Torque due to forward field

$$T_f = \frac{P_{gf}}{\omega_{ms}}$$

$$T_f = \frac{I_s^2 R_f}{\omega_{ms}} \quad ; \quad \omega_{ms} = \frac{2\pi N_s}{60}$$

$$T_f = \frac{I_s^2 R_f}{\frac{2\pi N_s}{60}}$$

Power transferred to the rotor due to backward field

$$P_{gb} = I_s^2 * R_b$$

Torque due to backward field

$$T_b = \frac{P_{gb}}{\omega_{ms}}$$

$$T_f = \frac{I_s^2 R_f}{\frac{2\pi N_s}{60}}$$

∴ The net torque is,

$$T = T_f - T_b$$

$$= \frac{I_s^2 R_f}{\frac{2\pi N_s}{60}} - \frac{I_s^2 R_b}{\frac{2\pi N_s}{60}}$$

$$T = \frac{I_s^2}{\frac{2\pi N_s}{60}} (R_f - R_b) \ \#$$

Braking :-

Refer page No-13 of Unit-I.

Advantages of Electric Braking over Mech Braking:

* Electric braking is fast and cheap
* No cost for maintenance
* capacity of the system is increased
* production of heat is not affecting the system.
* Braking is smooth.

Disadvantages:

* Electric Braking cant be used for holding the Machine after come to rest. ∴ Mech Braking is required in addition.

* High initial cost
* Choice of Motor is limited.

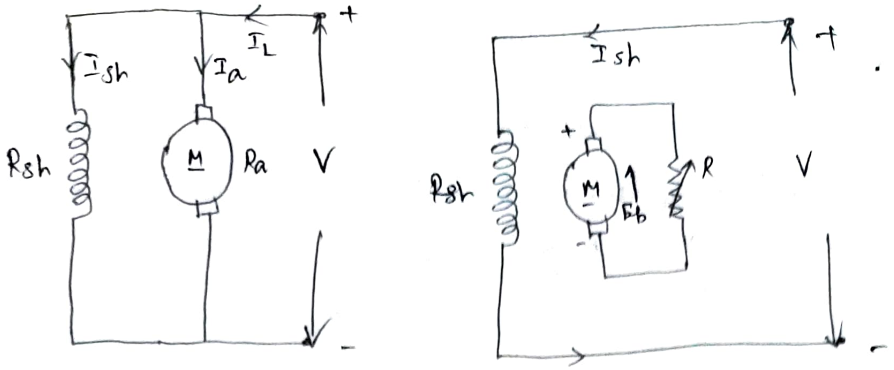
=> Electric Braking of DC shunt Motor:

The electric Brakings are

(i) Rheostatic (or) Dynamic Braking
(ii) Plugging
(iii) Regenerative Braking.

(i) Rheostatic Braking:

* The armature of the DC Motor is Disconnected from the supply and connected across a Braking resistance, while field remains connected to the supply.
* Now the Machine will run as a generator, loaded with a resistance.
* All kinetic energy is converted into electrical energy, which is dissipated by resistance.
* The magnitude of Braking torque can be controlled by varying the value of resistance.
* The Main drawback is, in case of Failure of electric supply, this method is ineffective.



(a) Running (b) Braking

The Armature current (I_a) is

$$I_a = \frac{E_b}{R_a + R} \Rightarrow \frac{\left(\frac{\phi PNZ}{60A}\right)}{R_a + R} \Rightarrow \frac{K_1 \phi N}{R_a + R} \rightarrow (1)$$

where $K_1 = \frac{PZ}{60A}$

The Braking Torque is

$$T_b = \frac{1}{2\pi} \phi Z I_a \frac{P}{A} \rightarrow (2)$$

sub (1) in (2)

$$T_b = \frac{1}{2\pi} \phi Z * \frac{\phi PNZ}{60A(R_a+R)} * \frac{P}{A}$$

$$= \left(\frac{P^2 Z^2}{120\pi A^2}\right) \frac{\phi^2 N}{(R_a+R)}$$

$$T_b = \frac{K_2 \phi^2 N}{(R_a+R)} \rightarrow (3)$$

where

$$K_2 = \frac{P^2 Z^2}{120\pi A^2} \rightarrow (4)$$

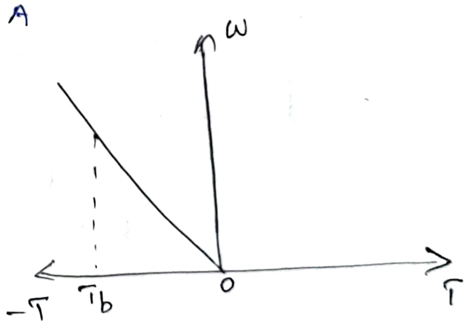


Fig: Speed - Torque.

* ∴ The Braking Torque is proportional to speed.

(ii) Plugging:

* A reversed torque is obtained by reversing either the current in the armature or field (Not both).

* During Normal running, the Back EMF is opposite to the direction of the armature current but during plugging, the back EMF and I_a are in same

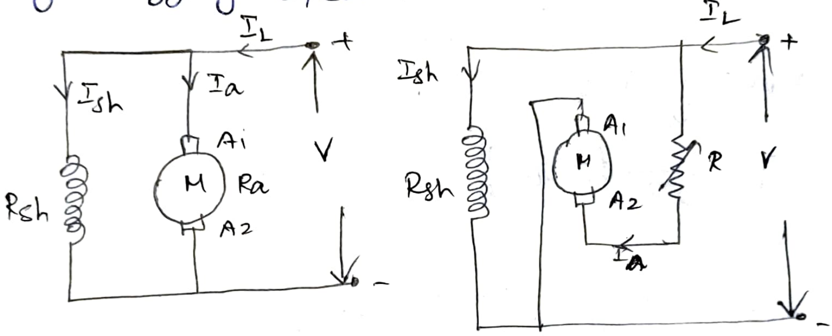
* For reversal of armature connections a voltage equal to (V+E) is impressed across the armature circuit.

where V - supply voltage

E - Induced Back EMF

* Since E is very nearly equal to V, the impressed voltage is 2V. This will cause great rush in armature circuit.

* To prevent this, it's necessary to re-insert the starting resistance in series with armature by plugging operation.



(a) Running (b) Braking

The I_a is

$$I_a = \frac{V+E_b}{R+R_a} \Rightarrow \frac{V}{R+R_a} + \frac{E_b}{R+R_a} \quad \text{but } E_b = \frac{\phi P N Z}{60A}$$

$$I_a = \frac{V}{R+R_a} + \frac{\left(\frac{\phi P N Z}{60A}\right)}{R+R_a}$$

$$I_a = \frac{V}{R+R_a} + \frac{k_1 \phi N}{R+R_a} \quad \text{where } k_1 = \frac{PZ}{60A}$$

The Braking Torque is

$$T_b = \frac{1}{2\pi} \phi Z I_a \left(\frac{P}{A}\right)$$

The plugging gives more braking torque than the rheostatic braking.

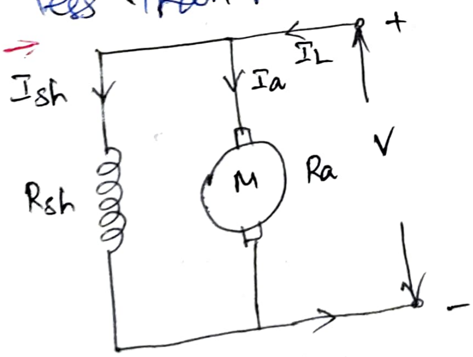
* Instead of being disconnected from the supply it remains connected and returns the braking energy to the line.

* Suppose the load causes the speed to be increased above normal, the field current remaining the same then the Back emf becomes greater than the supply voltage.

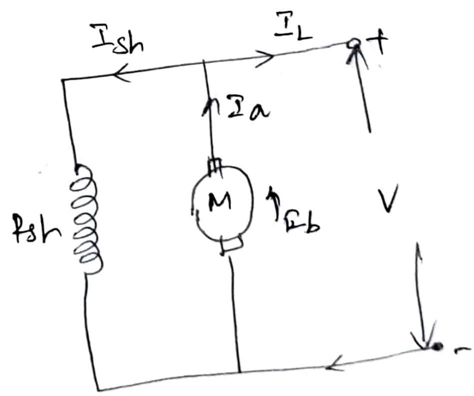
* current gets reversed and power will be supplied to the line, tending to prevent any further increase in the speed.

* By increasing field current, where motor quickly slowed down to the speed corresponding to the new value of the field current.

* Due to Reversal of I_a as $E_b > V$, armature torque is reversed and speed falls until E_b becomes less than V.



(a) Running

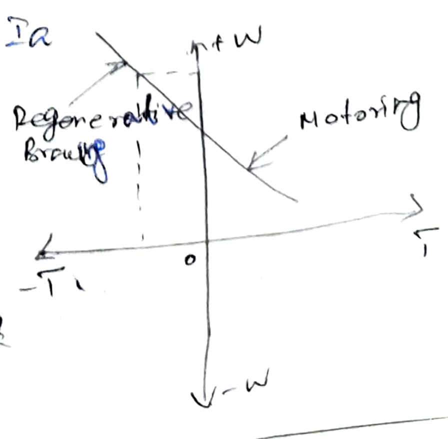


(b) Braking

$\therefore$ $I_a = \frac{V - E_b}{R} \Rightarrow \frac{E_b - V}{R} = -I_a$

$\therefore$ $T = -k\phi I_a$

and speed, $N = \frac{V}{k\phi} + \frac{R_a I_a}{(k\phi)^2}$



(62)

Electric Braking of D.C series Motor:

=> The Electric Brakings are

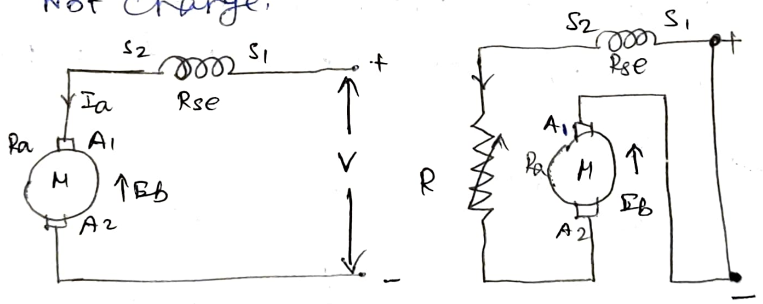
(i) Rheostatic (or) Dynamic Braking

(ii) Plugging

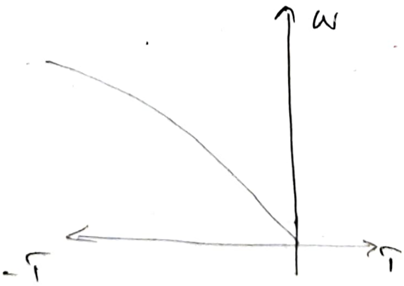
(iii) Regenerative Braking

(i) Rheostatic Braking:

* The Armature of the DC Motor is disconnected from the supply.
* The Direction of current through the armature reverses while braking.
* The Motor runs as a generator
* The direction of current through field does Not change.



(a) Running (b) Braking



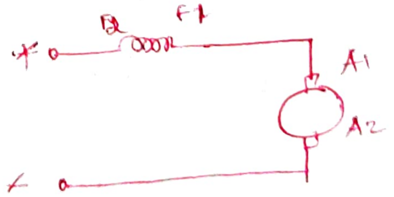
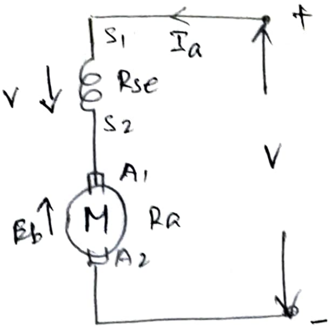


Fig. T-N characteristics.

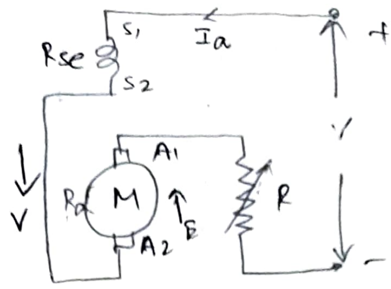
(ii) Plugging:

* Here the armature connection Remains same. ~~similar to DC shunt Motor.~~
* The resistance 'R' added can be controlled by control...

the braking Torque.



(a) Running



(b) Braking.

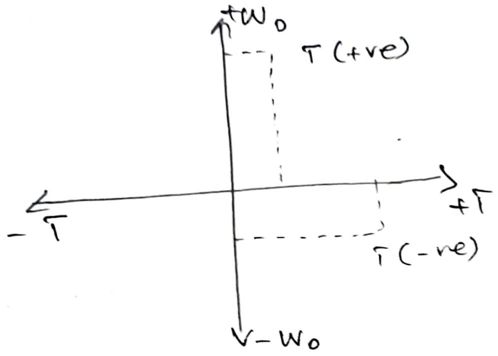
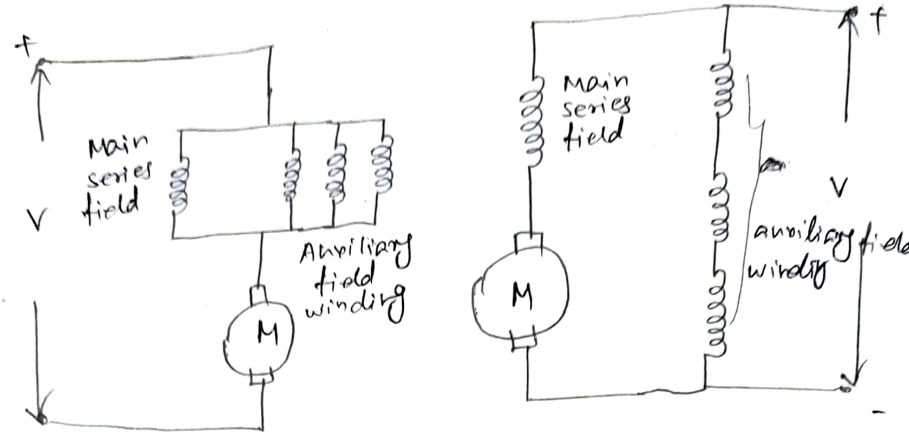


Fig: N-T characteristics.

(iii) Regenerative Braking:

* Increase in excitation results decrease in speed. As such it is not possible to get emf more than voltage.
* Regeneration Braking with series Motors is Not possible.
* Reversal of Ia necessary to produce regeneration would cause a reversal of field, ∴ series field connections must be reversed.
* Due to these complications this method is Not used for common industrial purposes But it may used for traction purposes.
* If there is a single DC series Motor to be ...ted auxillary field windings are connected ...

(64) * During Braking period the ... windings are put in series. It act as a differentially compounded generator. Fig (b)



(a) Running (b) Braking

=> Electric Braking of an Induction Motor:

The Electric Brakings are

(i) Rheostatic (or) Dynamic Braking
(ii) Plugging
(iii) Regenerative Braking.

(i) Rheostatic Braking:

* Quick stopping is achieved by connecting stator terminals to a DC supply.
* Any 2 terminals can be connected to a DC supply and 3rd terminal may be kept open (or) may be connected to other stator terminal. This is called DC dynamic Braking.

Types of Rheostatic Brakings are

(a) Two lead Connections: 3rd terminal is kept open, this is called 2 lead Connections
(b) Three lead Connections: 3rd terminal is shorted directly with other stator Terminal

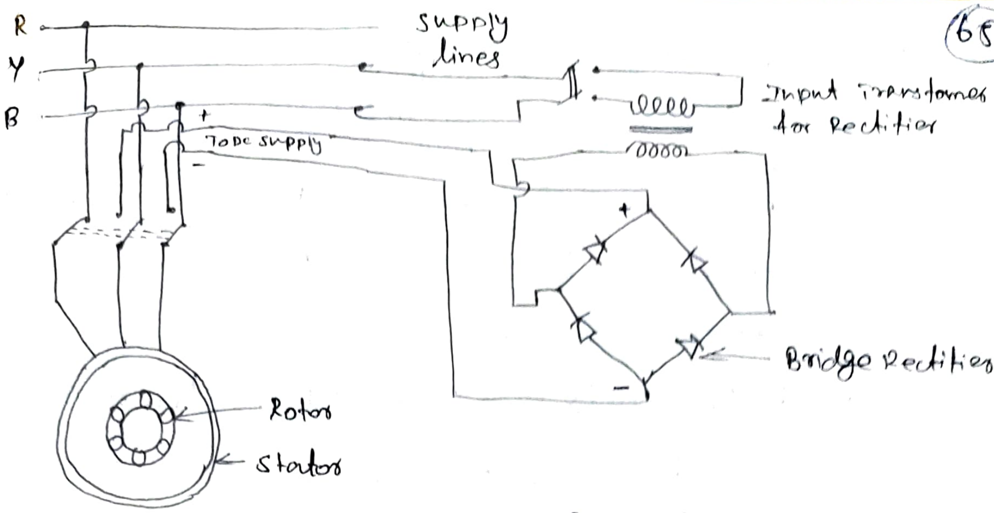
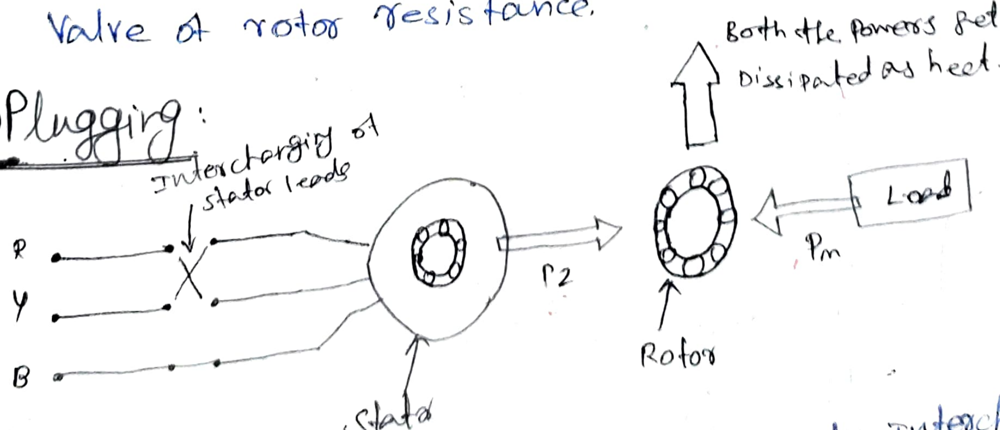


Fig: Dynamic Braking

* stator is connected to DC supply to produce stationary DC field.
* The short circuited rotor moves in the DC field due to the kinetic energy of the Motor, ∴ EMF is induced in the rotor conductors.
* Due to this induced EMF, current flows through the rotor circuit and Braking effect is obtained
* In case of wound rotor motors the braking effect can be controlled by variation of external Resistance inserted in the rotor circuit.
* But in case of squirrel cage motor only a particular Braking effect is obtained depending upon the value of rotor resistance.

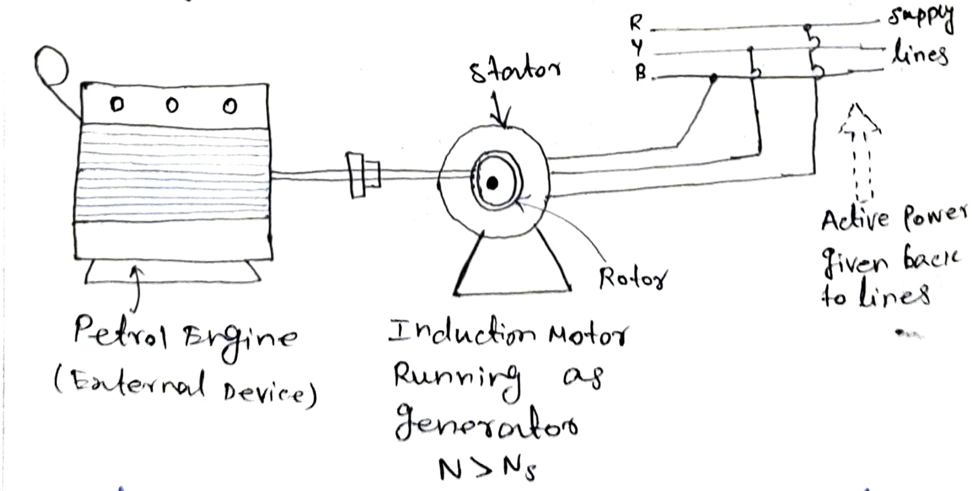
(ii) Plugging:



* It's can be achieved in a 3ϕ I.M by Interchanging two of the stator phases.

* when reversing any 2 Phases, the direction of rotation of magnetic field is reversed.
* Therefore the torque produced in the rotor also be reversed providing a braking action.
* At the instant of plugging the relative speed between the rotor conductors and the magnetic field will approximately twice the synchronous speed.
* Voltage induced in the rotor will be twice of normally induced voltage which causes to flow abnormal current in the rotor and stator.
* It should have additional insulation on the rotor and high resistance may have to be inserted in the rotor cor) stator circuit for the purpose of protection.

(iii) Regenerative Braking:



* If Rotor speed is increased greater than the synchronous speed with the help of external device, it acts as an induction generator.

... Mechanical Energy to an Electrical Energy which is given back to supply. It delivers active power to the 3φ line.

* The Power Flow Reverses hence rotor induced EMF and Rotor current also reverse. So Rotor Produces torque in opposite direction to achieve the braking.

* Electrical Energy is given back to the lines while braking, it's called regenerative braking.

* It's very seldom used for braking but it's application is very useful to lifts and hoists for holding decending loads at a speed only slightly above the synchronous speed.

Advantages:

* Generated Power can be used for useful Purpose.

Disadvantages:

* Fixed frequency supply it can be used only for speeds above synchronous speed.

---

1. A 4 pole, 3 phase, 50Hz, star connected induction motor has a full load slip of 4%. calculate full load speed of the motor.

given:

No of Poles, $P = 4$

$f = 50Hz$

% of slip, $S_{FL} = 4\% \Rightarrow 0.04$