ELECTRIC DRIVE

Electric Drive:- (i) It is defined as a form of machine equipment designed to convert electric energy into mechanical energy and give electric control to them.

Electric Drives those are used in Industry are divided into three types.

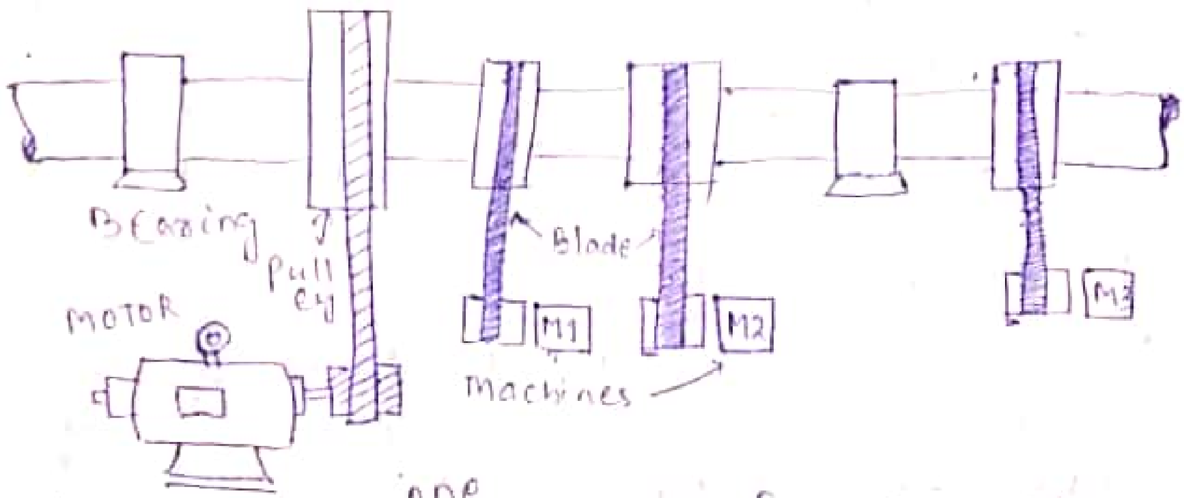
(a) Group Drive
(b) Individual Drive
(c) Multi motor Drive.

5.1 **Group Drive:-** (i) In this case one motor is used to drive two or more than two machines.

(ii) Here the motor is connected to long shaft on which belt and pulleys are connected to run other machine.

(iii) It is also called line shaft drive

(iv) It is more economical.



Here we use one motor for for 3 machines

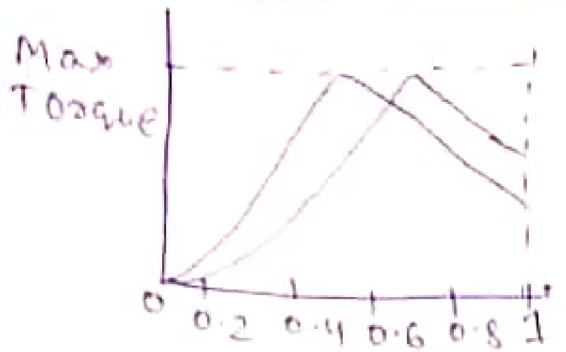
Restriction

(i) If there is a fault on one motor happened, then all connected machines to this motor will cease to operate.

(ii) If all the machines are not in operation the motor will be working at low capacity.

(iii) It is not possible to install a new machine at a far away distance.

Torque - Slip characteristics



This graph shows from a range S=0 to S=1.

(i) As S=0, T=0. So the Torque-slip ch. starts from origin.

We know $T = \frac{K_2 S R_2}{(R_2)^2 + (S X_2)^2}$

(ii) At normal speed, slip is small so that SX_2 is negligible as compared to R_2.

So Torque, $T \propto \frac{S}{R_2}$

$\propto S$ as R_2 is constant.

So it is a straight line from zero slip to a slip.

(iii) When slip increases beyond full load slip. Then T increases and become maximum at $S = \frac{R_2}{X_2}$.

(iv) When slip is increased beyond maximum torque. So $S^2 X_2^2$ increases very rapidly to R_2^2. may be neglected as compared to $S^2 X_2^2$

$T \propto \frac{S}{S^2 X_2^2}$ $T \propto \frac{1}{S}$

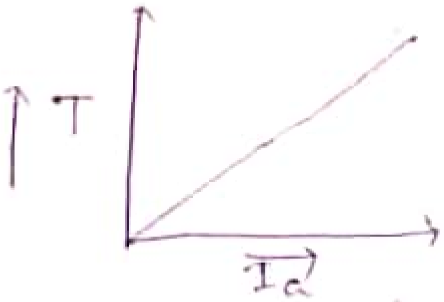
Running characteristics:

(i) At start the power factor is very low

(ii) When the load increases it draws active component current. so power factor is raised and on full load its value may be between 0.8 to 0.9.

$T_a \sim I_a$ characteristics

We know that $T \propto \phi I_a$. But due to in this case we make applied voltage V constant so the flux will be constant so here $T \propto I_a$. Hence there will be a straight line



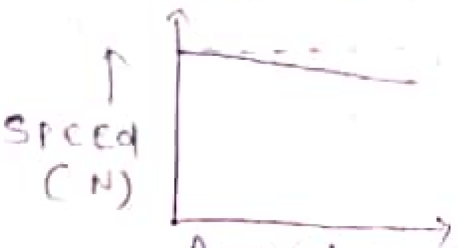
$N \sim I_a$ characteristics:-

We know that $N = \frac{E_b}{\phi} = \frac{V - I_a R_a}{\phi}$

We know $N \propto \frac{1}{\phi}$, but in this case V is constant so ϕ will be constant. So when the load on the motor will be increased the current in the armature increases that makes voltage drop in armature and decreasing the speed.

As the drop in voltage in armature very small, so drop in speed from no load to full load is again very small.

So remember shunt motor can be used for constant motor.



Speed Torque characteristics

When V is constant, ϕ is constant. So N depends upon I_a. N decreases with increase of I_a, But we know $T \propto I_a$. So torque will increase with I_a. So it will be a straight line.

Repulsion Motor: (i) It requires large starting torque and adjustable but constant speed just as in coil winding machines for service of

1-Ø Induction motor

Capacitor start single phase I.M:

These are used for compressors, refrigerators and portable hoists.

Capacitor start Capacitor run type I.M

Used in water cooler and large air conditioner.

Universal motor: These are suitable for sewing machines, table fans, vaccume cleaner, Portable drills, hair dryer, cooler pumps and Small blowers etc.

Characteristics of Single phase Series motor

It posses high starting torque of about 3 times the full load torque. The speed can be controlled on full range with the help of a transformer. Its maintainance cost is high and P.f is about 0.8-0.9 lagging

Characteristics ~~charact Control~~ of AC motor.

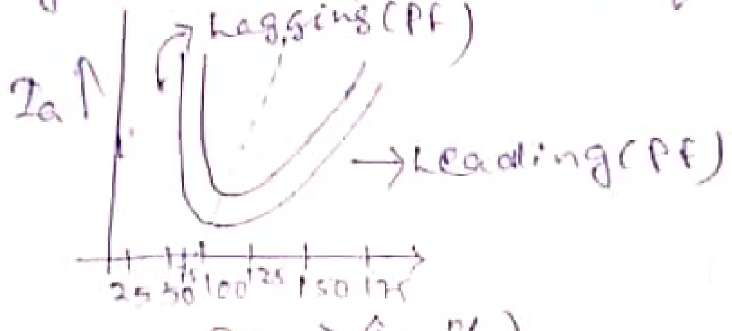
(i) Synchronous Motor: (i) In the case of AC motor synchronous motor runs a constant speed. It is in $N_s = 120f/P$. The speed doesn't depend on the load.

(ii) The graph between I_a and I_f is called V curve.

(iii) From the graph we can see the p.f at which motor will work depend on I_f. So, p.f can be changed by its I_F.

(iv) If I_F is less than rated value. It runs at a lagging power factor. If I_f more than rate rated value, then it runs at a leading power factor.

(v) Torque developed ∝ V. So it can withstand large over load and has a quite efficiency.



Single phase induction motor

(i) The construction of single phase I.M is similar to a polyphase induction motor.

(ii) The stator is provided with 1-ϕ winding. So the speed torque ch. are same as 3-ϕ induction motor. It has no self starting torque.

Repulsion motor: (i) ~~construc~~ The operating characteristics are similar to series motor.

(ii) Its speed can be adjusted by shifting the brushes with the help of specified lever.

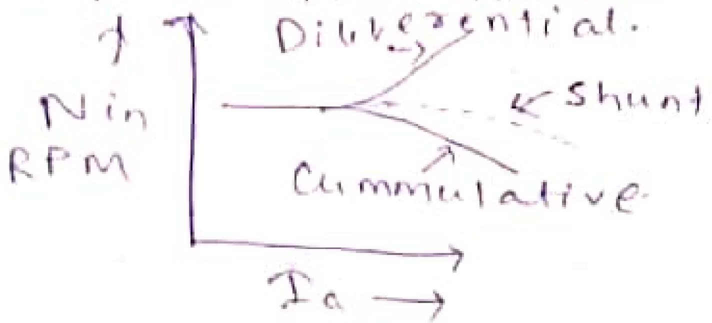
Scanned with CamScanner

For differentially compound motor

In this case ϕ_{se} opposes ϕ_{sh}. That will be seen in the figure. So the flux of this motor will be less than shunt motor. So the N will be more because $N \propto \frac{E_b}{\phi}$

If we plot three motors in the diagram

$N_{diff} > N_{shunt} > N_{cummulative}$



T ~ Ia characteristics (Compound motor)

We know that $T \propto \phi I_a$. So if I_a increases T will increase.

For cummulative compound motor

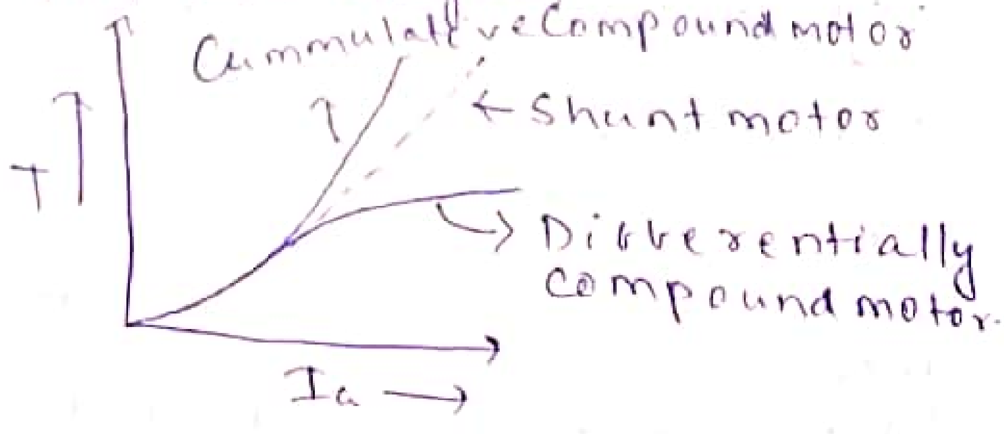
In the case of cummulative compound motor. ϕ_{cu} is more than shunt motor. Because we know that $\phi_{cu} = \phi_{se} + \phi_{sh}$; $T \propto \phi I_a$. So Torque developed is more than shunt motor.

Differentially compound motor

Here $\phi_{diff} < \phi_{sh}$ So Torque developed is lesser than that of a shunt motor.

$T_{cu} > T_{sh} > T_{diff}$

If we plot in a diagram



Application of Various D.C motor

DC shunt motor: It can be used for driving constant speed line shafts, lathes, vaccum cleaners, pressure blowers, centrifugal. pumps, washing machines and Printing press etc.

DC Series motor: (i) These motors are used for heavy duty applications such as electric traction, rolling mills and crain etc.

Cummulative Compound motors: These are used for driving compressors, stamping machines door lifts, shearing machines and passenger elevators etc.

Differential Compound motor:- Due to starting torque is at low. It has unstable operation. It is seldom used in practice.

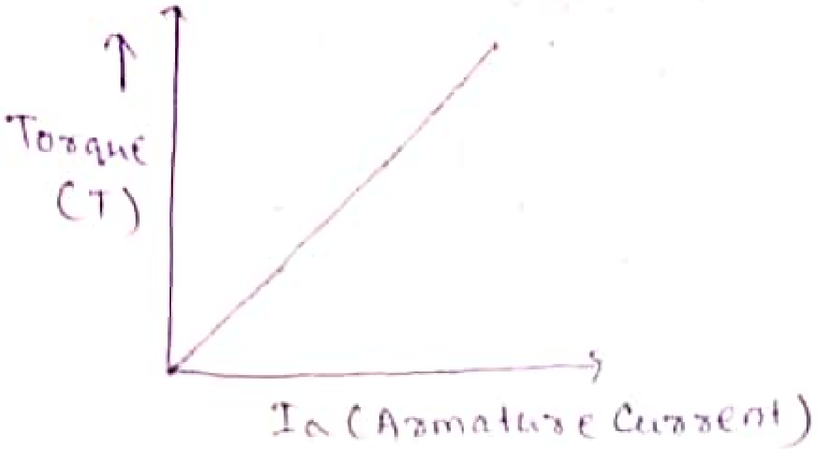
3-Ø Induction motor

Squirrel cage Induction motor:- (i) It can be used for driving low and medium power drives, where speed control is not required. These are used in tube wells, lathes, drilling machines, saws, grinders, blowers and line shafts etc.

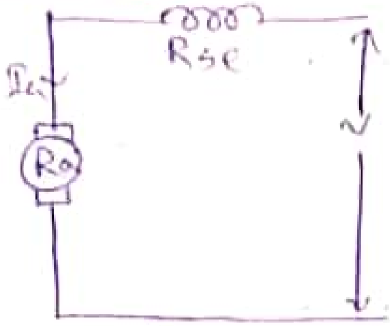
Slip ring Induction motor:- (i) It is used in drives requiring high power at high starting torque and adjustable speed ex:- line shafts, lifts, pumps winding machines and compressors etc.

3-Ø synchronous motor:- It is used for driving large fans, compressors, line shaft and pump where fairly constant and starting torque both are required.

Single phase series motor: (i) It is used for driving domestic appliances like vaccum cleaners and mixters etc.



DC Series motor:



In this case field winding is connected with the armature. Rse contains few turns of thick wire having low resistance. If mechanical load increases then Ia increases. Hence ϕ increases.

Torque - Current characteristics

We know $T_a \propto \phi I_a$

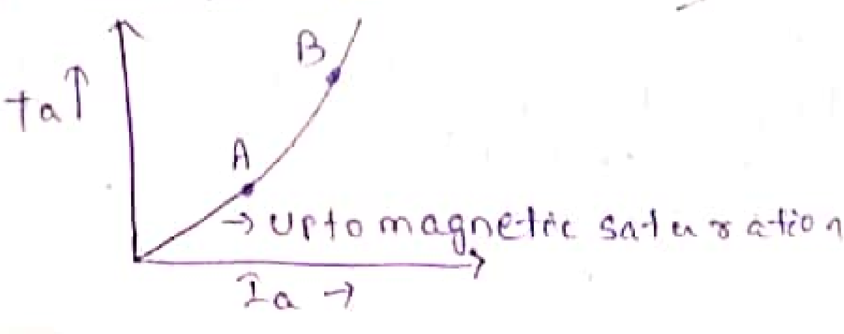
Upto magnetic saturation $\phi \propto I_a$

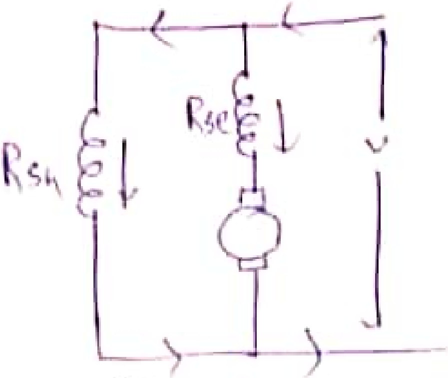
So $T_a \propto I_a^2$

So upto magnetic saturation, $T_a \propto I_a^2$. If Ia is doubled Ta is quadroupled. Upto magnetic saturation Ta/Ia is parabola.

However after magnetic saturation $T_a \propto I_a$. So it follows a straight line.

So because upto magnetic saturation $T_a \propto I_a^2$.

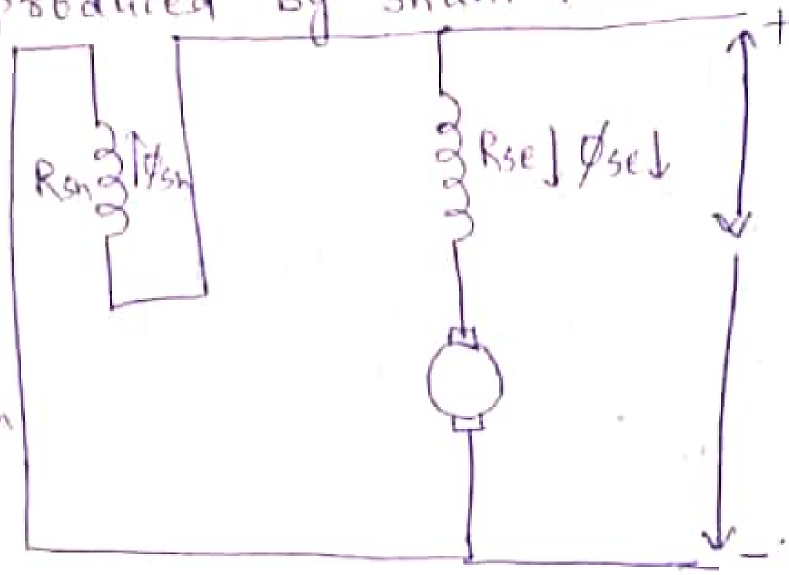




$\phi_{cu} = \phi_{se} + \phi_{sh}$.

Differential Compound motor

In differential compound motor, the flux produced by series field winding is opposite to flux produced by shunt field winding.



$\phi_{de} = \phi_{se} - \phi_{sh}$

We will se N~Ia characteristics of cummulatively compound motor and differentially compound motor.

N~Ia characteristics (Compound motor).

We know $N \propto \frac{E_b}{\phi}$ and $\phi \propto I_a$.

So N will decrease, Ia will increase.

For cummulative compound motor

Since $\phi_{cu} = \phi_{se} + \phi_{sh}$ So ϕ of cummulative compound motor will be more than ϕ of shunt. So ϕ increases. So N/speed of cummulative compound motor will be less than shunt motor.

Advantage of individual Drive

(i) Disconnection of the drive or its failure will not affect working of different machines.

(ii) For transmission of drive, there is no necessity of shaft

(iii) Efficiency of the system is high.

(iv) It is more reliable.

(v) It can be placed, where it is convenient.

(vi) More useful where constant speed is required.

5.2 Choice of Electrical Drive.

There are some important factors to choose electric drives

(a) **Requirement related to the source**:- Type of source and its capacity, magnitude of voltage, voltage fluctuations, power factor, harmonics, and their effect on other loads and ability to accept regenerated power.

(b) **Steady state operation requirement**:- Nature of speed torque characteristics, speed regulation, speed range, efficiency, duty cycle, quadrants of operation, speed fluctuation and ratings

(c) **Transient Requirements**:- starting, breaking values of acceleration and deacceleration, reversing performance.

(d) Capital and running cost, maintainance.

(e) Environment and Location.

(f) Reliability

(g) Space and weight restrictions

Universal Motor:- It operates at approximately the same speed and output on either dc or a.c voltage.

(ii) The characteristics is similar to d.c. series motor.

3-ϕ series Motor:- In this case the stator of such a motor is similar to the plain induction motor

(ii) characteristics:- Here the speed torque characteristics are just similar to the d.c series motor characteristics.

Schrage Motor: (i) It is an inverted wound rotor induction motor in which rotor winding is connected in star or delta is the primary winding and is supplied from 3-ϕ supply through slipping.

Characteristics:- It posses shunt speed torque characteristic and is used only when adjustable speed is required.

3-ϕ Induction motor

Starting characteristics:- starting torque developed by slip ring motor is more than squirrel cage motor

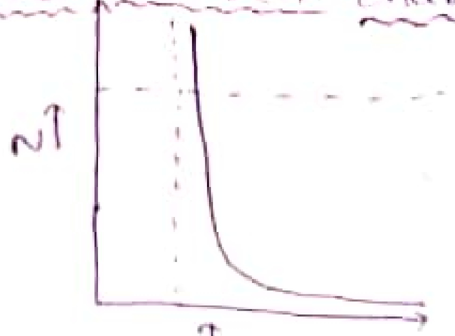
We know T_s = Starting Torque = $\frac{K V_2 R_2'}{(R_1+R_2')^2+(x_1+x_2')^2}$

starting torque will become maximum when rotor resistance is made equal to leakage reactance

So when we add starting resistance, the starting torque increases. The resistance is cut out gradually as the motor picks up speed.

We can see by Torque - slip characteristics.

Speed-Current characteristics



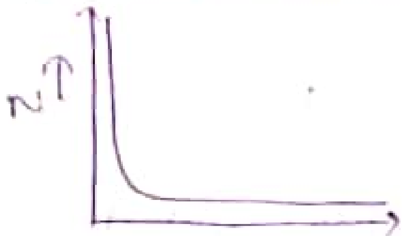
We know $N \propto \frac{E_b}{\phi}$, where $E_b = V - I_a(R_a + R_{se})$
So if I_a increases, E_b decreases where as ϕ increase. However under normal condition $I_a(R_a+R_{se})$ drop is quite small.

Upto magnetic saturation

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

Upto magnetic saturation it follows hyperabolic path. After saturation flux becomes constant So speed becomes constant

Ta/N characteristics



We know when Ta increases, it needs armature current, which is also field current. because of that ϕ increases, N decreases so at low speed you get high torque and vice-versa.

Compound motor

These are two types of motor
(a) Cumulative compound motor.
(b) Differentially compound motor.

Cummulative Compound :- In this motor the flux direction of series field and shunt field winding is same. The characteristics of such motors are the combination of series and shunt motors.

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(iv) Speed control of different machines using belts and pulley is cumbersome.

Individual Drive

(i) In this drive only a single electric motor is used to drive one individual machine.

(ii) It has disadvantage because it costs more than group drive.

(iii) It has advantage, each operator has complete control on its machine, when it is not operating, you can control the speed.

(iv) It can be located at convenient places.

Advantage of Group Drive

(i) Initial Cost:- (i) It is less as compared to that of individual drive.

(ii) Sequence of Operation:- (i) It is very useful because all the operations are stopped simultaneously.

(iii) Space Requirement:- (i) Less space is required in Group drive.

(iv) Low maintenance Cost:- (i) It requires less maintenance as compared to individual drive.

Disadvantage of Group Drive

There are some disadvantages:

Power factor:- (i) It has low power factor.

Efficiency:- (i) If all the machines do not work together, then the motor work at very much reduced load.

Reliability:- If main motor fails then whole industry will come to stand still.

Speed:- It does not provide constant speed.

Types of machines:- These are not suitable for driving heavy machines such as cranes, lifts etc.

Starting characteristics

i) The starting torque exerted by a motor should be large enough to accelerate the motor and load to the rated speed in reasonably short time.

(ii) In the case of driving mills, or oil expellers, some motors may have to start against full load torques.

(iii) In the case of lifts, hoists and haulage, cranes, the motors have to start frequently with high acceleration.

At the type of starting of motor, two types of torques comes into play.

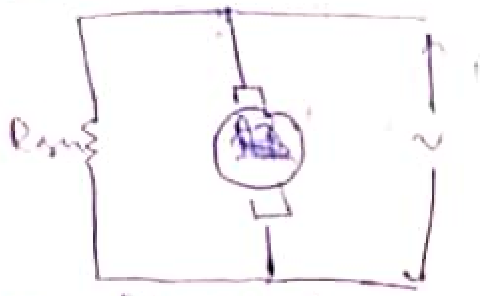
(i) The torque required to overcome the static friction.

(ii) The torque necessary to accelerates the motor and its load to desired speed.

Starters are used to limit starting current and also for developing starting torque.

Starting and Running characteristics of DC Shunt motor

DC Shunt motor



In DC motor field is connected parallel with armature.

Traction

Electric Traction system

Driving forward of vehicle is called traction and the system which employs this type of mechanism is called traction system.
It is basically two types.

1. Non electric Traction system
2. Electric Traction system.

Electric Traction system:- The system which we use electric power for traction systems i.e for railways or trolley is called electric traction.
(ii) Here driving force is obtained for electric motor.

System of Traction.

Direct steam Engine Drive

(i) (

System of Traction

Direct steam Engine Drive

(i) For railway work steam locomotive is mostly widely adopted method.

(ii) The reciprocating engine is employed because of its simplicity, the connection between the cylinder and the driving wheel and the speed can be controlled.

(iii) Because of difficult of installing a condensor on locomotive. So it is used without condensor. So it's efficiency is 6 to 8%.

Disadvantage

(i) Overload capacity is strictly limited.

(ii) It is only available for hauling for about 60% on its working day. Remainder of the time spent in preparing for service and its maintainance and overhauls examinate and repair it if necessary.

* there are some few locomotives employing steam turbines have been built with a condensor which have reduction gearing between turbine and driving wheels but efficient only 10 to 15%.

Direct Internal Combustion Electric drive

(i) The efficiency of this engine at normal speed is about 25%, overload capacity is limited usually at normal speed operation between 600 and 2000 rev/min, which is un economical. So the torque is constant at all speeds. So the torque cannot used in full capacity. So the engine cannot used in full capacity.

(ii) So the form of gear or torque converter can be employed.

Steam electric Drive:- (i) To avoid for a reduction of gear. The turbine can be made to drive a generator, which supplies current to suitable motor.
(ii) Because of mechanical difficult these can not be adopted generally.

Internal Combustion electric Drive:-
(i) Replacement of the reduction of gear and this system includes electrical generator and motor to drive.
(ii) Usually we used diesel engine, The weight of such locomotive is high, but we use because of coal is scarce.

Battery electrical drive:- (i) Direct Current motors are used for driving are supplied from a secondary battery carried on the vehicle. Those capacity are limited by small capacity of battery.

Track electrification:

(i) It is mostly widely used.

(ii) The electrical energy is supplied to the vehicle from an contact wire suspended above the track or from an additional rail along side it.

(iii) Because of this vehicle is less weight and efficiency is 80 to 90%. but overall efficiency is 10 to 15%.

(iv) The maintainance cost is much reduced and a lower grade of fuel can be burn.

(v) The maintainance of electric equipment is very less. so it can be service for 95% or more.

1. DC systems:- (i) The electric motors used are dc series motors.
(ii) for suburban railways and tram cars operating voltage is 600V and for main line railways operating voltage is 1500-3000V.
(iii) The motor recieve powers from overhead line with the help of a pantograph and the railway steel track is the return conductor
(iv) The over head wire is fed from various substations. These substations recieve power from 3-Ø 11kV, 3-Ø 33kV or 3-Ø 66kV transmission lines.
(v) AC power is converted into DC power using rectifier. Now we use semiconductor rectifiers
(vi) for suburban service the distance betwee substations is to 3to5km for main line service it is about 40to50km,
(vii) In India it exits only in Bombay region and some parts of Madras

Series- ...

AC systems

It is of four types

3-ϕ AC system:- It uses 3-ϕ slipring induction motor, speed control can be obtained by a combination of pole changing and rotor resistance method.

Advantage:- Regenerative braking happens when $(N > N_s)$

* voltage is used about 3600V and frequency $\frac{2}{3}$ cycles/second.

Disadvantage:- For 3-ϕ we use two overhead conductor. ~~and third~~ (and third being rail itself)

Hence the system is also out of use.

(b) 1-ϕ standard frequency system:- (i) It is composite systems. otherwise known as

(ii) It has single overhead wire supplied at 25 kV standard frequency 50hz, which is standard frequency

(iii) A transformer is placed on the train, it steps down the voltage which is further rectified and supplied to traction motors.

(iv) Substations are supplied at a high voltage of upto 132 kV, which is stepped down to 25 kV by transformer installed at each substation

(v) Driving force is obtained from DC series motor semiconductor rectifiers are used.

It is very popular.

1-ϕ Low frequency system:- (i) In this case each substation is supplied at high voltage. The voltage is stepped down to 400V at 50hz. and frequency is converted by motor-alternator set

(ii) Series motor is employed for traction

Advantages:- (i) Due to commutating difficulties at normal frequency, a low frequency is required

Disadvantage:- (i) A special low frequency power distribution network is required.

1-Ø to 3-Ø system (Kondo system):-

(i) In this system 1-Ø high voltage a.c system is employed for distribution network.

(ii) The locomotive carry a phase converter which converts 1-Ø a.c into 3-Ø.

(iii) The 3-Ø supply is connected to 3-Ø Ind^n motor for getting necessary driving force.

Advantage

(i) It has low cost distribution and cheap and robust construction of induction motor (I.M)

The voltage used for distribution network is 16,000V and 50hz. The system is adopted in Hungary.

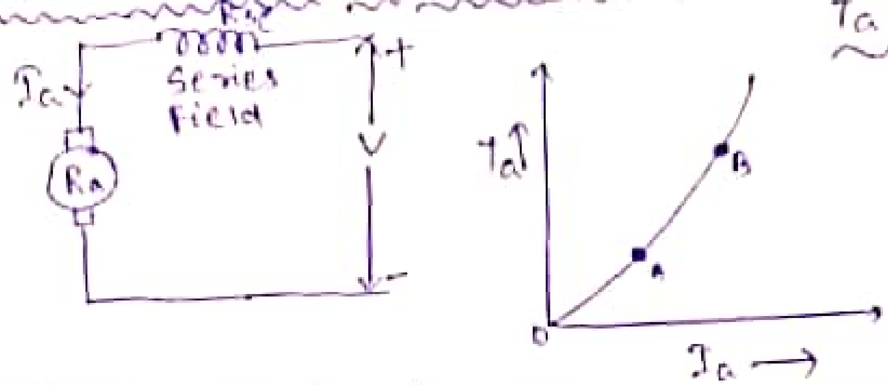
Running ch AC & DC Traction motor

~~Characteristics of series motor~~

Series and compound motors are employed for DC traction system. Single phase series and 3-Ø Ind^n motor is used.

Characteristics of series wound motor

Ta/Ia characteristics



In this case field winding is connected with the armature. Rse contains few turns of thick wire having low resistance. If the mechanical load increases then the armature current increases, Hence flux in series motor increase.

(a) Ta/Ia ch:(i)

We know $T_a \propto \phi I_a$

Upto magnetic saturation $\phi \propto I_a$

So $T_a \propto I_a^2$

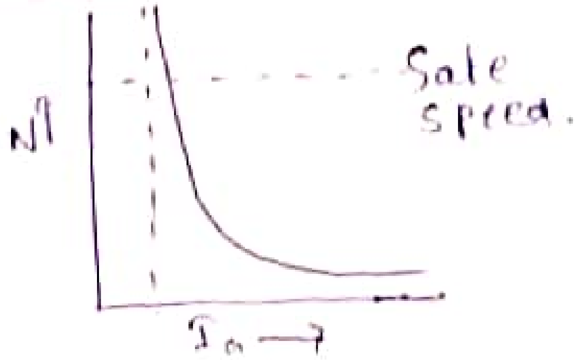
So upto magnetic saturation $T_a \propto I_a^2$. If Ia is doubled Ta is quadrupled. Upto magnetic saturation Ta/Ia is parabola.

However after magnetic saturation, $T_a \propto I_a$

So it follows a straight line.

So because of upto magnetic saturation $T_a \propto I_a^2$. So for the case of train, electric traction for high torque in starting we need series motor.

(b) N/I_a ch:



We know $N \propto \frac{E_b}{\phi}$

where $E_b = V - I_a(R_a + R_{se})$

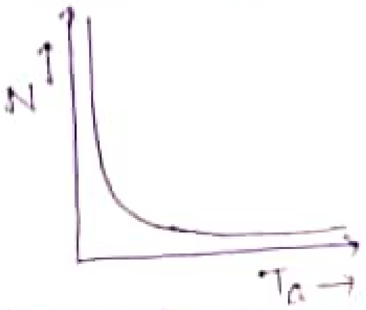
So If I_a increases E_b decreases, whereas ϕ increase $I_a(R_a+R_{se})$ drop However under normal condition $I_a(R_a+R_{se})$ drop is quite small.

Upto magnetic saturation

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

Upto magnetic saturation it follows hyperabolic path. After saturation the flux becomes constant So speed becomes constant.

T_a/N ch:- (i)



We know when T_a increases, it needs armature current, which is also field current, because of that ϕ increases N decreases So at low speed you get ~~~ high torque and vice-versa.

imp * DC series motor is a variable speed motor: It automatically adjusts the speed according to changing load. So if load increases speed decrease. It is required to adjust automatically to compensate for changes on the load. example - Traction work

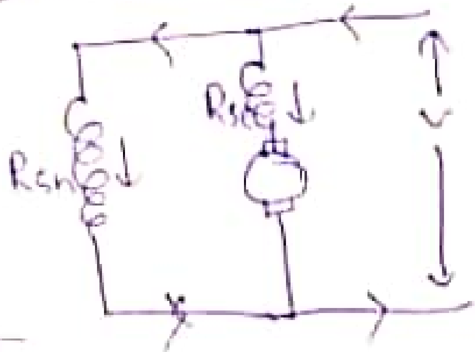
* When I_a reaches no load value, ϕ becomes very small. So $N \propto 1/\phi$, N rises to high value. This is dangerous for machines. So therefore series motor never should start at no load. So first we give mechanically load, then motor is started.
* The minimum load in DC motor should be enough to keep speed within limit

Compound wound motors

(i) It is a compromise between the shunt and series motor and combines the feature of both

It is of two types
① Cumulative compound motor
② Differential "

Cumulative Compound motor



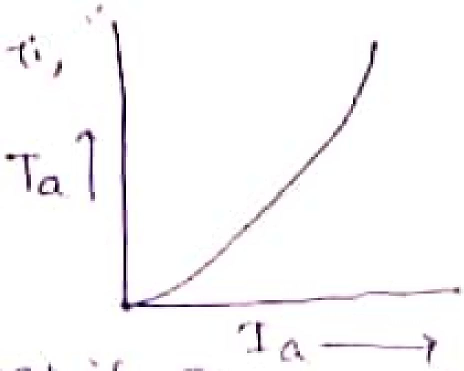
In this type of motor series field winding is so connected that flux produced by it is in same direction in shunt field winding.
So here any load the total flux is the sum of shunt and series flux

$$\phi = \phi_{se} + \phi_{sh}$$

So resultant flux depends upon current

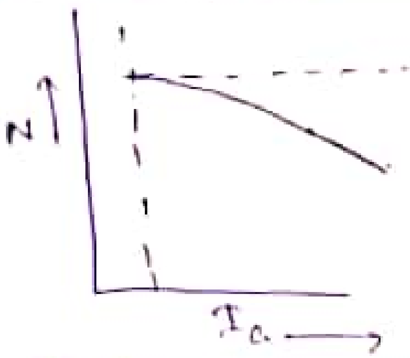
Ta/Ia characteristics:- (i)

We know $T_a \propto \phi I_a$
So here we know
$\phi = \phi_{se} + \phi_{sh}$



So Torque is increased if Ia increase.
(2) Here Ta v Ia is greater than shunt motor

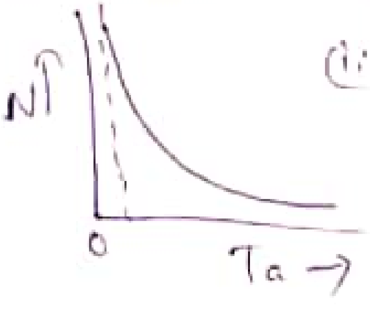
N/Ia characteristics



When load increases, total flux increases So speed of the motor decreases

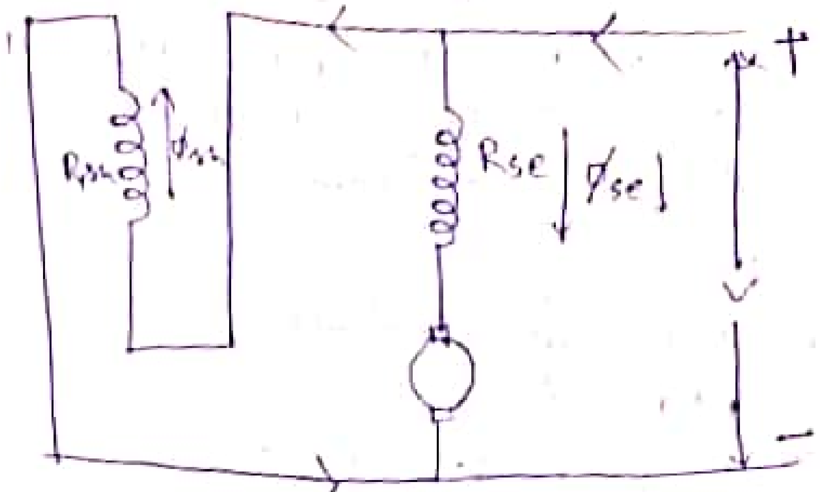
If the machine were running on either field alone. from N/Ia characteristics
(i) Speed of the motor reduced in the case of heavy loads in series motor.
(ii) It is in safe limit at no load. in the case of shunt motor, because shunt field winding produces flux with no load.

N/Ta ch:- (i) It lies betn that of shunt and series motor.
(ii) It has series motor characteristic with the additional feature feature that no load speed is with in safe limits



Ch. of Differential compound motor :

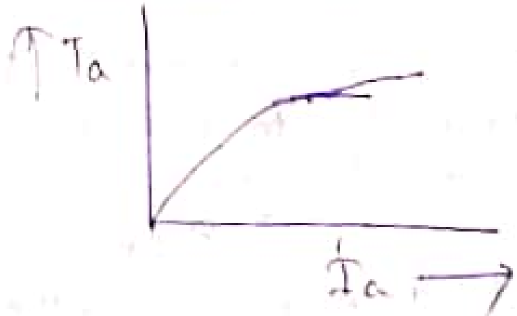
"In differential compound motor, the flux produced by series field winding is opposite to flux produced by shunt field winding.



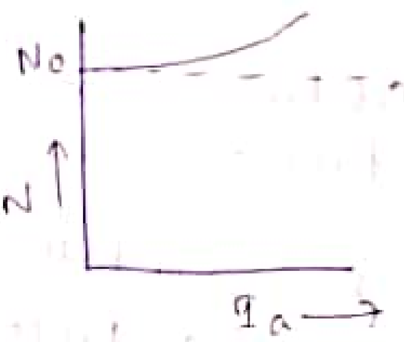
So here we can write $\phi = \phi_{sh} - \phi_{se}$

Ta/Ia characteristics

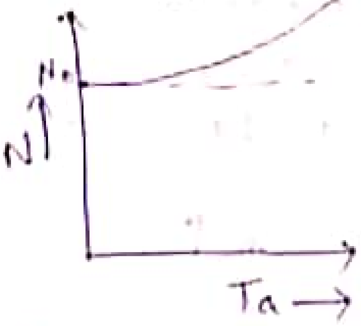
Since series winding opposes the shunt, so ϕ decreases as Ia increases. So because of this Ta increases with Ia but does not rapidly as series motor.



N/Ia characteristics. (i) when load increases, the resultant flux decreases, hence motor speed increases. So greater is load, lesser flux, and motor would be faster. It is very dangerous. So when we connect, care should be taken for connection



N/Ta characteristics

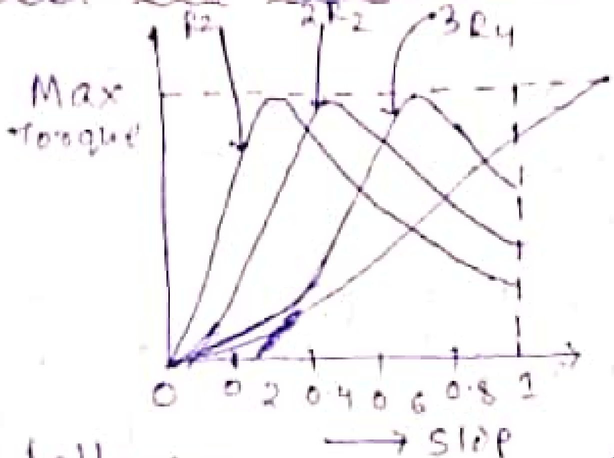


(i) If torque increases, the motor speed also increases. If the torque is too much increased, the machine may tend to attain dangerously high speed.

For AC traction system

3-φ Induction motor

Torque - Slip characteristics



The following graph shows for a range from S=0 to S=1.

(i) As S=0, T=0, so the torque/slip characteristics starts from origin.

We know $T = \frac{K_2 S R_2}{(R_2)^2 + (S x_2)^2}$

(ii) At normal speed, slip is small so that Sx_2 is negligible as compared to R_2.

So Torque, $T \propto \frac{S}{R_2}$

$\propto S$, as R_2 is constant

So it is a straight line from zero slip to a slip.

(iii) When slip increases beyond full load slip. Then T increases and become maximum at $S = \frac{R_2}{x_2}$.

Scanned with CamScanner

(v) when slip is increased beyond maximum torque. So $s^2x_2^2$ increases very rapidly so R_2^2 may be neglected as compared to $s^2x_2^2$

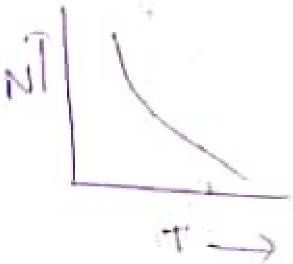
$T \propto \frac{s}{s^2} x_2^2$ $\quad T \propto \frac{1}{s}$

* These motors have been used for kendo system. These motor is not used any where in the world.

Single phase AC series motor

(i) The 1-ø series motor has practically same operating characteristics as d.c. series motor.

(ii) The torque varies nearly as square of the current and speed varies inversely as the current.



(iii) 1-ø series motor for a given kw o/p the weight is 1.5 times to 2 times of dc motor.

(iv) It has low power factor at starting and for a given current the starting torque is low. Then that of dc series motor. Due to poor starting torque this motors are not used for railway services, where there are frequent stop But it is used in Main line where high acc^n is not required.

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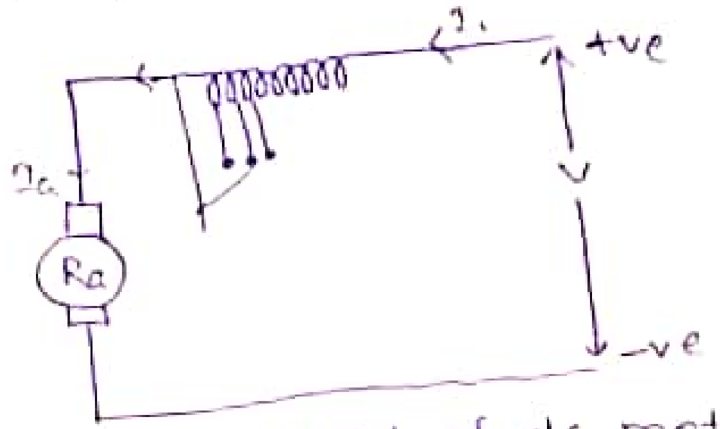
Tapped field Control :- We can control the speed by variation of field current. It is tapped field control method.



(i) We know speed of dc motor is inversely proportional to the flux i.e $N \propto \frac{1}{\phi}$. That means speed can be varied by varrying the flux assuming line voltage constant

(ii) In this method field coil is tapped dividing the number of turns. We select different value of ϕ by selecting a different number of turns

(iii) In this method flux is reduced, speed is increased by decreasing the number of the turns of series field winding.

(iv) In this case flux only can be reduced. Therefore this is known as field weakening method and speeds above normal can be obtained.

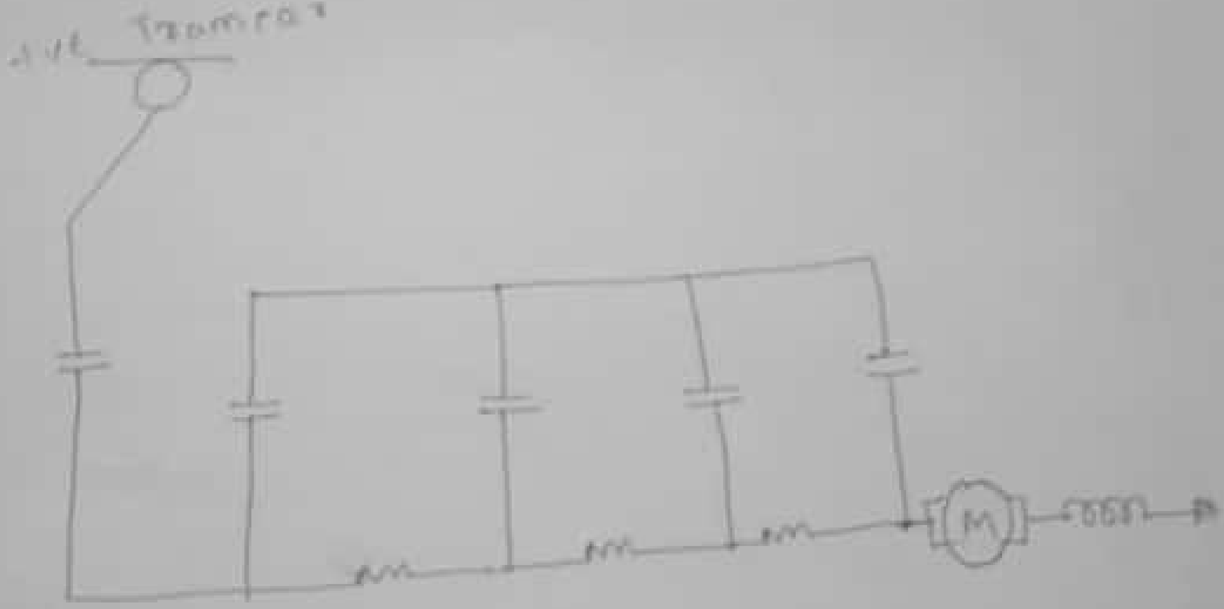
(v) By using this method, speed of the motor can be raised by 20% to 30% of the normal speed due to design difficulty with traction motors.

Rheostatic Control:- (i) Series motor can be started by connecting an external resistance in series with the main ckt of the motor.

(ii) At the time of start of the d.c series motor E_b will be zero. So in that condn full or maximum resistance is connected in series with the armature which is such of a value that the voltage drop across it with full load current is equal to the voltage.

(iii) At the time when motor picks up speed, the E_b developed with motor increases and with that the external resistance is gradually cut out in order to maintain the constant current through out the accelerating period.

(iv) A lot of power is wasted in external circuit.



Series Parallel Control

(i) In previous method, there is a wastage of electric power so for that we use series Parallel control method.

(ii) At least for this controls two motor have to be used. We can use 4 motors or 6 motors.

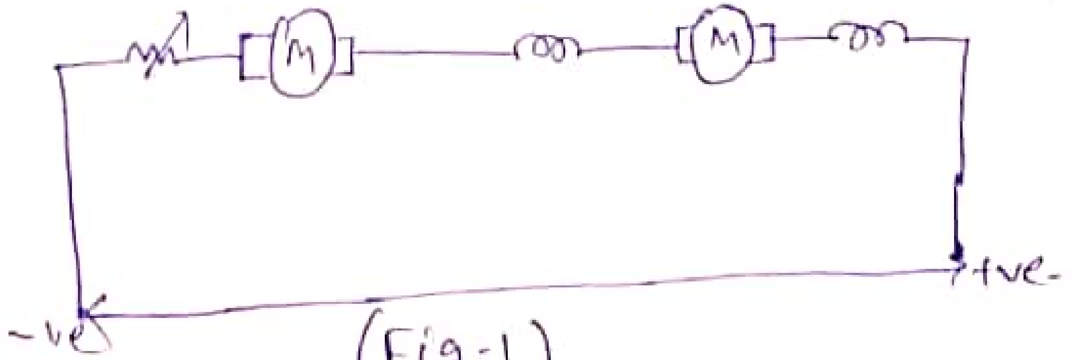
(iii) At starting, for low speeds trains are connected in series and than at full speeds these are connected in parallel.

(iv) In fig-1 The two motors are connected in series. In order to limit the starting current, we use series resistance. When the motor speed up, this is gradually cut out in fig-2

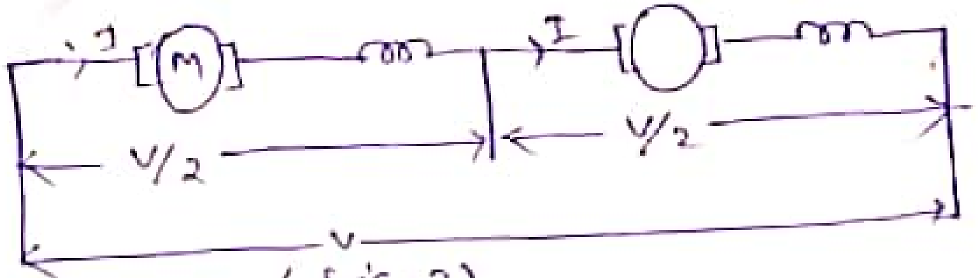
(v) Now the voltage across each motor will be half of the supply voltage across each motor So in this position due to this we get 1/2 of its normal speed.

(vi) When motor reaches its 40% of normal speed, then they are switched into parallel then an external resistance is connected (fig-3.), when it reaches full speed, the resistance gradually cut out.

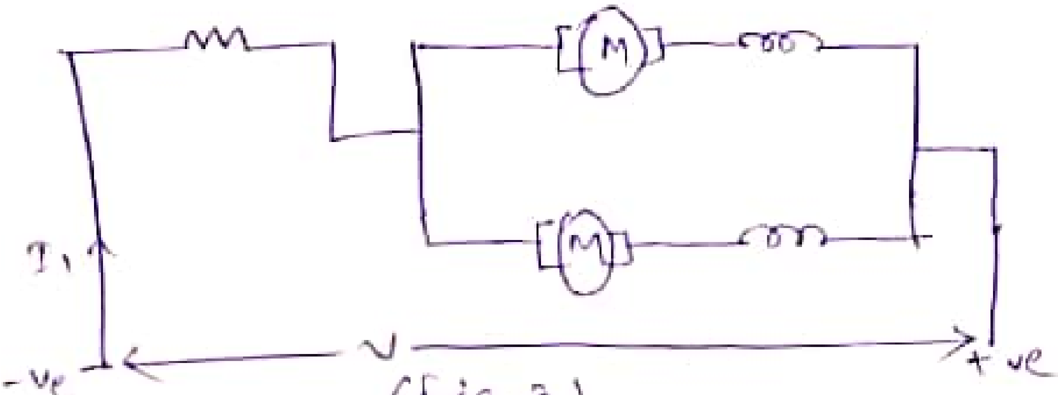
(vii) In this case voltage across each motor is V. So it has full speed.



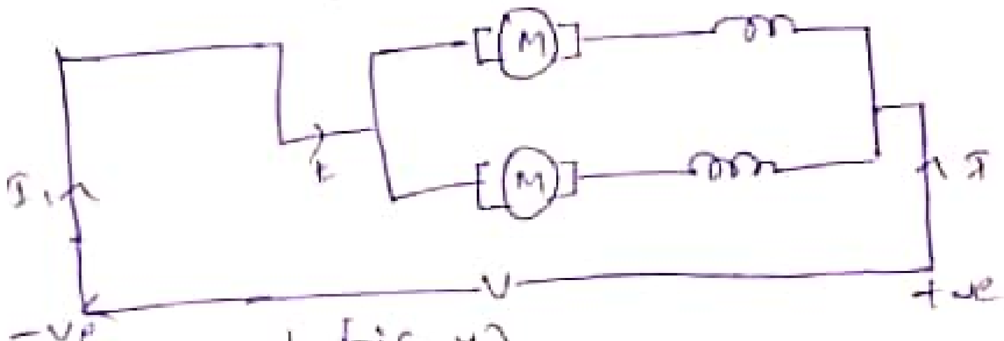
(Fig-1)



(Fig-2)



(Fig-3)



(Fig-4)

(viii) The biggest difficult in series parallel control to obtain a satisfactory method for transition from series to parallel without interrupting the torque or allowing any heavy rushes of current.

(ix) There are two methods
① Short circuit method
② Bridge Transmission method.

(x) In short circuit method, while transition happens torque reduced about 50% and in bridge Transmission method, when it is bridged, the torque remain constant

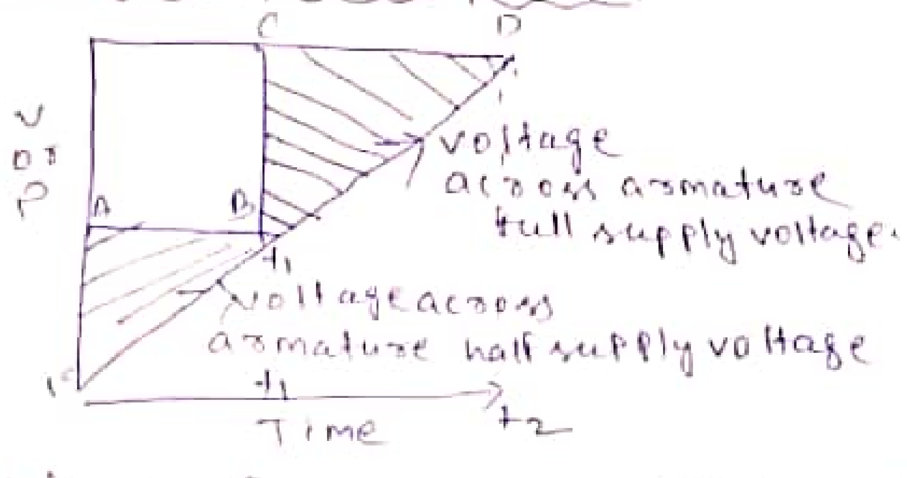
Advantage

(i) The biggest advantage of series parallel control method is, we can save energy loss in resistances during the starting period and when the motor is full speed or in parallel.

(ii) But in the case of rheostatic control, even if in those period there is wastage of electrical energy.

→ for Rheostatic control.

For Series Parallel Control



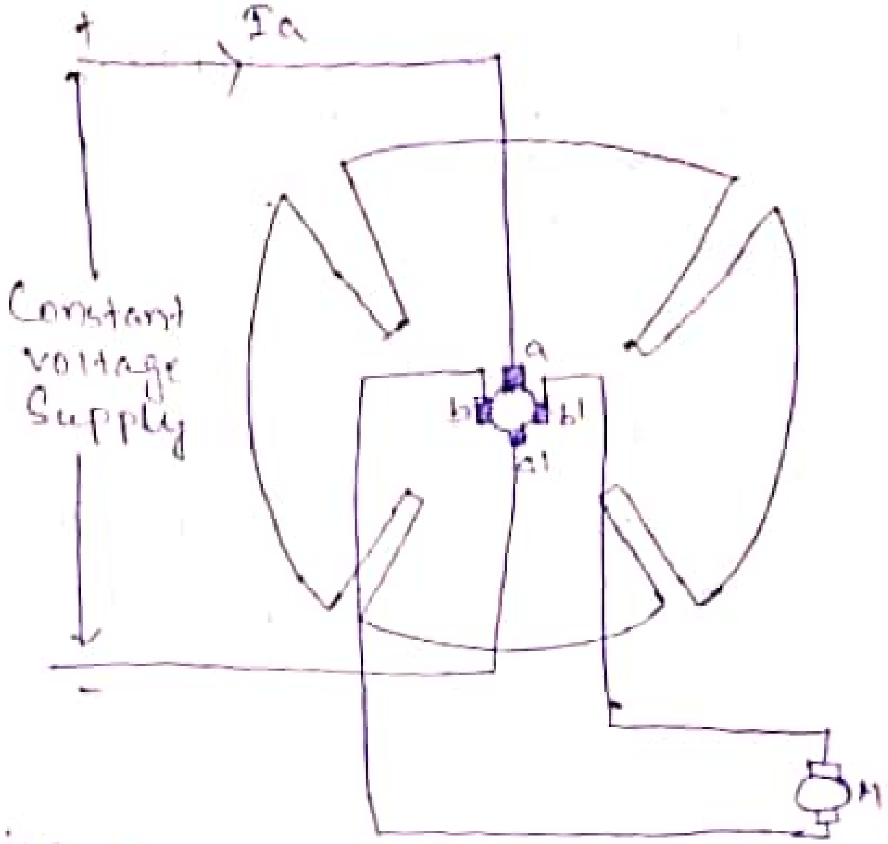
In this case from 0 to t_1, no resistance is inserted in the circuit, so energy wasted is showed in EAB.

When it is switched into parallel when time reaches to t_2 then. BCD represent the loss of energy by comparing the two diagram we see less energy wasted in series-parallel control.

in bridge transi......

bridged, the torque remain constant

Metadyne speed Control



(i) In this system metadyne converter is used w[hich] takes power at constant voltage and varia[ble] current and delivers same at constan[t] current and variable voltage.

(ii) In other control method there is a waste of electrical energy in series resistance.

(iii) But in this speed control, since curre[nt] throughout the starting period remai[ns] constant, uniform tractive effort is developed. This gives very smooth driv[e].

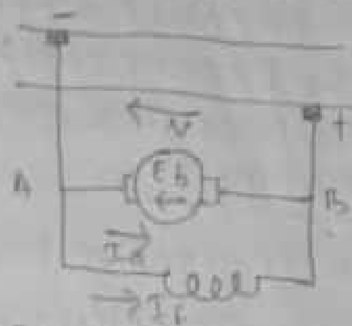
Construction:- (i) It has two pole d.c. armatu[re] and four pole field magnet. There are fou[r] sets of brushes one set connected to constant voltage supply main and the oth[er] is connected to load or traction motor.

Operation:- It draws Ia from the mai[n] and gives constant current to traction motor.

Braking of the system

Regenerative Braking: In other braking method, when mechanical energy is converted to electrical energy, then the energy was dissipated in the external resistance.

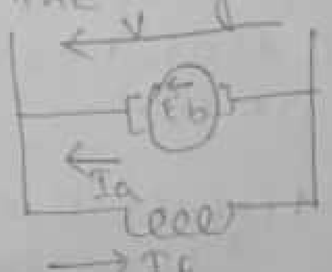
(ii) But in regenerative braking, the machine generates energy and feeds back to supply. Let us consider a shunt motor.



(ii) Here if Eb becomes greater than the applied voltage. The machine instead of taking power from the supply sends back power to supply. This can be achieved if

(i) Supply voltage V is reduced.
(ii) If field excitation is increased. then Eb becomes greater than V.
(iii) If N > N₀, then Eb becomes greater than V.

-So now the diagram will be



(iv) When Eb becomes greater than V the direction of Ia becomes reversed, but the field remaining same. The torque produced is in opposite (reverse direction). Thus braking effect is produced. But when the torque is reversed, the motor reduces the speed because of that it reduces Eb

So it is not possible to obtain regenerative braking at very low speed, because E_b falls down.

(v) So It cannot stop the motor. It can only applied to overhauling load which tends to drive motor at speed greater than no load speed. It can take place in a crane motor.

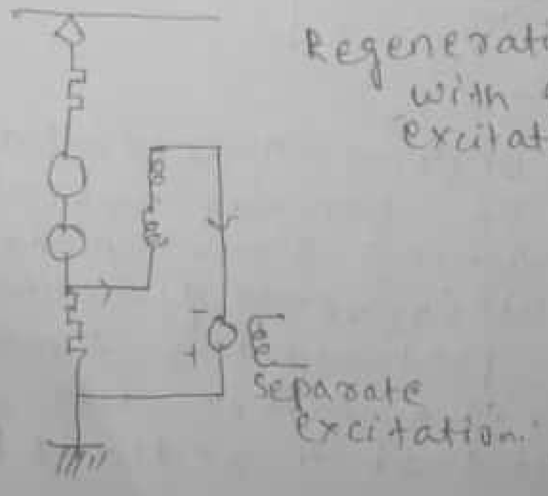
(vi) The conditions with a series motor are not so simple because when I_a reverses then I_f reversed. So Regenerative braking cannot be applied to DC series motors.

Braking with AC series motor:

(i) When we apply regenerative braking it is very difficult with DC series motor because of necessity of maintaining a high power factor in order to secure a reasonable braking effect.

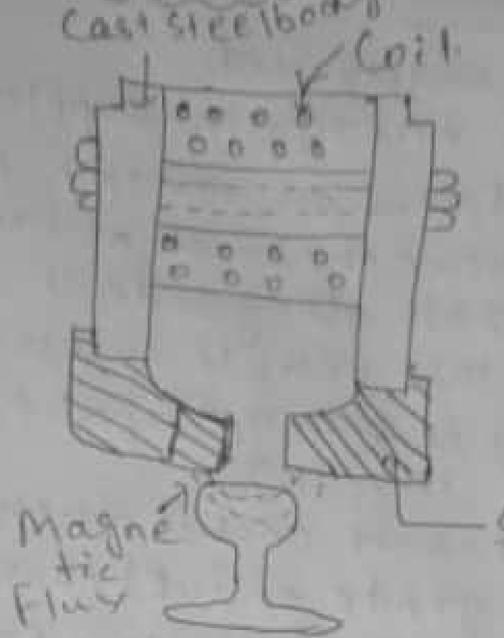
(ii) To obtain this the fields must be separately excited and provided with a phase-shifting device to secure the correct phase angle.

(iii) For Rheostatic braking, machines operating as generators excited from the supply or self excited as d.c machines and loaded on resistances.



Regenerative braking with separate excitation

Magnetic Braking



(i) It consists of a bipolar electromagnet with elognated pole faces a short distance apart and along with rails.

(ii) Its body is made of cast steel and pole faces of soft steel. Pole faces are parallel to the rail.

(iii) Passage of current through exciting coil, which passes produces magnetisation perpendicular to the rail face. This produces force of attraction between magnetic pole faces and rail.

$$F = \frac{B^2 a}{2\mu_0} \text{ newtons}$$

$$= \frac{B^2 a}{8 \times 10^{-3}} \text{ newtons}$$

(iv) The magnetic force in effect increases the weight on braking wheels with the result that braking force of the magnitude "μF" is produced.

(v) Magnetic brake is fitted in between wheels of bogie and runs logitudinal along the track.