22/2/23

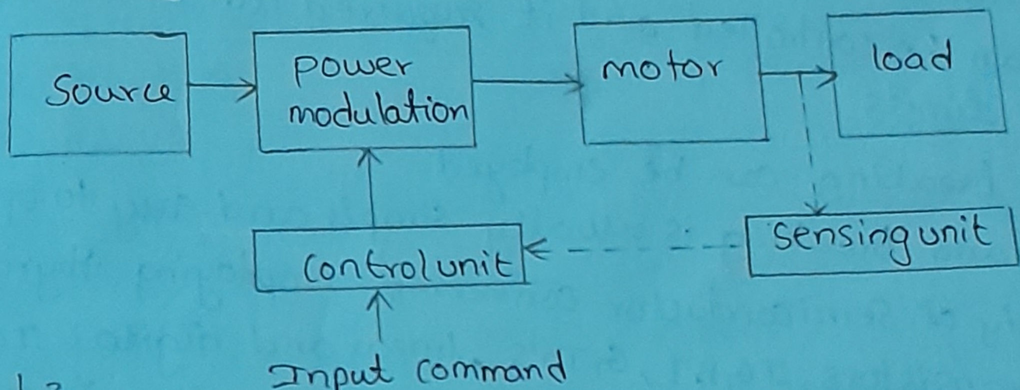
UNIT-1

Introduction to electrical drives

Motion control is required in large nod industrial and domestic applications like transpotation system, rolling milles, paper machine, textile milles, machine tools, fan, pumps, robots, washing machine etc.,

* Systems employed per motion control are called drives and may employed any of the prime movers such as diesel or petrol engines, gas or stream turbines, stream engines, hydralic motors and electric motors.
* Drives employing electric motors are known as electrical drives.

Block Diagram of an electrical drive



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→ Block diagram of an electric drive which as shown in fig.

→ Block diagram of an electric drive which as shown in fig. Block diagram load is usually a machinary design to accomplish a given task.

EX :- Fans, pumps, robots, washing machine, machine tools, trains and drills

→ load requirements can be specified in terms of speed & torque demands.

→ A motor having speed and torque characteristics and capabilities compartable to the load requirements is choosen.

Functions of power modulator :-

Modulator flow of power from the source to the motor, In such a manner, the motor is imported speed torque characteristics required by the load.

→ During transient operations, such as starting, breaking and speed reversal, It restricts source and motor currents with in the premmisable values
(sudden change in voltage (or) current)

→ converts electrical energy of the source in the form suitable to the motor.

→ selects the mode of operation of the motor i.e. motoring (or) breaking.

Advantages of electrical drives :-

* The study state and dynamic characteristics of electrical drives can be shaped to to satisfy the load requirements. Speed can be controlled and it required can be controlled in wide limits.
* electric breaking can be employed
* starting and breaking is usually simple and easy to operate
* Availability of semiconductor converters employing thyristor, power transistors, IGBT, GTO's, linear and digital IC's and micro computers have make the control characteristics more flexible
* This drives can be provided with automatic fault detection systems.
* They are available in wide range of torque, speed and power
* Electric motors have high efficiency, low no load losses and considerable short time over load capacity.
* electrical drives have longer life, lower noise, lower maintanance requirements and cleaner in operation.
* Don't pollute the environment

* They are adoptable to almost any operating conditions Such as explosive and radio active environment. Submerged in liquids, vertical mountains etc.,
* Can operate in all four quadrants
* There is no need to refuel (or) warm up the motor
* They can Started instantly and can immediately be fully loaded
* They are powered by electrical energy which has more no. of advantages over other forms of energy.

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Choice of electrical Drives :- G.K. Dubey

→ Some important factors that effects the choice of an electrical drive are

1) Study state operation requirements
   i) Nature of speed-torque characteristics
   ii) speed regulation
   iii) Speed Range
   iv) efficiency
   v) Duty cycle
   vi) quadrants of operation
   vii) Ratings
2) Trangient operation requirements
   i) values of acceleration and ~~dece~~ deceleration
   ii) Starting, breaking and reversing performance
3) Source related requirements
   i) Types of Source and it's capacity
   ii) Magnitude of voltage, voltage fluxuation
   iii) power factor
   iv) hormonics and their effects
   v) Ability to accept re-generated power

4) Capital and running cost, maintenance cost needs, life

5) Space and wait restriction if any

6) Environment and location

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Dynamics of electrical drives:-

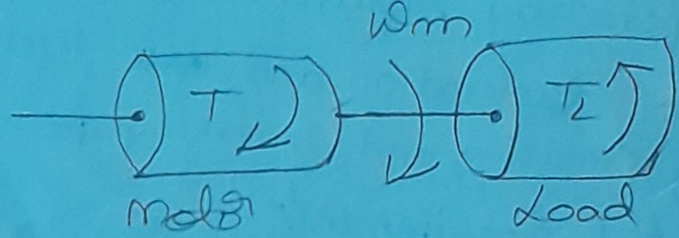
Finalizing, dynamic relation that are applicable to all types of electrical drives.

Fundamental torque equations:-

Generally a motor driving a load through some transmission system. The motor always tense to rotate but the load may rotate or may undergo a transulational motion.

If the load has many parts, there speeds may be different and while some may rotate, other may flow through a tranlulational motion.

It is however, convient to represent the motor load system by an equivalent rotational system as shown in fig.



→ Various notations used are J → polar movement of inertia of motor-load system refered to the motor shaft ($kg-m^2$)

→ ω_m - instantaneous angular velocity of motor shaft (rad/sec)

→ T - instantaneous value of developed motor torque [N-m]

→ T_L - instantaneous value of load torque refered to motor shaft [N-m]

→ Load torque includes friction and windage torque of motor.

The fundamental torque equation of the above shown motor-load system is given by

$$T - T_L = \frac{d}{dt}(J\omega_m)$$

$$= J \cdot \frac{d\omega_m}{dt} + \omega_m \frac{dJ}{dt} \quad \text{—— ①}$$

Eq-① is suitable for variable inertia drives such as mine winders, reel drives, industrial robots etc.

→ For drives with constant inertia, $\left(\frac{dJ}{dt}\right) = 0$

$$\therefore \quad T = T_L + J\frac{d\omega_m}{dt} \quad \text{—— ②}$$

Eq-② shows that torque developed by motor is counter balanced by the load torque (T_L) and dynamic torque $\left(\frac{J d\omega_m}{dt}\right)$

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→ The torque component $J \cdot \frac{d\omega_m}{dt}$ is called a dynamic torque because it present only during the transient operations

→ Drive accelerates and decelerates depending on whether 'T' is greater are lesser than 'T_L'

→ During the acceleration, motor should supply not only the load torque but an additional torque component $J\left(\frac{d\omega_m}{dt}\right)$ in order to overcome the drive inertia.

→ energy associated with dynamic torque $\frac{J d\omega_m}{dt}$ is stored in the form of kinetic energy given by $\left(J \cdot \frac{\omega_m^2}{2}\right)$

→ During deceleration, dynamic torque $J \cdot \left(\frac{d\omega_m}{dt}\right)$ has -ve sign, ∴ It assiset the motor torque T and maintains drive motion by extracting energy from the stored kinetic energy.

Speed Torque conventions and multiquadrant operation

Motor speed is consider positive when rotating the forward directions, in loads involving up and down motions, the speed of motor which causes upword motion is consider forward motion.

→ For reversable drives, Forward speed is choosen arbitraly when the rotation in opposite direction gives reverse speed which is alligned the -ve sign.

→ positive motor torque is defined as the torque which produces acceleration or the positive rate of change of speed in forward direction.

Motor torque is consider -ve, if it produces deaceleration

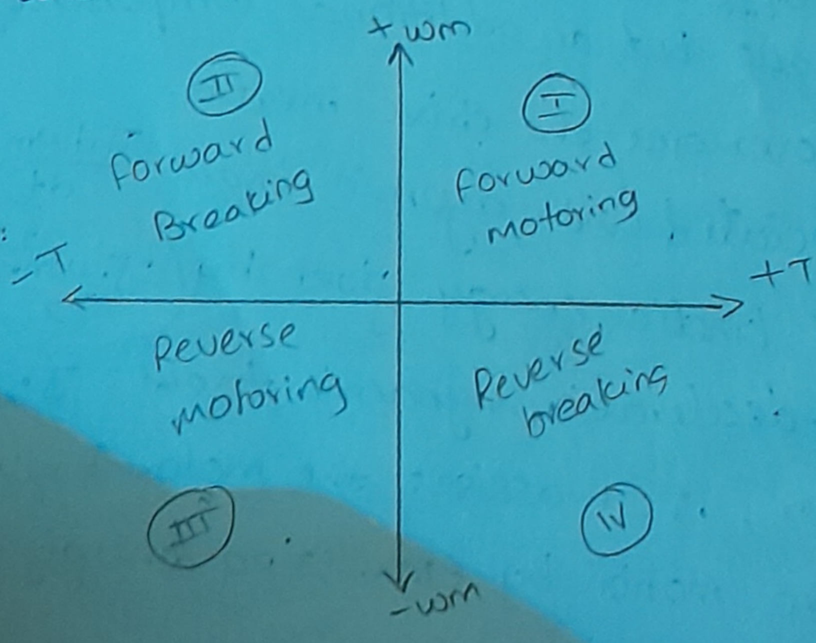
a motor operates in two modes

1. Motoring
2. Breaking

In motoring, it converts electrical energy to mechanical energy which supports its motion.

In Breaking, it works as generator converting mechanical to electrical energy and thus opposes the motion

→ Motor can provide motoring & breaking operations for both forward and reverse directions.



→ power developed by a motor is given by the product of Speed and torque

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→ In quadrant ① developed power is positive. Hence the machine works as a motor supplying mechanical energy

∴ This operation is called forward motoring

→ In quadrant II power is Negative. Hence the machine works under breaking opposses the motion.

∴ This operation is known as forward breaking.

→ In quadrant III power is Positive. Hence the motoring operation.

∴ This operation is called reverse motoring.

→ In quadrant IV power is Negative.

∴ this operation is called reverse breaking.

Typical load - Torque characteristics:-

Load - torque (T_L) can be divided as

1) friction Torque (T_F) :-

friction will present at motor shaft and also in various parts of the load.

2) Windage Torque (T_W):-

when a motor runs, wind generates a torque which opposses the motion. This is known as windage torque.

3) Torque required to do the useful machanical work is know load torque (T_L)

Nature of this torque depends on particular application

→ Nature of this torque depends on particular application

→ A low speed hoist is an example of a load where the torque is constant and independent of the Scheme

At low speed windage torque is negligable
∴ Net torque is only due to the gravity which is constant and independent of speed.

→ fans, compressors, Aeroplane's, centrifugal pumps, ship properlers, coilers, high speed hoists, traction etc... Cranes Railyway

→ Are the examples of the ~~wind cage~~ case where load torque is function of speed.

→ In fans ~~and~~, compressors and Aeroplane's, the windage dominates consequently load torque is proportional to the speed square which is shown in fig ⓐ. windage is the opposition offered by air to the motion.

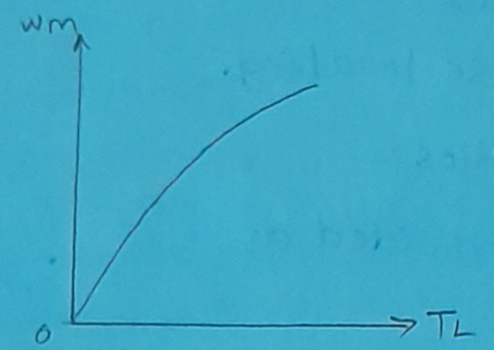
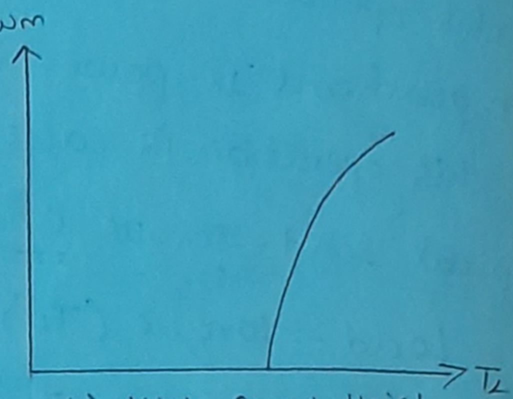


Fig ⓐ $T_L \propto \omega_m^2$



b) High Speed Hoist

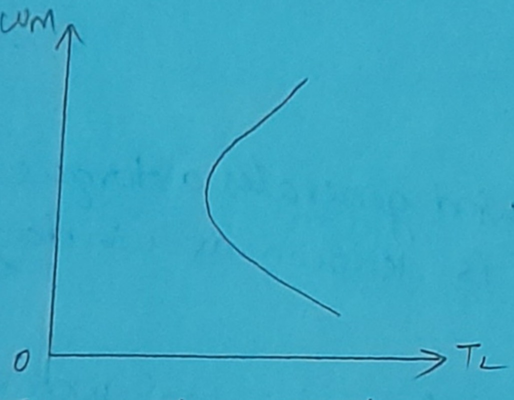
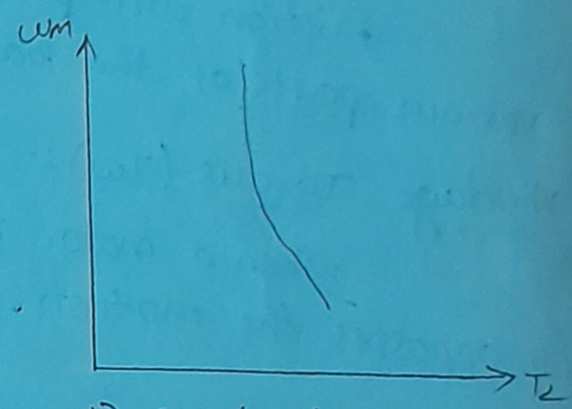


Fig ⓒ Traction load



d) constant power loads

4/3/23 In high speed hoist, viscous friction and windage also have appreciable magnitude in addition to gravity, thus give in the load torque characteristics of fig ⓑ

→ In nature of load and torque characteristics of a traction load when moving on a level ground is as shown in fig (c). Because of it's heavy mass, ~~st~~ stiction is large. At '0' speed, net torque is mainly due to stiction.

-> The stiction disappears at a finite speed and then windage and viscous friction dominate.

-> Because of large stiction and need for accelarating a heavy mass, the torque required for starting a train is much larger than what is required to run it at full speed.

* Torque in a coilar drive is also a function of speed it is approximately hyperbolic in nature as shown in fig (d).

The developed power is nearly constant at all speeds.

Study state ~~stabi~~ stability :-

Equilibrium speed of a motor load system is obtained, when motor torque equals to the load torque. Drive will operate in study state at ~~disk~~ this speed, provided it is the speed of stable equilibrium.

-> concept of study state stability has been developed to readily evaluate the stability of an equilibrium point from the study state speed-torque curves of the motor and load

-> During tragient operation, motor can be assumed to be in electrical equilibrium. Implying that study state speed-torque curves are also applicable to the tragient operation.

As an example let us examing the study state stability of equilibrium point 'A' in fig (a).

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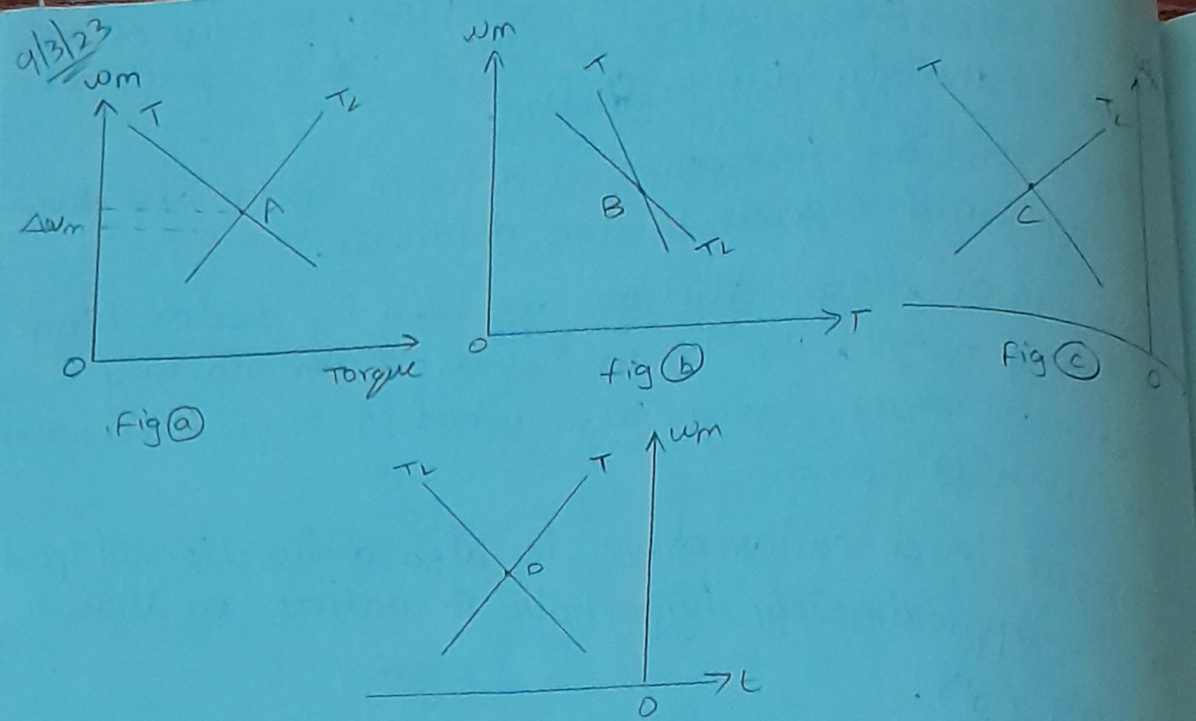

Fig (a) fig (b) Fig (c) Fig (d)

A

The equilibrium point will be turned as Stable when the operation will be restored to it after a small departure from it due to disturbance in the motor or load.

→ let the disturbance causes a reduction of $\Delta \omega_m$ in speed at new speed motor torque is greather than the load torque, then sequently motor will accelerate and operation will be restored to 'A' simillarly when a disturbance caused by increase of $\Delta \omega_m$ in speed the motor torque will make load torque greather than the restoration of resulting into deacceleration and operation to point (A).

→ Hence, the drive is study state stable at point A.

→ ~~equilibrium~~ point

→ let us now examine equilibrium point B as shown in fig (b) which is obtain when the same motor use another load a decreases in speed is causes the load torque become greather than the motor torque, drive deaccelerates and operating point moves away from B. Simillarly at B an increase in speed will may motor torque greater than the load torque, which will move the operating point away from B. thus B is an unstable point of equilibrium.

→ Above discussion suggets that a equilibrium point will be stable when an increase in speed causes load-torque to exceed the motor torque
i.e. At equilibrium point the following condition is satisfied.

$$\frac{dT_L}{d\omega_m} > \frac{dT}{d\omega_m} \quad — ①$$

In equality in eq ① can be derived by an alternating apporoach.
let a small change in speed ($\Delta\omega_m$) results in (ΔT) and (ΔT_L) changes in T and T_L respectively.

$$T = T_L + J\frac{d\omega_m}{dt} \quad — ②$$

$$(T+\Delta T) = (T_L + \Delta T_L) + J\frac{d(\omega_m+\Delta\omega_m)}{dt}$$

$$T+\Delta T = T_L + \Delta T_L + J\frac{d\omega_m}{dt} + J\frac{d\Delta\omega_m}{dt} \quad — ③$$

sub eq ② from eq ③ and rearranging we get

$$\therefore J\frac{d\omega_m}{dt} = \Delta T - \Delta T_L \quad — ④$$

For a small changes, the speed-torque curves of motor and load can be assumed to be straight lines
thus

$$\Delta T = \left(\frac{dT}{d\omega_m}\right)\Delta\omega_m \quad — ⑤$$

$$\Delta T_L = \left(\frac{dT_L}{d\omega_m}\right)\Delta\omega_m \quad — ⑥$$

11/3/23 where $\frac{dT}{d\omega_m}$ and $\frac{dT_L}{d\omega_m}$ are respectively the slopes of the study state speed torque curves of the motor and load at operating point under consideration

→ Substitute in eq ⑤ & ⑥ in eq ④ and rearranging the terms we get

$$J\frac{d\Delta\omega_m}{dt} + \left(\frac{dT_L}{d\omega_m} - \frac{dT}{d\omega_m}\right)\Delta\omega_m = 0 \quad \text{—— ⑦}$$

This is a first order linear differential equations

→ If intial deviathion speed at (t=0) be $(\Delta\omega_m)_0$, then the solution of eq ⑦ will be

$$\Delta\omega_m = (\Delta\omega_m)_0 \exp\left\{-\frac{1}{J}\left(\frac{dT_L}{d\omega_m} - \frac{dT}{d\omega_m}\right)t\right\} \quad \text{—— ⑧}$$

An operating point will be stable when $\Delta\omega_m$ approaches zero as T-approaches infinity. for this to happen the exponent in eq ⑧ must be negative.

→ This yealds the inequality of eq ①

Selection of motor :-

The power rating of a motor for a specific application must be carefully choosen to achieve Economic with reliability.

→ using of motor having insufficient rating, either fails to drive the load or lowers the productivity and reliability

→ Under the operating condition of the motor, heat is produced due to the losses (copper, iron & frictional loss)

→ As the temperature increases ~~the~~ beyond the ambint value, the heat produced may flows out to the surrounding medium.

AS the motor temperature rises, the heat outflow increases and sets in the equilibrium (heat generator = heat dissipated) into the surrounding medium called study state temperature, which is directly proportional to the power loss.

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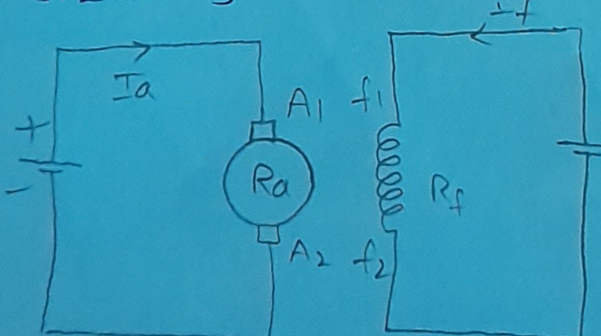
Dynamic Breaking :—

In dynamic breaking motor armature is disconnected from the source and connected across a resistance R_B.

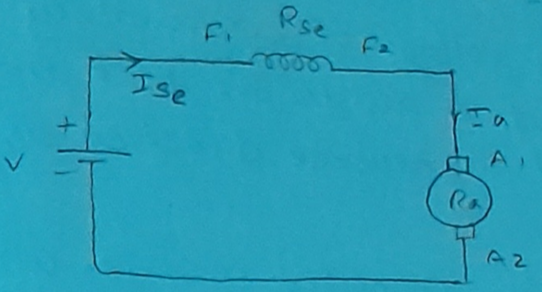
→ The generator energy is discipated in R_B & R_a

→ For motoring connections are shown in fig a & b, the breaking connections are shown in fig c & d



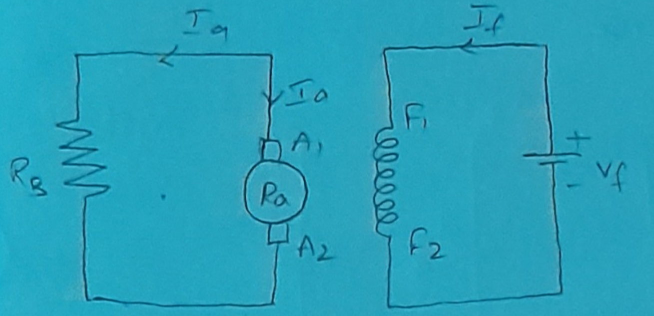
(a)

→ Separately excited DC motor – fig (a)

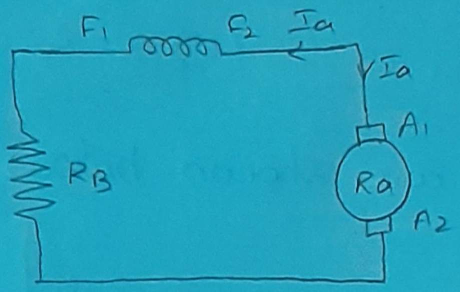


{they both are motoring operations}

(b) DC series motor

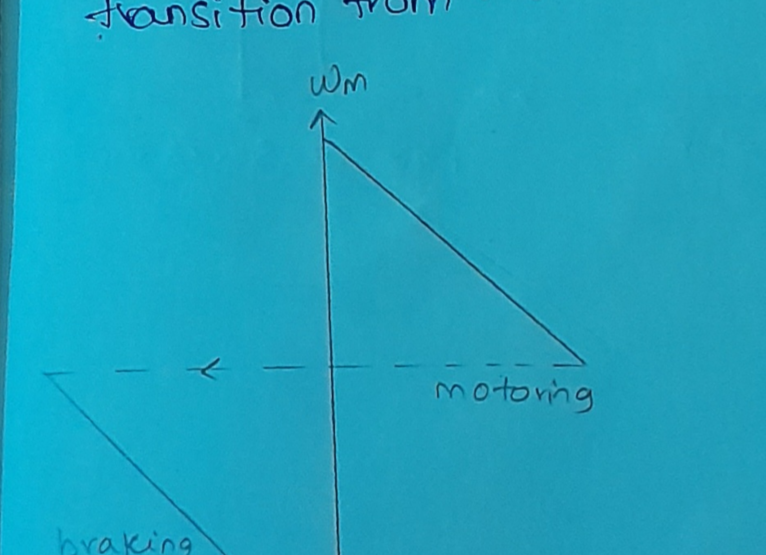


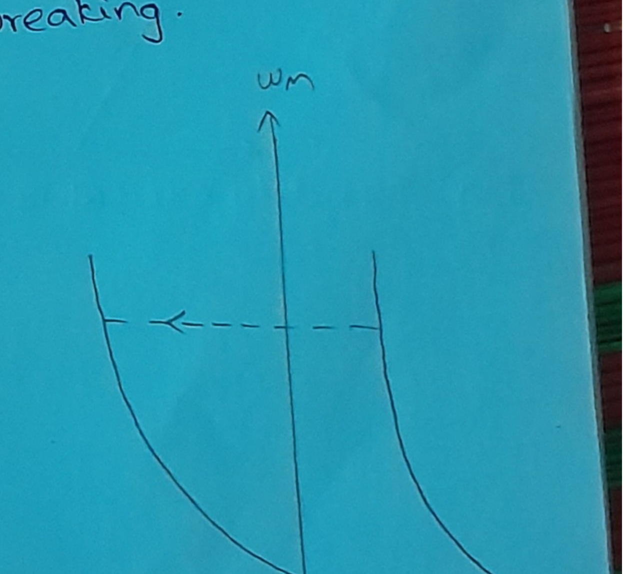
(c) Breaking diagram separately excited DC motor



(d) DC series motor

→ Fig E & F shows the speed torque curves and transition from motor into breaking.



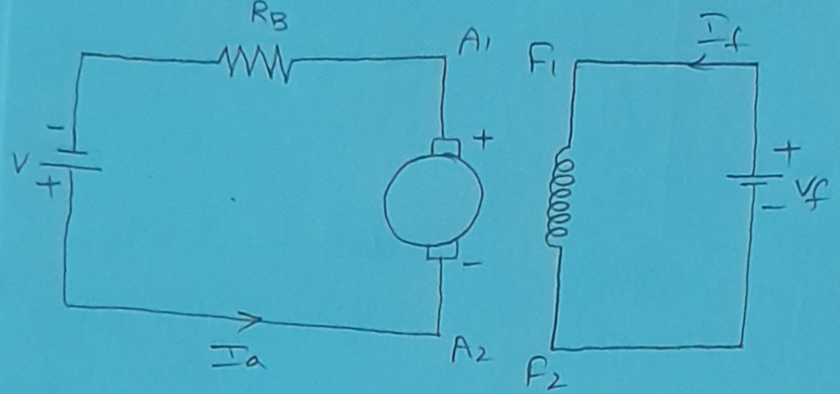


(e) Separately excited DC motor (f) DC series motor

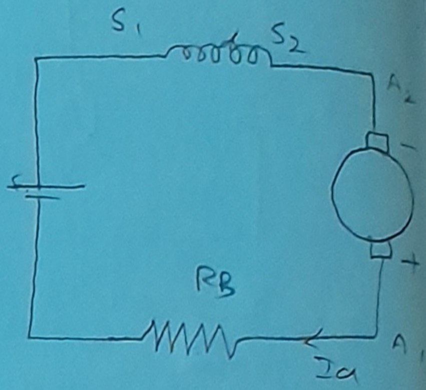
20/3/23 plugging :—

plugging, the supply voltage of a separately excited motor is reverse so that it assists the back emf in forceing armature current in reverse direction as shown in the fig.

→ A resistance R_B is also connected in series with armature to ~~limiting~~ limit the current. For plugging of series motor armature alone is reverse



Fig(a)- Separately excited DC motor



(b) DC Series motor

→ The Speed-torque curves are shown below

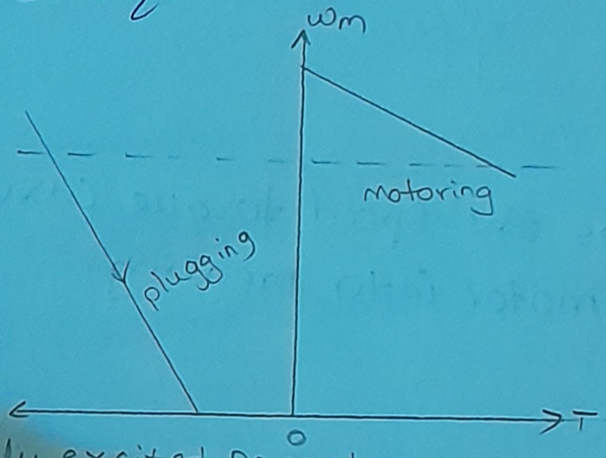


Fig:- separately excited DC motor

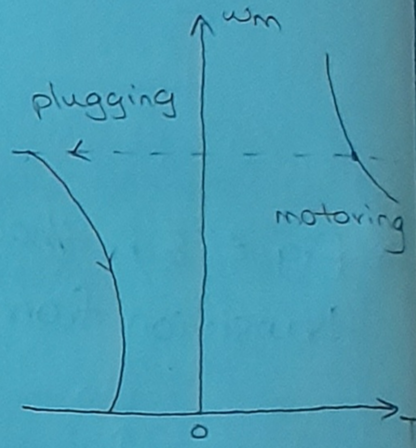


Fig:- DC Series motor

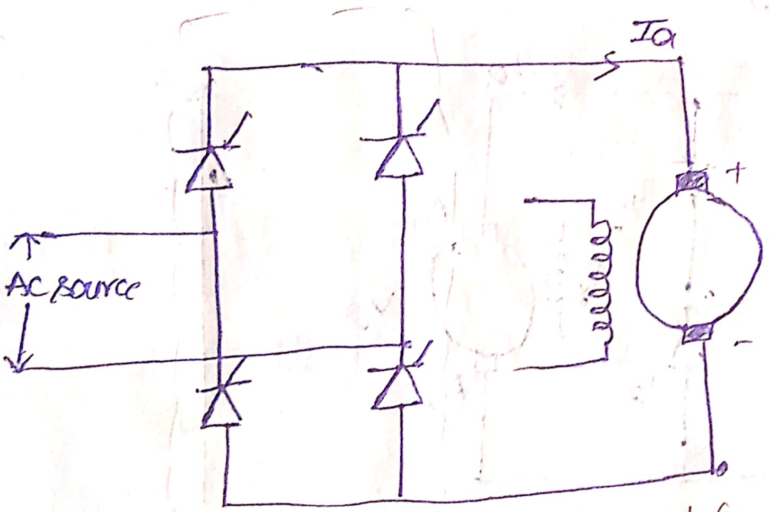
Unit - 2

Rectifier
converter/ chopper fed DC motors Drives.

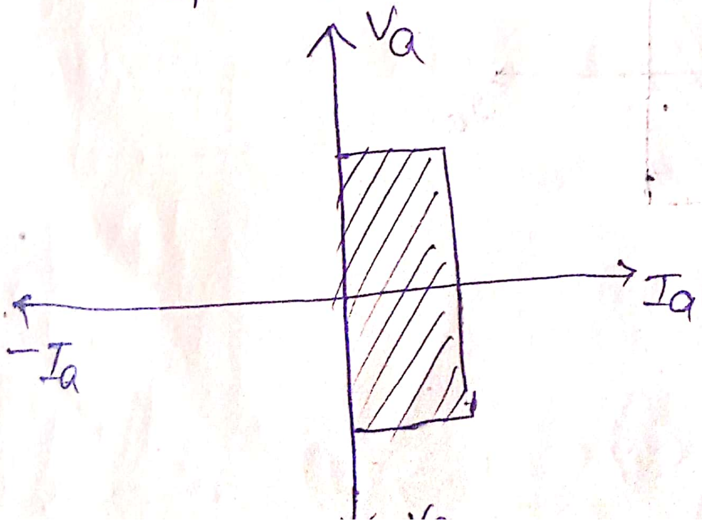
Introduction :-

Diode
controlled Rectifiers (Converter) or used to get variable DC voltage from AC source of fixed voltage.

The figures below shows commonly used controlled rectifier circuit quadrants within which they can operate on $V_o - I_a$ plane
anode voltage, anode current



single full controlled Rectifier.
fig :- single phase fully controlled Rectifier fed seperatly excited DC motor.



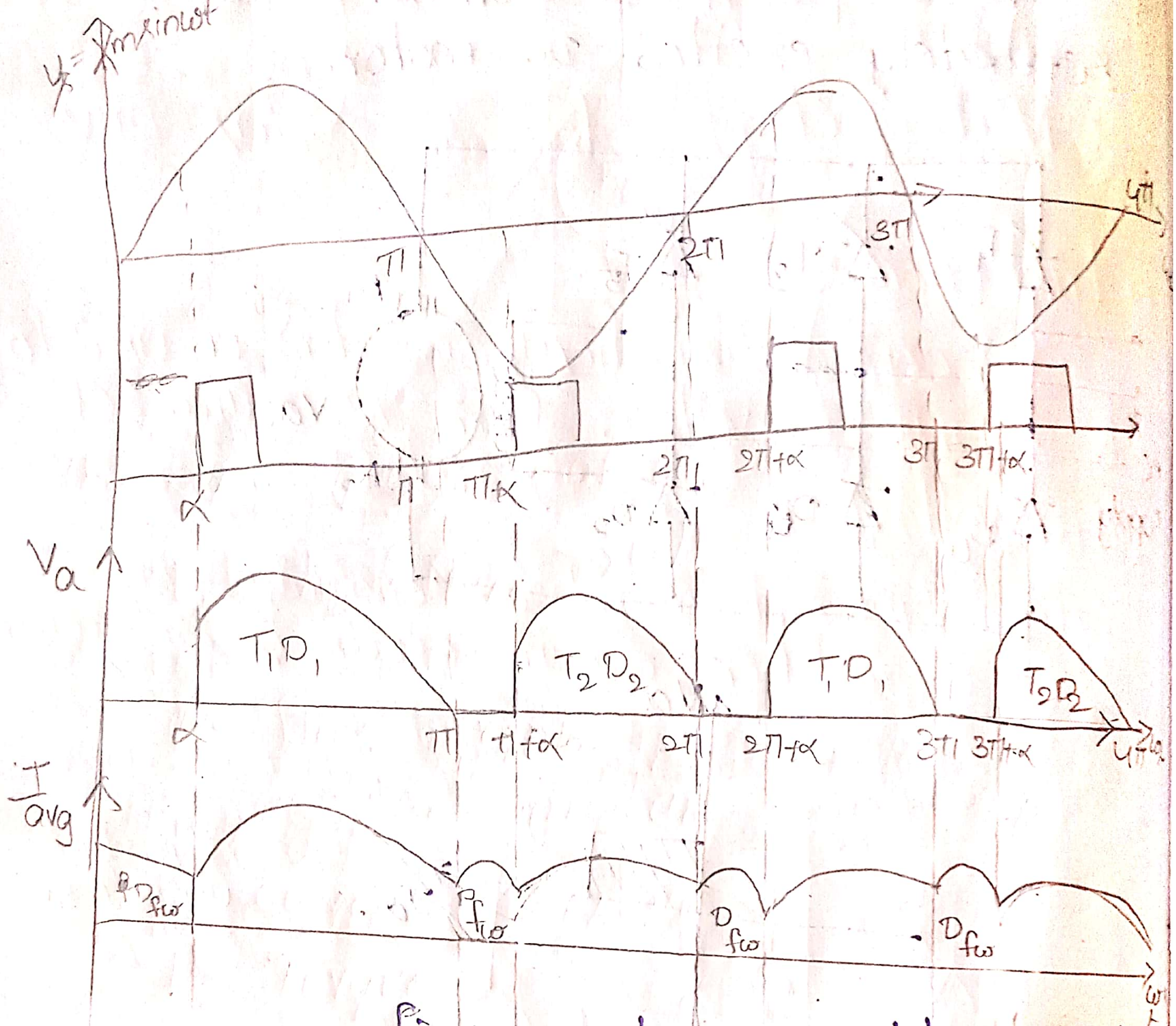


fig b:- continous condition mode waveforms.

$$V_s = \frac{1}{\pi}\int_{\alpha}^{\pi} V_m \sin\omega t$$

from figure b the average DC output voltage across the motor terminal.

$$V_a = \frac{1}{\pi}\int_{\alpha}^{\pi} V_m \sin\omega t \, d(\omega t)$$

$$V_a = \frac{V_m}{\pi}\left[-\cos\omega t\right]_{\alpha}^{\pi}$$

$$\boxed{V_a = \frac{V_m}{\pi}\left[1+\cos\alpha\right]} \rightarrow (1)$$

Scanned with OKEN Scanner

During the period, $\alpha < \omega t < \pi$, the armature loop equation is

→ when the motor is connected to the source

$V_a = V_s$

$$V_a = R_a I_a + L_a \frac{di_a}{dt} + \underbrace{E_b}_{\text{Back Emf}} \rightarrow (2)$$

~~we~~ are discussing

During period, $\pi < \omega t < \pi + \alpha$, the armature loop equation is

$$0 = R_a i_a + L_a \frac{di_a}{dt} + E_b \rightarrow (3)$$

The steady state speed equation com.

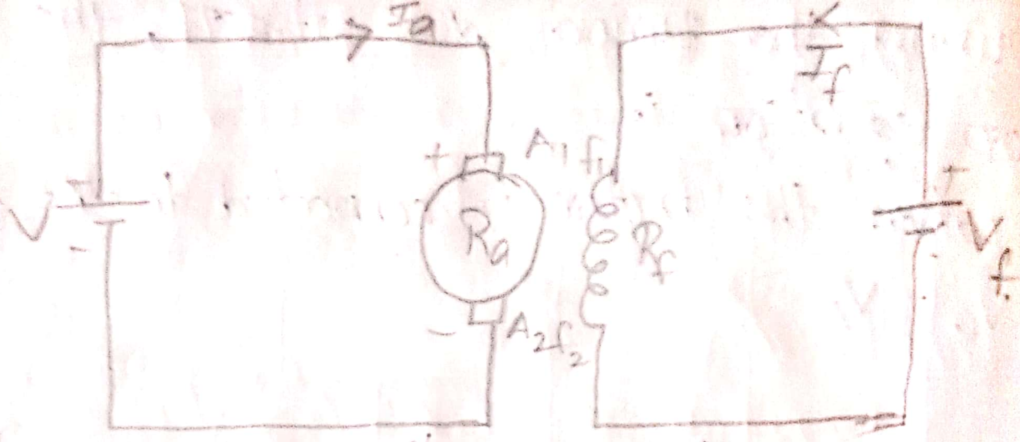
$$\omega_m = \frac{V}{K} - \frac{R}{K^2} T.$$

$$\boxed{\omega_m = \frac{V_m(1+\cos\alpha)}{\pi K} - \frac{R_a}{K^2} T.} \rightarrow (4)$$

In the above equation the term represents the theoritically no load speed and 2 second term represents by speed drop produced by armature current I_a and hence Torque T.

Performance of DC motor:-

separately excited DC motor:-



The basic equation of all DC motors

$$E_b = K_e \phi \omega_m \rightarrow ①$$

where

ϕ - flux per pole.

ω_m - angular armature speed rad/sec

K - ~~e~~ motor constant.

T - Torque.

$$V = E_b + I_a R_a \rightarrow ②$$

$$T = K_e \phi I_a \longrightarrow ③$$

from equation (1) & (3)

$\omega_m =$

from ① $\Rightarrow$ $\omega_m = \dfrac{E_b}{K_e \phi} \rightarrow$

from ② $\Rightarrow$ $\omega_m = \dfrac{V - I_a R_a}{K_e \phi} \rightarrow ④$

$$\omega_m = \frac{V}{K_e \phi} - \frac{I_a R_a}{K_e \phi}$$

substitude from ③

$$I_a = \frac{T}{K_e \phi} \rightarrow$$

$$\omega_m = \frac{V}{Ke\phi} - \frac{Ra\,T}{Ke\phi \times Ke\phi}$$

$$\boxed{\omega_m = \frac{V}{Ke\phi} - \frac{Ra\,T}{(Ke\phi)^2}} \rightarrow (5)$$

In case of shunt and seperately excitated motor with a constant field current, flux can be assumed to the constant.

Let $K_e\phi = K(\text{constant}) \rightarrow (6)$

from equation 1, 3, 4, 5, 6.

$E_b = K\omega_m \rightarrow (7)$

$T = K\,I_a \rightarrow (8)$

$\omega_m = \frac{V}{K} - \frac{I_a R_a}{K} \rightarrow (9)$

$$\boxed{\omega_m = \frac{V}{K} - \frac{R_a}{K^2}T} \rightarrow 10.$$

$T \propto \phi I_a$

$\phi \propto I_f$

$\phi = K_1 I_f$

$\boxed{T = K_t I_f I_a}$

$E_b = K_d I_f \omega_m$

$I_f = \frac{V_f}{R_f}$

A single phase 230V, 50Hz supply feeds single phase semi converter to a seperately excited DC motor through one for end one single phase semi converter. for amarature firing angle semi converter field is zero the field Resistance 200 Ω and armature Resistance 0.3 Ω the load Torque is 50 N/m at 900 rpm, the Voltage constant is 0.8 V/A - rad/sec. and the Torque constant is 0.8 ~~N/m~~ N-m/A² resume that armaratature and field currents are continous and constant and neglected the losses.

Find the following

1) field current

2) firing angle of the converter in the armature circuit.

Given data

$R_f = 200\,\Omega$

$R_a = 0.3\,\Omega$

$T_L = 50$ N-m

$N = 900$ rpm

Since the firing angle of the converter in field circuit is zero. $\alpha_f = 0$

field current $I_f = \dfrac{V_f}{R_f}$

$$V_f = \frac{V_m}{\pi}(1+\cos\alpha)$$

$$\Rightarrow \frac{V_m}{\pi}(1+\cos 0)$$

$$V_f = \frac{2V_m}{\pi}$$

$$\Rightarrow \frac{2\times\sqrt{2}\times 230}{\pi}$$

I_f $\Rightarrow 207.04\,V$

$V_{Rms} = 230$

$V_{rms} = \dfrac{V_m}{\sqrt{2}}$

$V_m = \sqrt{2}\times V_{rms}$

$V_m = \sqrt{2}\times 230.$

$$I_f = \frac{V_f}{R_f}$$

$$I_f = \frac{207.04}{200} \Rightarrow I_f = 1.035A$$

2A

ii) $V_0 = \frac{V_m}{\pi}(1+\cos\alpha_a)$

Average output voltage at armature

$V_a = \frac{V_m}{\pi}(1+\cos\alpha_a)$

$V_a = E_b + I_a R_a$

$=$

$E_b = K_t I_f \omega$

$\omega \Rightarrow \frac{2\pi N}{60}$

$\Rightarrow \frac{2\pi \times 900}{60}$

$I_a = \frac{T}{K_t I_f} = \frac{50}{0.8 \times 1.035}$

$\omega = 94.24$

$\Rightarrow 60.38A$

$E_b = 0.8 \times 1.0352 \times 94.248$

$V_a = 78.05 + 60.38(0.3)$

$E_b = 78.05V$

$V_a = 96.162V$

I

$V_a = \frac{V_m}{\pi}(1+\cos\alpha_a)$

$96.162 = \frac{V_m}{\pi}(1+\cos\alpha_a)$

$(1+\cos\alpha_a) = \frac{96.162 \times \pi}{\sqrt{2} \times 230}$

$1+\cos\alpha_a = \frac{302.101}{} \Rightarrow 0.9287$

$\cos\alpha_a = 0.9287 - 1$

$\cos\alpha_a = -0.0713$

$\alpha_a = \cos^{-1}(-0.0713)$

$\boxed{\alpha_a = 94.084^\circ}$

2) single phase half controller fed from a 120V, 60 Hz supply and provides a variable DC voltage but the terminal of DC motor the thyristor trigged continously by a DC single the Resistance of the armature circuit 10Ω and because of fixed motor excitation and high inseria the motor speed consider as constant so that the back Emf 60V. find the average value of the armature current negalating armature Inductance.

I_{avg}

$$V_a = E_b + I_a R_a$$

$$I_a = \frac{V_a - E_b}{R_a}$$

$$V_a = \frac{V_m}{\pi}(1 + \cos\alpha)$$

$$V_a \Rightarrow 108.03V$$

$E_b = 60V$

$R_a = 10\Omega$

$\alpha = 0^\circ$

$V_{Rms} \Rightarrow 120$

$V_m = \sqrt{2} \times V_{Rms}$

$V_m = \sqrt{2} \times 120$

$$I_a = \frac{108.03 - 60}{10}$$

$$I_a \Rightarrow 4.803A$$