is larger than the average load power when the vehicle operates with a stop and go operating pattern

As a requirement of normal highway driving at constant speed on a flat or a mild grade road, the power needed is expressed as

$$P_e = \frac{V}{1000\eta_{t.e}}\left(M_v g f_r + \frac{1}{2}\rho_a C_D A_f V^2 + M_v g i\right)$$



Engine power required at constant speed on a flat road and a 5% grade road

The above - designed engine power should be evaluated so that it meets the average power requirements while driving on a stop and go patterns. In a drive cycle. the average load power of a vehicle can be calculated by

$$P_{ave} = \frac{1}{T}\int_0^T \left(M_v g f_r V + \frac{1}{2}\rho_a C_D A_f V^3 + \delta M_v V\frac{dV}{dt}\right) dt$$

kW)

The average power that the engine can produce with full throttle can be calculated as

$$P_{max-ave} = \frac{1}{T}\int_0^T P_e(V)\,dt$$

where T is the total time in drive cycle, and $P_e(V)$ is the engine power with full throttle. which is a function of vehicle speed when the gear ratio of the transmission

Design of electric Motor Drive power capacity.

In HEV, the major function of the electric motor is to supply peak power to the drive train. In the motor power design, acceleration performance and peak load power in typical drive cycles are the major concerns

The acceleration is directly related to the torque output of an electric motor by

$$\frac{T_m i_{tm} \eta_{tm}}{r} = \delta_m M_v \frac{dv}{dt}$$

where T_m is the motor torque and δ_m is the mass factor associated with the electric motor.

Using the output characteristics of the electric motor and a specific acceleration time t_a from zero speed to final high speed V_f

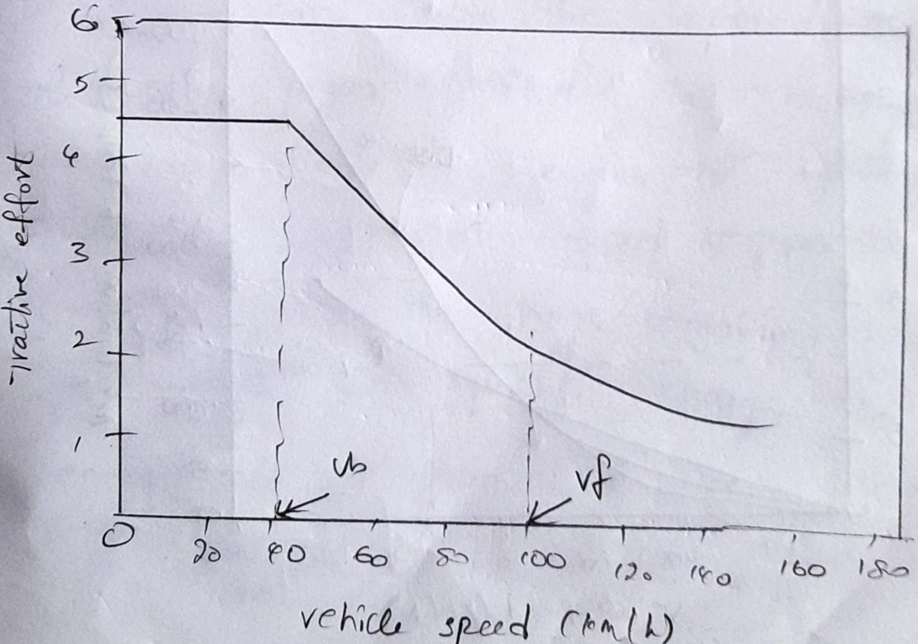
and referring the motor power rating is expressed as

$$P_m = \frac{\delta_m M_v}{2\eta_{t,m} t_a}(V_f^2 + V_b^2).$$

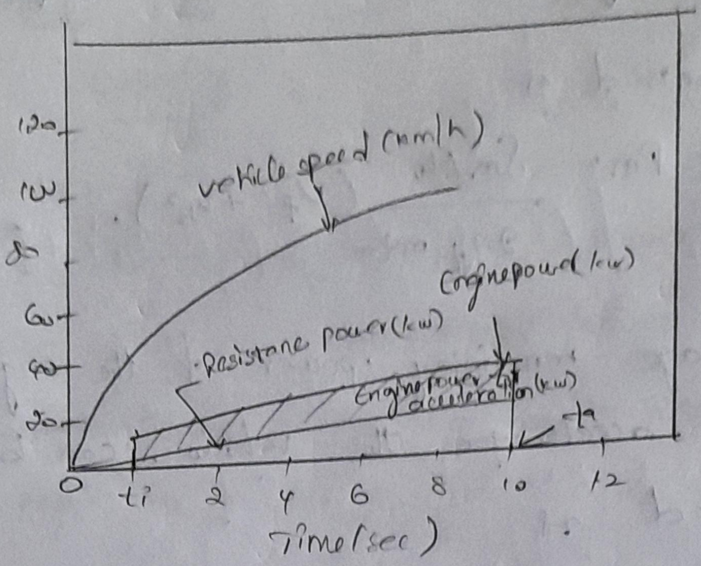
The average remaining power of the engine used to accelerate the vehicle can be expressed as

$$P_{e,a} = \frac{1}{t_a - t_i}\int_{t_i}^{t_a}(P_e - P_r)\,dt.$$

where P_e and P_r are the engine power and resistance power, respectively

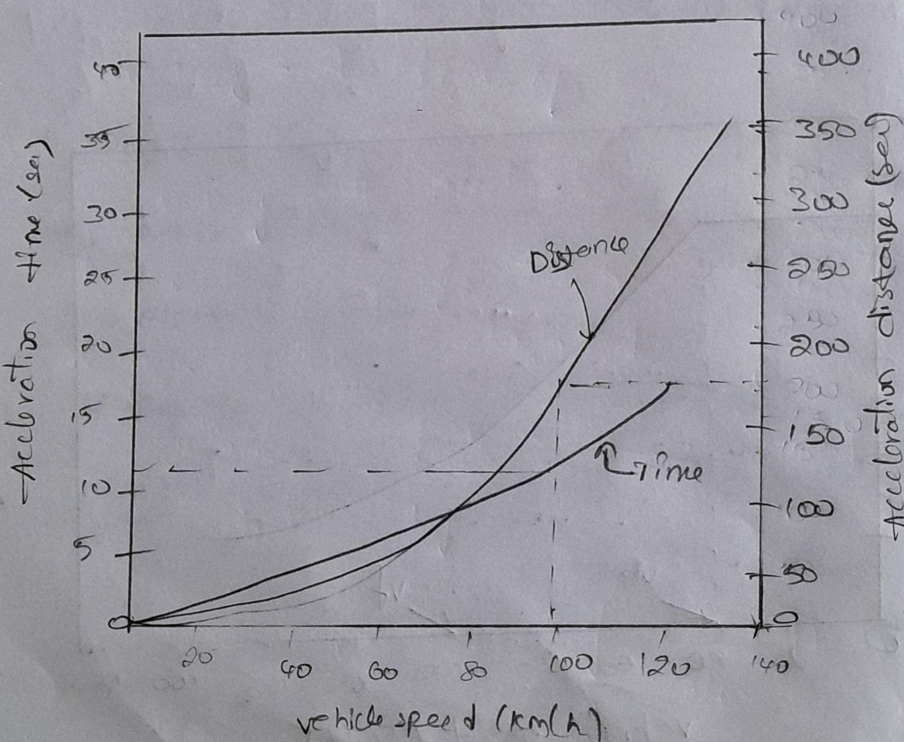


Tractive effort vs vehicle speed of an electric motor-driven vehicle



vehicle speed, engine power and resistance power vs acceleration time

Transmission Design



Acceleration time and distance vs vehicle speed

Since the electric motor supplies the peak power and has high torque at low speed single-gear transmission between the electric motor and the driven wheels can produce sufficient torque for hill climbing and acceleration

However. a multigear transmission between the engine and driven wheels can indeed enhance the vehicle performance

The use of multigear transmission can effectively increases the remaining power of the engine. consequently the vehicle performance can be improved. on the other hand, the energy storage can be charged with the large power of the engine. The vehicle fuel economy can also be improved. since the use of proper gears of the multigear transmission allow the engine to operate closer to its optimal speed region;

further more. the large remaining power of the engine can quickly charge the energy storage from the low SOC to high SOC!

Energy Storage Design

The energy storage design mainly includes the design for the power and energy capacity. The power capacity design is somewhat straight forward.

The terminal power of the energy storage must be greater than the input electric power of the electric motor

that is

$$P_s \geq \frac{P_m}{\eta_m}.$$

where P_m and η_m are the motor power rating and efficiency

During the acceleration period, the energies drawn from energy storage and the engine can be calculated along with the calculation of the acceleration time and distance by

$$~~E_s=~~ \quad E_s = \int_0^{t_a} \frac{P_m}{\eta_m} dt$$

and

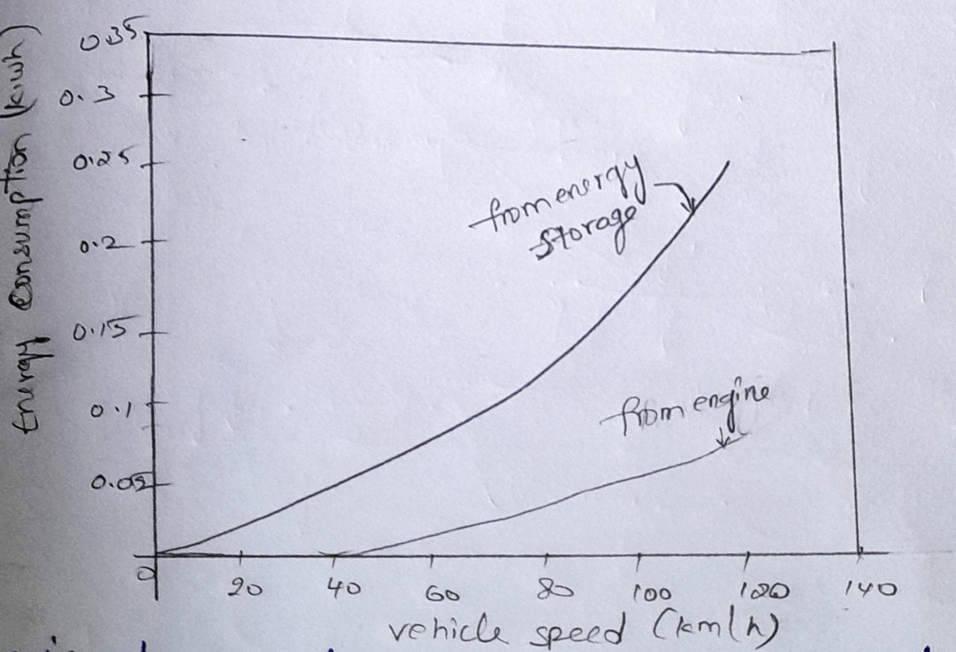
$$E_{eng} = \int_0^{t_a} P_e \, dt,$$

where E_s and E_{eng} are the energy drawn from the energy storage

The energy changes of the energy storage can be obtained by

$$E_c = \int_0^t (P_{sc} - P_{sd}) \, dt$$

where P_{sc} and P_{sd} are the charging and discharging power of the energy storage with a given control strategy. The charging and discharging power of the energy storage can be obtained by drive train simulation



Energies drawn from the energy storage and engine in the acceleration period

Unit - 5

Methods of Charging :

There are four Commonly used and popular Charging methods :

* Constant Current Charging
* Constant Voltage Charging
* Constant Current - Constant voltage Charging
* Multi-stage Constant Current charging

1) CC - Constant Current Charging :-

→ CC charging is a simple method that uses a small constant Current to charge the battery during the whole charging process.

→ CC charging stops when a predefined value is reached.

→ This methods is widely used for charging NiCd or NiMH batteries, as well as Li-ion batteries

→ A high Charging Current provides a quick charge but also significantly affects the battery aging process.

→ A low Charging Current provides a high Capacity utilization but also produces a very slow charge.

2) CV - Constant voltage Charging :-

→ It regulates a predefined Constant Voltage to charge batteries.

→ Since, the voltage is Constant, the Charging Current decreases as the battery Charges.

→ A high Current value is required to provide a Constant terminal voltage at a nearly stage of the charging process.

→ A high Charging Current from 15% to 80% SOC provides fast charging.

→ The main challenge for CV charging is selecting a proper voltage value that will balance the charging speed, electrolyte decomposition, and capacity utilization.

→ The high battery current causes the battery lattice frame to collapse & contributes to the active battery pole substance.

3) CC-CV - Constant Current & Constant Voltage.

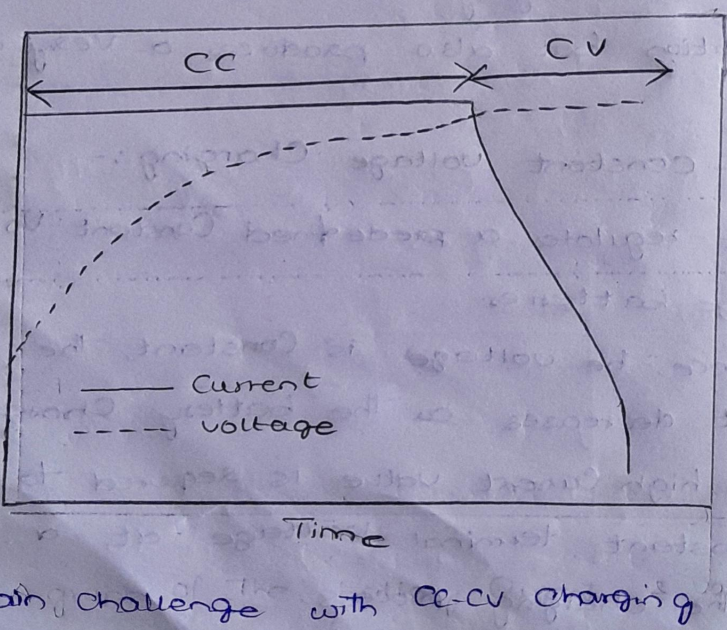
→ The CC-CV charging method is a hybrid approach the combines the two previously mentioned charging methods.

→ It uses CC charging in 1st charging stage and when the voltage reaches maximum safe threshold value.

→ It shifts to the CV charging methods

→ CC-CV charging was initially used to charge lead-acid batteries & later to charge Li-ion batteries [Li-ion requires much longer CC mode].

→ The CC-CV charging is more efficient than either CC or CV methods



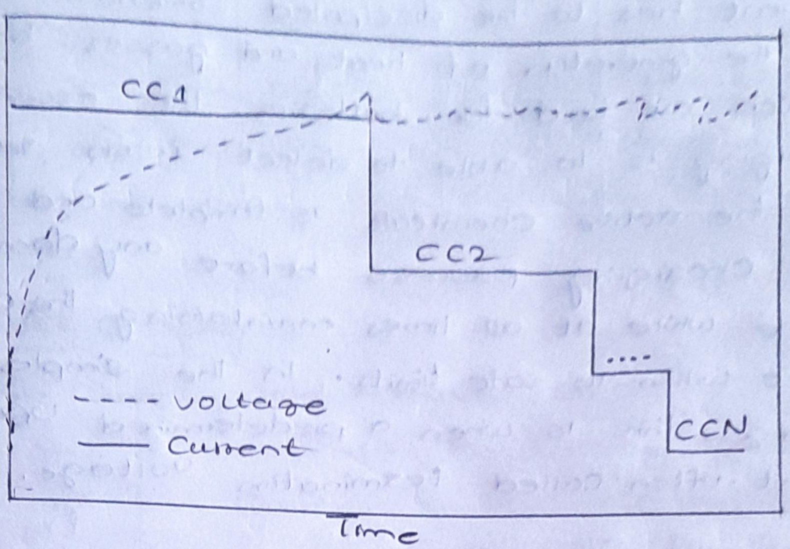
The main challenge with CC-CV charging is defining suitable constant values for each mode

→ The suitable current value will provide a balance between charging performance and battery safety.

4) MCC - multi-stage Constant Current

The MCC charging methods includes several constant current stages, where the current is gradually decreased as the terminal voltage reaches a default voltage threshold.

The charging process continues until the battery reaches the terminal conditions.



The MCC method is suitable for charging the following battery types: lead acid, Ni-MH and Li-ion batteries. with equal initial current values, the MCC charging process take a bit more time compared to CC-CV charging method.

Comparision of Traditional Charging methods.

Method	Advantages	Dis-advantages	Key parameter
Constant Current	Easy to Implement	Capacity utilization is low	charging current rate
Constant voltage	Easy to Implement	Causing the lattice Collapse of battery	Charging voltage rate
Constant Current - Constant voltage	* Capacity utilization is high * Stable terminal voltage	Challenge to balance charging speed, energy loss, temperature variation	* Charging Current rate in CC mode * Charging Voltage rate in CV mode

Multi stage Constant Current	* Easy to Implement * fast charging	Challenge to balance charging speed, capacity utilisation and battery lifetime	* The no. of CC stages. * Charging current rates for each stages

2) Charge Termination:-

Once a battery is fully charged, the charging current has to be dissipated somehow. The result is the generation of heat and gasses both of which are bad for batteries. The essence of good charging is to able to detect when reconstitution of the active chemicals is complete and to stop the charging process before any damage is done while at all times maintaining the cell temperature within its safe limits. In the simplest of chargers this is when a predetermined upper voltage limit, often called termination voltage.

Charging Rates

Batteries can be charged at different rates depending on the requirement.

1. Slow charge = Overnight or 14 - 16 hours charging at 0.1C rate

2. Quick charge = 3 to 6 Hours charging at 0.3C rate

3. fast charge = Less than 1 hour charging at 1.0C rate

Slow Charging

Slow charging can be carried out in relatively simple chargers and should not result in the battery overheating. when charging is complete batteries should be removed from the charger

* NiCads are generally the most robust type with respect to overcharging and can be left on trickle charge for very long periods since their recombination process tends to keep the voltage down to a safe level.
* Lead acid batteries are slightly less robust but can tolerate a short duration charge. flooded batteries tend to use up their water, and SLAs tend to die early from grid corrosion.
* NiMH cells on the other hand will be damaged by prolonged trickle charge.
* Lithium Ion cells however can not tolerate over charging or overvoltage and the charge should be terminated immediately when the upper voltage limit is reached.

Fast / Quick charging

As the charging rate increases, so do the dangers of overcharging or overheating the battery. preventing the battery from overheating and terminating the charge when the battery reaches full charge become much more critical. Each cell chemistry has its own characteristics charging curve and battery chargers must be designed to detect the end of charge conditions for the specific chemistry involved.

In addition, some form of temperature cut off (TCO) or Thermal fuse must be incorporated to prevent the battery from overheating during the charging process.

Fast charging & quick charging require more complex chargers. Since these chargers must be designed for specific cell chemistries, it is not normally possible to charge one cell type in a charger that was designed for another cell chemistry involved and damage likely to occur.

Universal chargers, able to charge all cell types must have sensing devices to identify the cell type and apply the appropriate charging profile.

	Charge Termination Methods			
	SLA	Nicad	NIMH	Li-ION
Slow charge	Trickle ok	Tolerate Trickle	Timer	Voltage limit
Fast Charge 1	I min	NDV	dT/dt	Imin at voltage limit
Fast Charge 2	Delta TCO	dT/dt	dV/dt = 0	
Backup Termination 1	Timer	TCO	TCO	TCO
Backup Termination 2	Delta TCO	Timer	Timer	Timer

TCO = Temperature Cut off

Delta TCO = Temperature rise above ambient

Imin = minimum Current

3) Charger Types

Charger normally incorporate some form of voltage regulation to Control the Charging voltage applied to the battery.

* Switch mode regulator
* Series Regulator
* Shunt regulator
* Buck regulator
* Pulsed Charger
* Universal Serial Bus Charger
* Inductive Charging

1. Switch Mode Regulator (Switcher):

* It uses pulse width modulation to Control the voltage.

* Low power dissipation over wide variations in i/p &

battery voltage.

* More efficient than linear regulators but more Complex.
* Needs a larger passive LC (inductor & Capacitor) o/p filter to smooth the pulsed waveform.
* Switching heavy currents give rise to EMI and electrical noise.

2. Series Regulator (Linear) -

* Less Complex but more lossy - requiring a heat sink to dissipate the heat in the series, voltage dropping transistor which takes up the difference between the supply and the o/p voltage.
* All the load current passes through the regulating transistor which consquently must be a high power device
* This makes it suitable for low noise wireless & radio applications.

3. Shunt Regulator:-

* Shunt regulators are Common in photovoltaic (PV) systems since they are relatively cheap to build & simple to design.
* The charging current is controlled by a switch or transistor connected in parallel with the photovoltaic panel and storage battery.
* Overcharging of the battery is prevented by shorting (shunting) the PV output through transistor when the voltage reaches a predetermined limit
* If the battery voltage exceeds the PV supply voltage the shunt will also protect the PV panel from damage due to reverse voltage by discharging the battery through the shunt
* Series regulators usually have better control and charge characteristics

4) Buck Regulator:

* A switching regulator which incorporate a step down DC-DC converter.
* They have high efficiency and low heat losses.
* They can handle high output currents and generates less of interference than a conventional switch mode regulator.
* A simple transformerless design with low switch stress & a o/p filter.

5) pulsed Charger -

* It uses a series transister which can also be switched.
* It have low battery voltages the transistor remains on and conduct the source current directly to the battery.
* pulsing allows the battery time to stabilise with low increments of charge at progressively high charge levels during charging.
* During rest periods the polarisation of the cell is lowered.
* pulse chargers usually need current limiting on the input source for safety reseons, adding to the cost.

6) Universal Serial Bus Charger:

* The USB specification was developed by a group of computer and peripheral device manufactures to replace a plethora of proprietary mechanical and electrical interconnection standards for transferring data b/w computers and external devices.
* It included a two wire data connection, a ground (earth) line and a 5 volt power line provided by the host

device which was available to power the external devices.

* The original USB standard specification specified a data rate of 1.5 mbits/sec and a maximum charging current of 500mA

* In this case the peripheral device itself must incorporate the necessary charge control circuitry to protect the battery.

7) Inductive Charging:-

* Inductive charging does not refer to the charging process of the battery itself. It refers to the design of the charger

* Essentially the i/p side of charger. The part connected to the AC mains power, is constructed from a transformer which is split into two parts.

* The primary winding of the transformer is housed in a unit connected to the AC mains supply.

* while, the secondary winding of the transmer is housed in the same sealed unit when contains the battery. along with the rest of the conventional charger electronics.

* This allows the battery to be charged without a physical connection to the mains and without exposing any contacts which could cause & electric shock to the user

* The technique is also used to charge medical battery implants

battery charger Application:

* output voltage purity
* Efficiency
* Inrush Current
* power factor