B) Power modifier :-

- Power modulator is used to modify the flow of power from the source to the motor. In this manner, motor parameters like speed, torque, load characteristics, can be controlled.

- During the transient operation, the modulator restrict the source and motor current upto a safety limits in case of overload.

- The mode of operⁿ (whether its starting or ~~braking~~ causing period), the power modulator can adjust accordingly.

- It consists of various power electronic devices and circuits such as cyclo-converter, buck-boost converter, MOSFET based chopper etc.

C) Control unit :-

- The control ckt sends various commands to power modulator and regulates the output in terms of voltage, current and Power.

- The sensing unit acts as the feedback path for the control unit.

D) Sensing unit :-

- Sensing unit consists of a transducer or measuring instruments to generate a feedback signal in terms of motor/load Parameters.

- The current and voltage output of sensing unit is used for protection circuit as well as control unit.

Various types of motor used as drives -

A) DC shunt motor.
B) DC series motor.
C) DC compound ~~wo~~ motor
D) 1ϕ and 3ϕ Induction motor.
E) Syn. motor.

Advantages :-

- Drives provides us wide range of voltage, current, RPM, Power, torque.

- Efficency of the system increases because of drives.

- It doesn't Pollute environment.

- They have flexible control characteristics.

- It requires less space because of its compac nature.

- The speed control is easy and smooth.

Disadvantages :-

- The inherent disadvantages of electrical drives are -

- It comes to stop as soon as there is a failure of power supply.

- It can't be used at far-off places. These proble can be overcome by using temporary sources like ~~DC~~ diesel driven DC generator and turbine driven 3ϕ ~~motor~~ alternator.

factors :-

Following are important factors of selection of Electrical drives -

I A) Steady-state oper^n requirement :-

- The nature of speed-torque characteristics should be satisfied as per the requirement of the process.

(B) Speed range and regulation :-

(C) Efficiency :-

The efficiency of the electrical drive should be optimum.

(D) Duty cycle :-

The duty cycle of the process should be as per our requirement.

(E) Quadrants of operants selected suitablly :-

(F) Speed flactuation tolerance

(II) Transient oper^n requirement :-

- Values of acceleration and ~~decell~~ deceleration should be considered. Starting, braking and reversing performance should be considered.

(III) Power requirement :-

- The type of source and its capacity should match the requirement of our process. The magnitude of voltage, voltage fluctuation, power factor, harmonics and their effect on load.

• The ability of the source to acess regenerati power

(IV) Capital & running cost, maintainance frequency, and life-cycle of Product :-

(V) Reliability :-

(VI) Enviromental factors & location :-

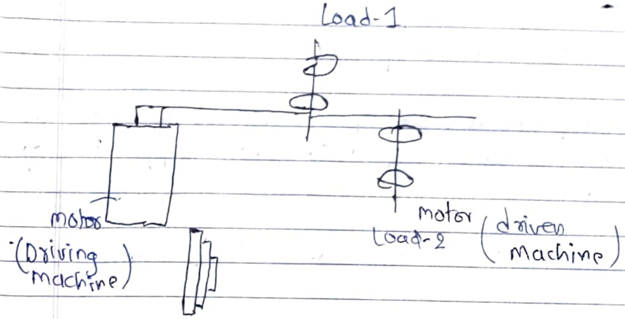
(VII) Space & weight requirement :-

Classification :-

Electrical drives can be divided into three groups.

A) Grouped drive :-

• A drive in which a single electric motor drive a line-shaft. by means of which an entire group of working machines may be operated is called as grouped drives. Sometimes it is also called as line-shaft drives, fitted with multi-steped pulleys and belts. that connects these pulleys and the shaft of the driven machines



Advantages :-

• It helps in saving intial costs (150KW motor is less costier than 15KW-10 motors) required to drive 10 seperate machines.

• The efficency and P.f of large grouped drive motor will be higher, Provided that it should operate near its rated load.

• If the machines are subjected to short but sharp overload, the group drive can handle efficently.

• Grouped drives can be used in those industrial Process where, there is a sequence of continuity in operati

Disadvantages:-

- It is less safe to operate.
- In group drive, the speed control of individu machine is very difficult using stepped pulley and belts.
- Noise level at working side is very high.

ii) Individual drives:-

- In ~~invid~~ individual drives, each machine is driven by its own seperate motor with the help of gears, pulleys etc.
- For example, Single-spindle drilling machine, types of metal working machines,

Advantages:-

- Flexiblity in installement of motor.
- Each operator has full control of machines which can be quickly stopped in case of accident.
- In case of motor fault, only its connected machine, will stop whereas other will continue working.
- The maintainance and repair of line shaft, pulle belts etc, is elliminated.

Disadvantages:-

- ~~Invid~~ Individual have high intial cost.

Applications:-

- For driving heavy machines such as lifts, cranes, lathe machine, etc. where constant speed and flexibl of speed is required.

iii) Multi-motor drives:-

- In multi-motor drives, separate motors are providesd for actuating different parts of driven mechanism
- Example of multi-motor drives, in travelling Cranes, three motors are used one for hoisting, another for long travel motion and third motor for cross-travel motion.
- Such a drive is required in complicated metal cutting machine, Paper making machine, rolling mills, etc.

Selection of motor in Electric drives

Following are the factors affecting ~~the selection of motor~~ in the selection of driving motor for a suitable applications depends upon condition under which the motor has to operate while selecting the motor.

i) Cost :-

- The cost of the motor as well as its accessories should come under the budget for deciding the initial cost of our electric drive.
- The running cost of the motor should lie between 20-30% of initial cost.

ii) Electrical Characteristics :-

a) Starting characteristics :-

- Such a curve tells us about the starting speed current and torque relationship. It is known as starting characteristics.

b) Running characteristics :-

This characteristics indicates about variation in torque (T), armature current (Ia), as soon as the load changes under running conditions.

c) Speed-control characteristics :-

- In case of dc motor, by controlling armature current we can control the speed. But, In case of induction motor (SRIM), we can insert external resistance to control the armature current which in turn control the speed of motor.
- Therefore, the graph between speed and torque (or current Ia) gives the information about speed-control characteristics

d) Braking characteristics :-

iii) Mechanical characteristics:-

- Vibration of motor
- Bearing assembly
- Casing Enclosure
- Class of temperature.

Motor characteristics:

For selection of motor following are characteristics –

A) DC motor characteristics:-

In dc motor, following are the characteristics –

i) Shunt and seperately excited motor:-

Consider the equivalent circuit of dc machine, If the field winding and armature connected to a common source.

- In seperately excited ~~moat~~ motor, the field and armature can be controlled independent of each other.

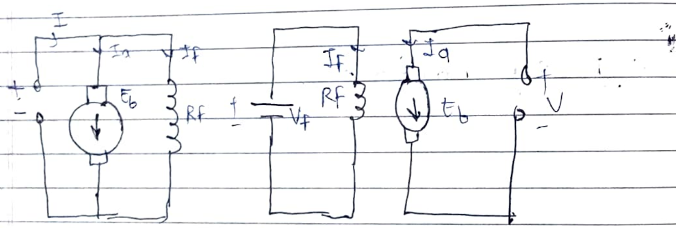


fig:- Eq. circuit of Shunt & ~~st~~ seperately excited motor

- The basic eqⁿ applicable to dc machine ~~of~~ are –

⇒ Back emf, $E_b = \frac{P\phi Z\omega}{60A} = K_e\phi\omega_m$ eqⁿ (i)

⇒ And, terminal voltage, $V = E_b + I_aR_a$

⇒ Torque developed motor –, $T = \frac{P\phi Z I_a}{2\pi A} = K_e\phi I_a$ ... eqⁿ (ii)

Where, ω_m = Armature speed in rad/sec.
K_e = motor constant
ϕ = flux/pole in weber

Putting value of ~~ba~~ eqⁿ (i) in eqⁿ (ii),

$\Rightarrow V = \frac{P\phi\omega_m Z}{60A} + I_aR_a + K_e\phi\omega_m$

$\Rightarrow \omega_m = \frac{V - I_aR_a}{K_e\phi}$

$\Rightarrow \omega_m = \frac{V}{K_e\phi} - \frac{I_aR_a}{K_e\phi}$ .... eqⁿ (iv)

from eqⁿ (iii), Putting value of I_a, we get –

$\Rightarrow \omega_m = \frac{V}{K_e\phi} - \frac{T R_a}{(K_e\phi)^2}$ .... eqⁿ (v)

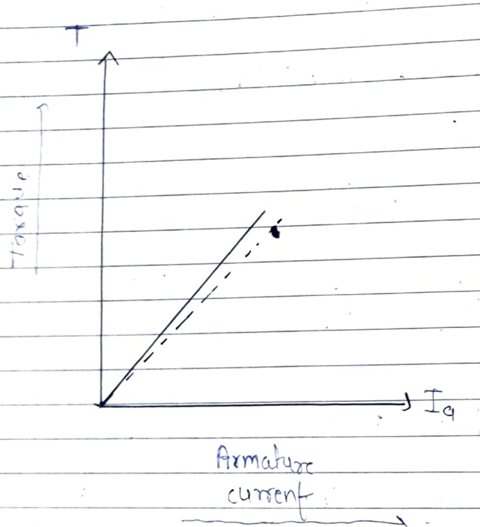
{∵ from eqⁿ (iii), $I_a = \frac{T}{K\phi}$ }

In shunt dc motor, with a constant field current the flux (ϕ) can be assumed to be constant.
Therefore, $K_e\phi = K$
And, Eq^n (iv) & (v) becomes-

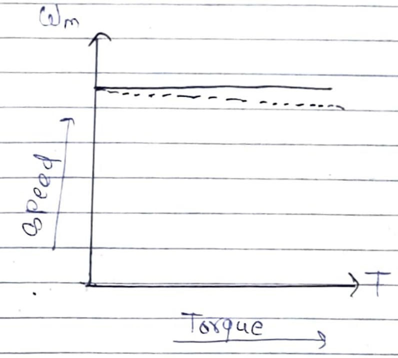
$$\Rightarrow \omega_m = \frac{V}{K} - \frac{I_a R_a}{K} \quad \text{--- eq}^n \text{ (vi)}$$

$$\Rightarrow \text{And, } \omega_m = \frac{V}{K} - \frac{T}{K^2} \quad \text{--- eq}^n \text{ (vii)}$$

The ~~Sp~~ current-torque characteristics is given below-



The Speed-torque characteristics is given below-



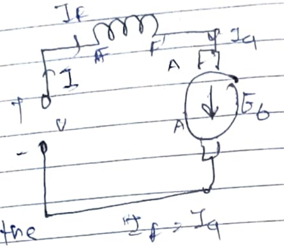
- The Speed-torque characteristics is a straight line with the no-load Speed is determined by the value of armature voltage and field excitation.
- The Speed (ω_m) ~~increases~~ decreases as the torque increases and Speed-regulation depends on armature circuit resistance. This type of characteristics are used in the applications requiring good speed regulation.

ii) D.C series motor :-

In dc series motor, the field winding is connected in series with the armature

Here,

⇒ $E_b = K_e \phi \omega$



⇒ $V = E_b + I_a R_a$

⇒ $T = K_e \phi I_a$

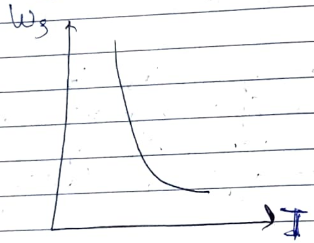
- Since in series motor, the same amount of current flows through the armature as well as field winding. Therefore, main field flux is proportional to armature current. When, load on motor shaft is increased, the armature current also increases.

Torque and armature current characteristics is based on the eqn ~~be~~ given below —

⇒ $T = K_e I_a \phi$

⇒ $T \propto \phi I_a$

⇒ $T = K_e I_a^2$



- The torque - current characteristic is a parbolic curve upto ~~to~~ magnetic saturation point (OA). From the graph, it is clear that, the starting torque of dc series motor is very high. ($T \propto I_a^2$)

⇒ We know, $E_b = K_e \phi W_m$

⇒ $W_m = \frac{E_b}{K_e \phi}$

⇒ $W_m \propto \frac{E_b}{\phi}$ . . . eqn (i)

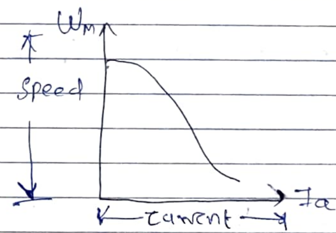
But, for dc series motor —

⇒ $E_b = V - I_a R_a$

⇒ Then, $W_m \propto \frac{V}{\phi} - \frac{I_a R_a}{\phi}$ . . . eqn (ii)

- With increase in armature current, the back emf is decreased due to ohmic drop in the armature and series field resistance. Whereas the flux is increased.

- Under normal operating condition, the graph ~~graph~~ below show speed - armature current characteristics



⇒ $W_m \propto \frac{V}{\phi}$ {∵ I_a and ϕ is same & R_a is negligible}

⇒ Or, $W_m \propto \frac{1}{I_a}$ . . . eqn (iii) {∵ V = constant & $\phi = I_a$}

- From the graph, it is clear that the series motor has high torque at low speed. But, under no-load condition the armature current is very small and consequently the flux is very small. Hence, the speed increases to a dangerous high value. Therefore, the series motor should never be started under no-load condition.

Slip in induction motor

Slip is the relative speed between the rotating magnetic flux of the stator and rotor expressed in terms of P.U synchronous speed given by—

$$S = \frac{N_s - N_s}{N_s}$$

For induction motor the value of slip lies between 0 and 1.

Case-I Slip, $S = 0$ —

- Zero slip means that the rotor speed is equal to synchronously rotating magnetic flux. Under this condition there won't be any relative motion b/w rotor and rotating magnetic flux (RMF). This means that no Em. Torque will be produced.

Case-II Slip, $S = 1$ —

- Under this condition, rotor speed (N_r) is zero. The induction motor is said to be standstill.

$$S = \frac{N_s - 0}{N_s} = \frac{N_s}{N_s} = 1$$

Case-III Slip is negetive—

- Negetive value of slip in an induction motor can be achieved when the rotor speed is more than the ~~Ns~~ synchronously rotating magnetic flux. The rotor is now ~~rotor~~ rotated in direction of RMF. The machine will now operates as induction generator.

Case-IV Slip greater than one—

- For an induction motor when slip is more than one it implies that the rotor is rotating in a direction opposite to the direction of rotation of magnetic flux.

- The relative speed b/w them is given by, $N_s + N_r$. In braking or plugging of induction motor, slip greater than 1 is achieved to quickly ~~brake~~ bring the rotor to a rest.

Torque-slip characteristics of Ind^n motor

- It is a graphical relation between torque and slip of an induction motor. For a 3ϕ induction motor, the electro-magnetic torque developed by a stator is related to the slip according to the eq^n given below –

$$T = \frac{KSE_2R_r}{R_r^2+SX_r^2} \quad \cdots \; eq^n \; (i)$$

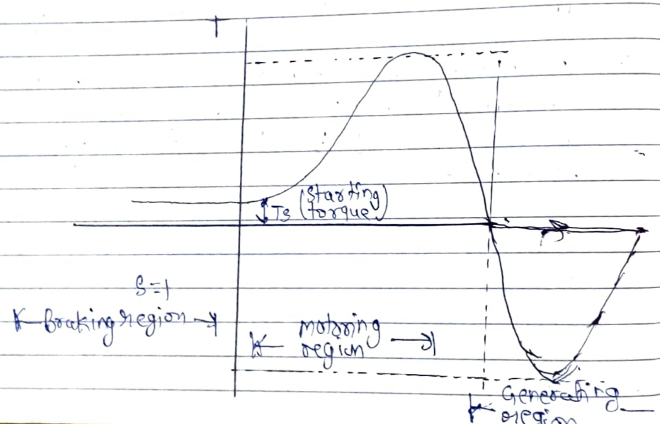
Where, K = motor constant

R_r = rotor resistance / phase.

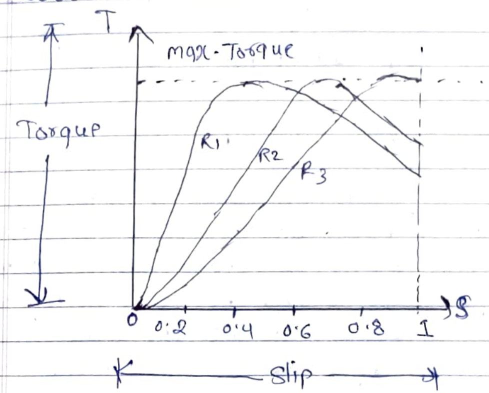
X_r = rotor reactance / phase

S = slip.

The torque-slip characteristics for a different value of slip.



Now consider a SR induction motor in which rotor resistance can be varied. as given by the graph below –



Case-I $S=0$:–

Putting value in eq^n (i), we get torque is zero. Therefore, the T-S curve starts from origin.

Case-II At normal speed of motor :–

- At normal ~~slip~~ operating of motor the slip is small and SX_r is also small or practically negligible as compared to rotor resistance R_r.

$\Rightarrow$ Then, $T = \frac{KSR_r}{R_r^2} = \frac{KS}{R_r}$

$\Rightarrow$ or, $T \propto \frac{S}{R_r}$ {for Slip-ring Induction motor}

⇒ $T \propto S$ {∵ Squirrel-cage motor}

- Therefore, the torque is directly proportional to slip and T-S curve is a straight line from $S=0$, to slip corresponding to full load.

Case-II If S = exceed full-load slip:-

In this, the torque increases and become maximum, when $R_r = SX_r$. This maximum torque in 3φ induction motor is known as breakdown torque, or pull-out torque. The value of breakdown torque is atleast double the value of full-load torque when the induction motor is operated at rated frequency and voltage.

Case-III When S become greater than slip corresponding to max. torque:-

In this, $R_r < SX_r$ and R_r^2 can be neglected as compared to $(SX_r)^2$. Therefore, torque is proportional to $S : SX_2^2$. Hence torque inverse proportional to slip. Thus, T-S curve is rectangular hyperbola.

⇒ $T \propto \frac{S}{S^2 X_r^2}$

⇒ $T \propto \frac{1}{SX_r^2}$

Torque-Speed characteristics of 3φ motor

- For a 3φ induction motor, the torque depends upon speed but we can't express it with mathematical expression. We can plot the Torque-Speed characteristics to show the relationship two quantities as given below-

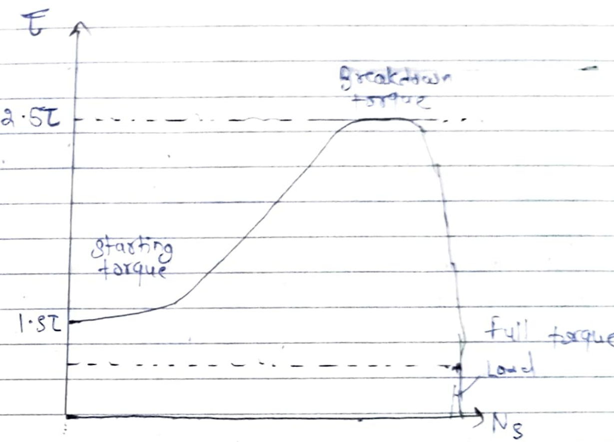


fig:- Torque-speed Characteristics

- If the full-load (T), then starting torque $T_{st} = 1.5T$ and the max. torque and breakdown torque is 2.5 times of full-load torque.

- At full-load, if the speed of rotor is N_r and if the mechanical load on the shaft increases, the value of N_r will drop until the motor torque is equal to load torque. Once, the two torques are equal the motor will run at constant speed.

- For a 3φ induction motor, the torque-speed curve is essentially a straight line b/w the point of no-load and full-load. The slope of curve line depends upon resistance of rotor circuit. Greater resistance will show sharper slope.

Heating and Cooling curve of motor

- In an electrical machine various energy losses occurs are finally converted into heat. This results in increase in temperature which depends upon
a) Heat absorbing capacity of various Parts of machi
b) The facility with which heat is conducted away or radiated or dessipated from surface of machine.

- In the beginning the temperature rise will be linear but after sometime, steady condn leads to saturation. At that time, there would be no further increase the in temperature because the rate of heat Production would become equal to the rate of heat dessipation. The relationship showing heating curve of the machine as variation of rise in temperature w.r.t time, is given below :-

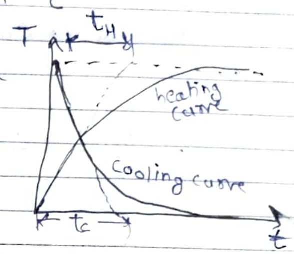
$$~~\theta = \theta_f~~ \quad Q = Q(m)\left(\cancel{1} - e^{-t/T_h}\right)$$

The heat curve is exponential

Where, Q_m = ~~Rise in tem~~ final steady temperature rise while heating.
T_H = heating time constant in sec.
Q = Rise in temp. in °C

Putting the value of $T = T_h$

$$Q = Q_M\left(1 - e^{-T_h/T_h}\right)$$
$$= ~~0.326~~\ 0.632 Q_m$$



The heating time constant (T_h) is the time taken by the machine to attain 0.632 of its final steady temperature rise. The heating time constant of conventional electrical machine is usually within the range of $\frac{1}{2}$ – 3-4 hrs.

- If the machine is shut-down, no-heat is produce and its final steady temperature rise when cooling is zero. Under this condn the relationship b/w cooling temperature and time is given by –

$$Q = Q_i\, e^{-t/T_c}$$

Where, Q_i = intial temp. rise over ambient medium
By, $t = T_c$ –

$$\Rightarrow Q = Q_i\, e^{-T_c/T_c}$$
$$= 0.368 Q_i$$

The cooling time constant (T_2) is the time taken by the machine for its temperature to fall ~~0.632~~ 0.368 of its initial value. It is usually larger due to poor ventilation. The graph showing heating curve is given —

Insulation materials in motor

- The temperature rise in any electric motor safe withstand without any fault can be determined by the insulating material used in them.
- With the use of materials of higher thermal stability, motor of the physical size may be rated for large power output.

Classes	Insulating material Included	Limiting insulating temperature.
Class-Y	cotton, silk, Paper, cellulose, wood, etc. Impregnated nor emersed in oil. material of Y-class are extremly hygroscopic.	90°c
Class-A	When materials of class-Y impregnated with natural resins, esters, mineral oil Laminated wool, and varnish Paper are also used.	105°c
Class-E	synthetic resin anamel, cotton and Paper laminates with foraldehyde bonding.	120°c
Class-B	Mica, glass fibres, asbustus with suitable bonding substance	130°c
Class-F	The materials of class-B with bonding materials of higher thermal stability.	155°c
Class-H	Glass fibre and asbustus material and built up with mica with sillicon resin.	180°c
Class-C	mica, ceramic, glass, quartz, without binders or with sillicon resins of higher thermal stability.	Above 180°c.

Size and rating of motor:-

For any Particular service the following factor govern the size and rating of Motor.

- The max. temperature rise of the motor under given load condn
- The max. torque required.

It has been observed that, the motor which satisfy the max. temperature rise condn also satisfy the torque requirement condn.

Standard ratings:-

i) Continous rating:-

It is an output which motor can deliver contino without exceeding Permissible temperature. It can deliver 25% overload for 2hrs.

ii) Continous max. rating:-

It is similar to continous rating but not allow any overload. It is used for motors of capacity larger than 2kW/RPM.

iii) Short-time rating:-

This is an output which a motor can deliver for a specified Period. Say - 1hr, 1/2hrs, 1/4 hrs. without exceeding specified temperature rise.

iv) Intermetant rating:-

This rating indicates the max. load of motor for specified time followed by a no-load Period, during which the machine cools down to its original temp.
For intermetant loads short time rated motors can be used if the loading condn corresponds to short time rating of motor.

Classes of duty:-

- The rating of a motor depends on the load condition or duty to which it is subjected, the loading conditions are classified under eight classes of duty:-

i) Continous duty:-

It denotes the operation of constant load of sufficent duration for thermal equalibrium to be reached. For example, centrifugal Pumps, compressers, fans, and conveyor system are some examples of machine which run continously with some constant load.

ii) Short time duty :-

It denotes the operation at constant load during a given time, less than that required to reach thermal equilibrium. followed by a rest of sufficent duration. to reestablish equality of temperature. For example, motor used for open'ir and closing of bridges or lockgates; motors used in battery charging unit. The value for short time duty are 30 min, 40 min etc.

iii) Intermitant Periodic duty :-

It denotes a sequence of identical duty cycle each consisting of a period of operation of constant load at rest Period, these Periods being ~~to~~ too short to attain thermal equalibrium during one duty cycle. For example, motors used in different kinds of hoisting mechanism. such as tramps, trolley, buses etc.

iv) Intermitant Period duty with starting :-

It indicates a sequence of identical duty cycle each consisting of a period of starting, operation at a constant load and a rest Period, the operati and rest Period being too short to attain thermal equalibrium. For example, motor that drive metal cutting lath-machine, and motor used in rolling mills.

v) Intermitant Periodic duty with starting & braking :-

It denotes a sequence of identical duty cycle each consisting of a Period of starting, Period of operatio of constant load, period of braking and rest Period. For example, the auxilary equipment used in rollin mills, metal-cutting lath-machine. The duty braking is ~~r~~ rapid. and it done electrically.

vi) Continous duty with intermitant Periodic loading :-

Enclosure for rotating electrical machine

The Problem of ventilation in rotating electrical machi is closely linked with the type of enclosures used. The various types of enclosures are—

i) Open Machine :-

The enclosing system in which there is no ventilation other than that of good mechanical constructed Case.

ii) Open Pedestal machine (OP) :-

An open machine which have a Pedestal bearing support independly of machine frame.

iii) Open-End Bracket machine (OEB) :-

It is the machine that having an end bracket of which the ~~br~~ bearings of an integral Parts.

iv) Protected machine (P) :-

In this machine, the internal Parts are live parts, protecte mechanically from accidental and advertent contact, while ventilation is not materially impeded.

v) Screen-Protected Machine (SP) :-

A Protected machine in which the ventilating openings are not less than 64.5 mm^2 in area. Such a protection is

Provided from screen of wire mesh, expanded metal etc.

vi) Drip-proof machine (DP):-

In this the openings of ventilations are so protected to exclude vertically falling water or dirt.

vii) Splash-Proof Machine (SPLP):-

A machine enclosure in which ventilating openings are so constructed that drop a liquid of solid Particles falling on or reaching any part of the machine at any angle between vertically downward direction and 100° from direction can't enter the machine.

Loads on the drives

loads or drives or load torque can be classified as -

i) Active loads:-

- The loads that are due to forces of gravity, tension or compression in the springs or any elastic body are called active loads or Potential loads.

- It can be +ve or -ve depending upon the aid or resist the motion of drives.

ii) Passive loads:-

- These loads / torque is due to friction, cutting or any deformation of any inelastic bodies. It always opposes motion of drives ~~and changes its~~ direction of drives rotation changes.

- Examples - Friction torque always opposing the driving torque.

Speed control of dc motor

There are some factors that affect the speed control of a dc motor. They are generally more adaptable to adjusted speed service. The adjustment of the speed over a wide range has a variety of methods is one of main reasons of strong competative positions of Dc machinary in modern industrial applications. The various methods of speed control of dc motor are

(i) Field Control
(ii) Rheostatic Control
(iii) Voltage control.

(i) Field control:-

- The field control method is one of commonly used and outstanding advantageous of shunt motor and ~~the~~ compound motor. Adjusting the field current and hence the flux and speed is controlled without and special changes.

- The speed (N) is inversely proportional to flux (ϕ) and field current (I_f) given by:-

$$N \propto \frac{1}{\phi} \propto \frac{1}{I_f}$$

- The lowest obtainable speed is corresponding to the max. field current, and the higher speed is limit by effects of armature reaction under work-field condition causing motor instability and poor commun

- Since, voltage across motor remains constant, contin deliver constant output. This characteristics makes it suitable for constant load applications. The characteristics is shown in figure:-

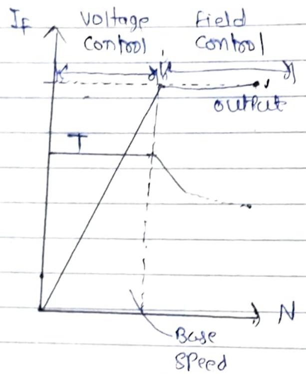


fig:- field control characteristics

(ii) Rheostat control:-

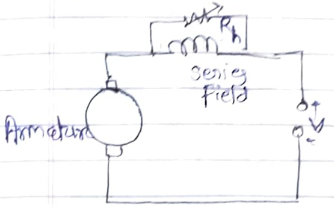


fig:- Rheostat method in series motor

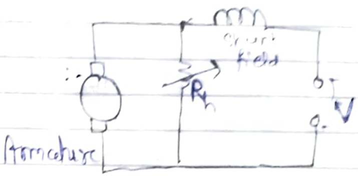


fig:- Rheostat method in shunt method

- It is common method of series motor, generally analogous is action to wound-rotor induction motor control by series rotor resistance.

- In this, speed is adjusted by using a rheostat in series with armature which allows to control the armature current in motor, thereby affect motor speed. Essentially, increase in resistance of rheostat leads to decrease I_a and so on decreases speed of motor

(iii) Voltage control:-

- When speed of dc motor is controlled by using terminal voltage (V) while contant field current is given to motor. It is known as voltage control ~~of~~ method of speed control. The circuit is shown below-

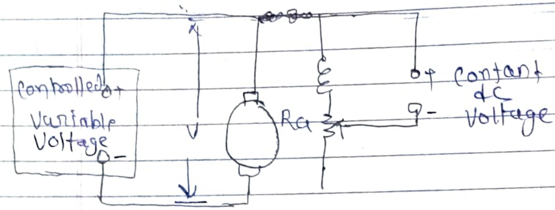


fig:- Voltage control of dc motor

- This method is also known as Ward-leonard method. In this not only gives a wide range of speed but also reduces losses to minimum level. take place at starting and stopping.

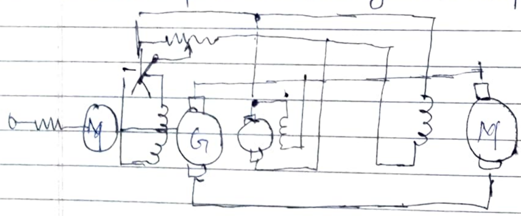


fig:- Ward-leonard Method.

- In this method, a prime AC or DC motor is used to drive a generator at constant speed. If the generator voltage is varied, motor voltage is chang Since, speed of motor proportional to voltage.