D.C. Motor [Ch-2]

Motor is a electrical device which converts electric energy into mechanical energy.

principle :-

Motor works on a principle that when a current carrying conductor is placed in a magnetic field, It experiences a a mechanical force, whose direction is given by flemings ~~right~~ left hand rule and whose magnitude is given by F = BIl newton,

Back e.m.f.

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

maximum power developed

$$P_m = VI_a - I_a^2 R_a$$

$$\frac{dP_m}{dI_a} = V - 2I_a R_a = 0$$

$$I_a R_a = \frac{V}{2}$$

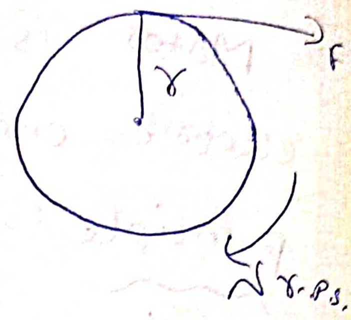
$$V = E_b + I_a R_a$$

$$E_b = \frac{V}{2}$$

$\omega = 2\pi f$

Torque

Torque is the turning or twisting moment of a force about an axis.



$T = F \times r$

Work done for one revolution

$= \text{force} \times \text{distance}$

$= F \times 2\pi r$ Joule

Power developed $= F \times 2\pi r \times N$ Joule/second

$= (F \times r) \times 2\pi N$ watt

$P = T \times \omega$

$$P = \frac{2\pi N}{60} \times T \text{ watt}$$

$$P = \frac{NT}{9.55} \text{ watt}$$

$E_b I_a = T_a \times 2\pi N$

$E_b = \phi Z N (P/A)$

$T_a \times 2\pi N = \phi Z N (P/A) \times I_a$

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

$$T_a = 0.159\, \phi Z I_a (P/A) \text{ N-m}$$

$$T_a = \frac{E_b I_a}{\frac{2\pi N}{60}} = 60 \frac{E_b I_a}{2\pi N} = 9.55 \frac{E_b I_a}{N}$$

N - rps

=

$$T_{sh} = \frac{\text{output in watt}}{\frac{2\pi N}{60}}$$

$$\boxed{T_{sh} = 9.55 \frac{\text{output}}{N}}$$

Speed of a DC motor

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

$$N = \frac{E_b}{\phi} \times \left(\frac{60A}{PZ}\right)$$

$$N = k \frac{E_b}{\phi}$$

For series motor

$\phi \propto I_a$

so

$$\frac{N_2}{N_1} = \frac{E_{b2}}{E_{b1}} \times \frac{I_{a1}}{I_{a2}}$$

For shunt motor

$\phi = \text{const.}$

$$\frac{N_2}{N_1} = \frac{E_{b2}}{E_{b1}}$$

Speed Regulation :-

It is the ratio of difference in speed from No load to full load to the full load speed

% Speed regulation = $\frac{\text{N.L. speed} - \text{F.L speed}}{\text{F.L. speed}} \times 100$

Motor characteristics

(1) Torque and armature current

T_a / I_a (electrical)

(2) speed and armature current

N / I_a charateristics

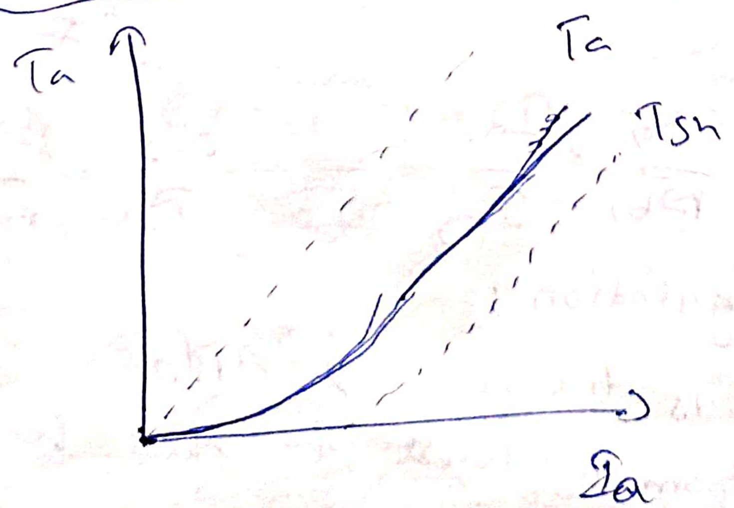
(3) speed and Torque

N / T_a charac.

$T_a \propto \phi I_a$, $N \propto \frac{E_b}{\phi}$

characteristics of series motor :-

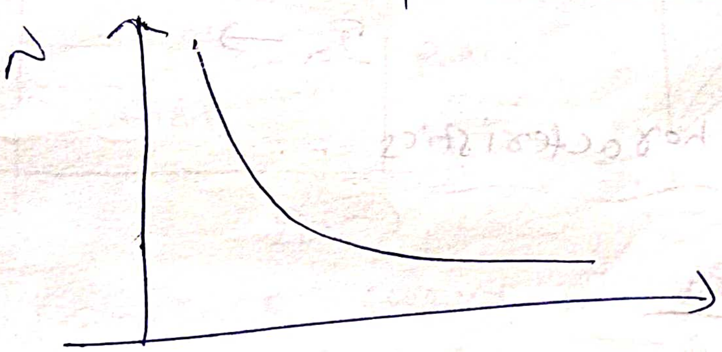
T_a / I_a characteristic :-



Before magnetic saturation on heavy loads a series motor exerts a torque proportional to the square of armature current. So where huge starting torque is required for accelerating heavy masses quickly as in hoists and electric trains etc.

N/I_a characteristics

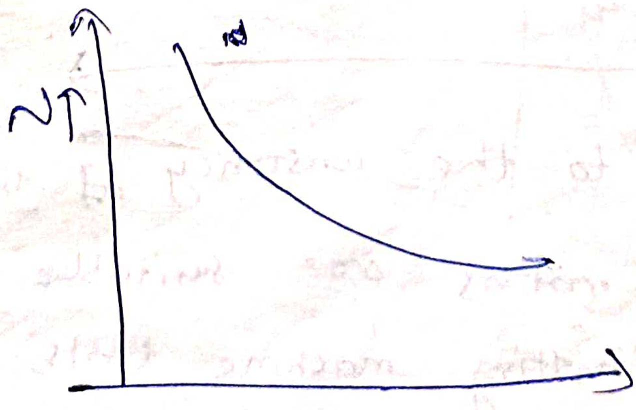
$N \propto \frac{E_b}{\phi}$ $\qquad N \propto \frac{1}{I_a}$



When load current falls to a small value, speed becomes dangerously high.

N/T_a characteristics :-

From above

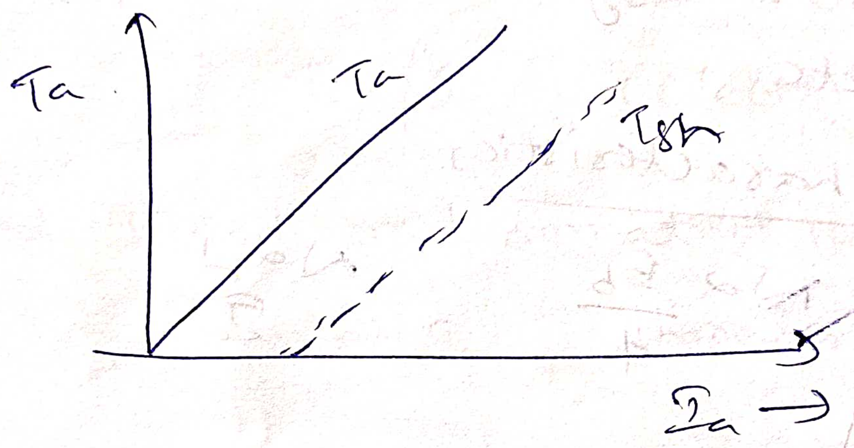


Characteristics of shunt motor :-

① T_a/I_a characteristic :-

as ϕ = const.

$T_a \propto I_a$

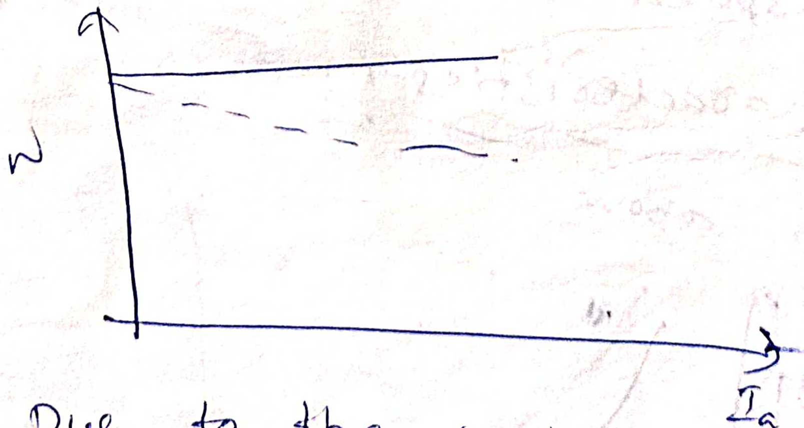


② N/I_a characteristics :-

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

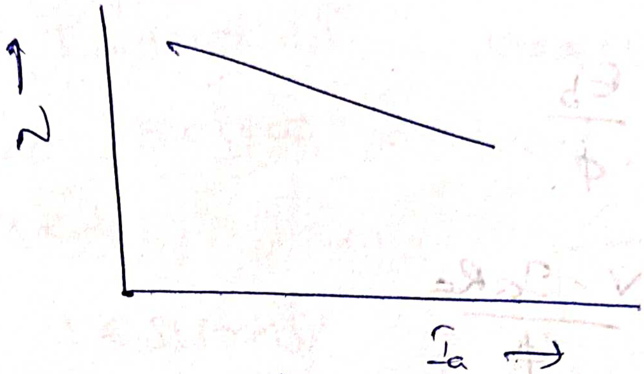
ϕ = const.

$N \propto E_b$ E_b = const.

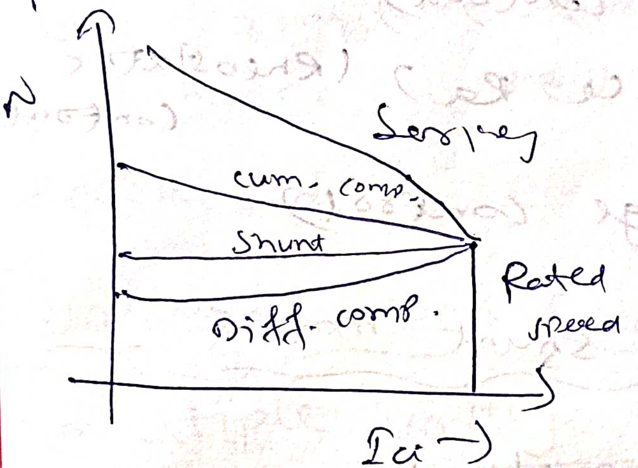


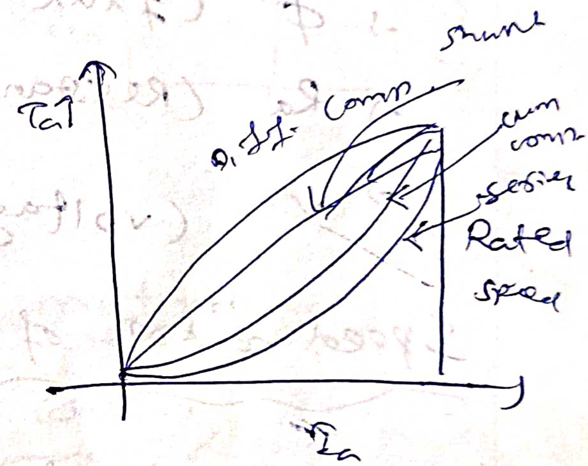
Due to the constancy of their speed shunt motors are suitable for driving shafting, machine tools, lathes, wood working.

N/Ta characteristics :-



compound motors :-

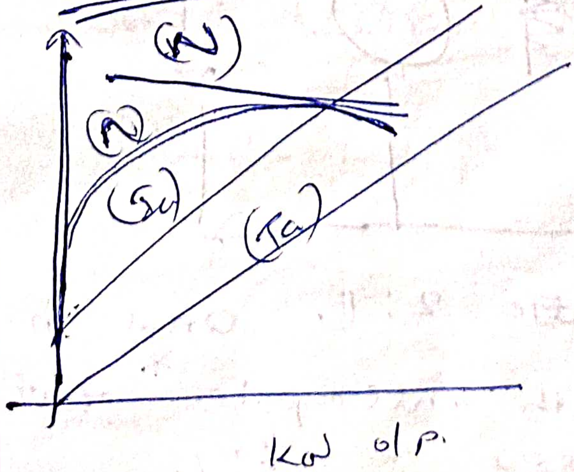


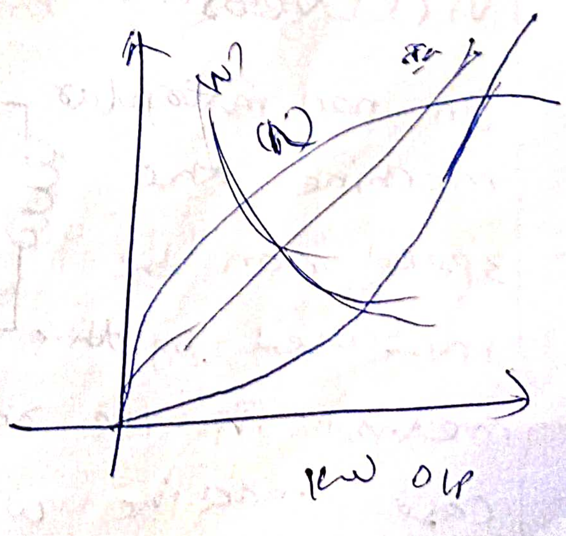


performance curve of motor :-

- When four essential characteristics i.e. torque, current, speed & efficiency plotted as a function of motor output power known as performance curves of a motor.

Shunt





Speed control of DC motors :-

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

$$N \propto \frac{V - I_a R_a}{\phi}$$

Factors controlling speed

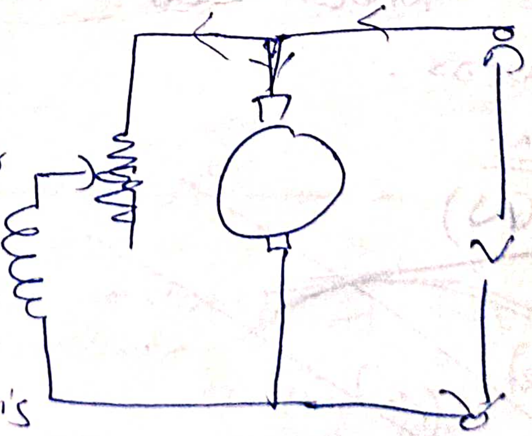
- ϕ (flux control)
- R_a (Resistance R_a) (Rheostatic control)
- V (voltage control)

Speed control of shunt motors :-

Flux control method

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

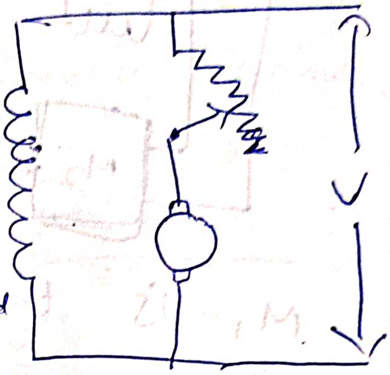
By decreasing the flux the speed can be increased and vice versa.



In non interpolar machine the speed can be increased by this method in the ratio 2 : 1. and in case machine with inter poles ratio max to min speed is 6 : 1

Armature of Rheostatic control method

This method is required when speeds below no-load speed are required.



When resistance is increased p.d. across the armature decreased and hence speed decreased

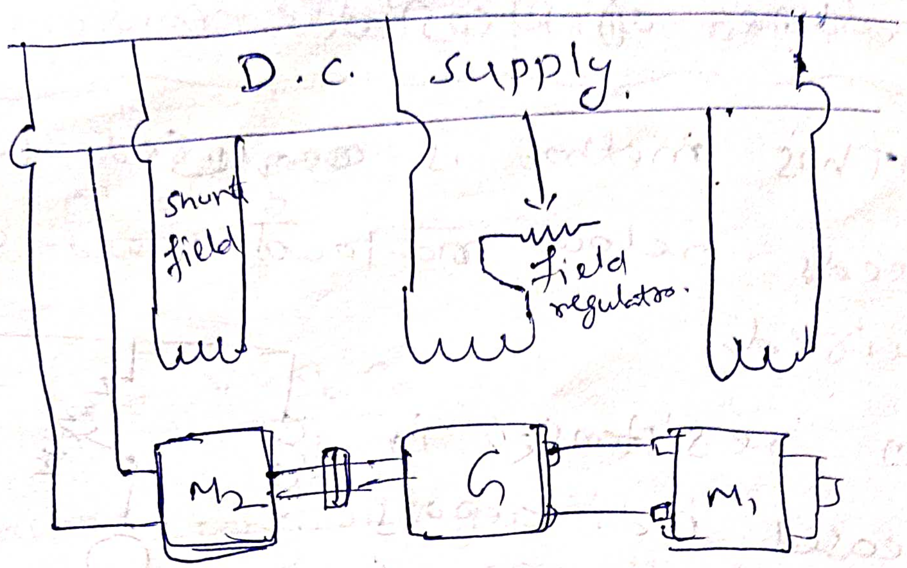
Voltage control method :-

multiple voltage control

In this method armature is supplied with different voltages by connecting it across one of the several different voltages, by ~~means of~~ The armature Voltage is approximately proportional to these different voltages.

Ward Leonard System :

wide range (10 : 1)



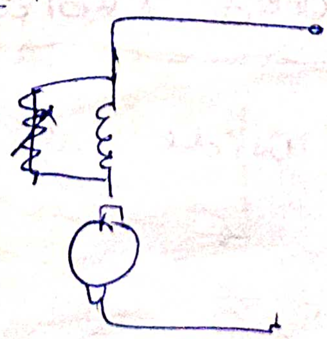
M_1 is the main motor whose speed control is required.

The motor M_2 runs at approximately const. speed. The output voltage of G is directly fed to the main motor M_1. The voltage of the generator can be varied from zero up to its maximum value by means of its field regulators.

Speed control of DC Series motors

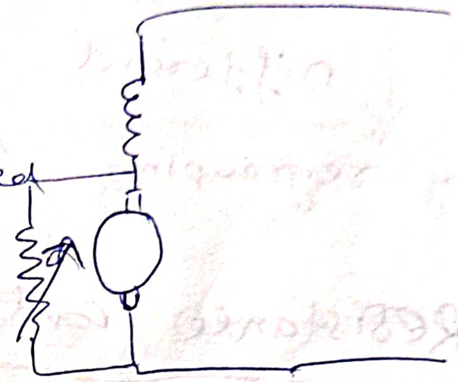
Flux control method

(a) field diverters



The series winding shunted by a variable resistance known as field divertor. Any desired amount of current can be passed through the divertor by adjusting its resistance. Hence the flux can be decreased and consequently speed of motor increased.

(b) Armature diverter :-



$T \propto \phi I_a$

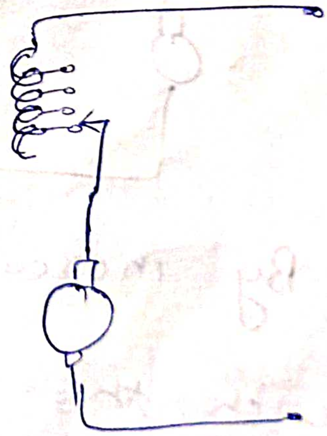
when I_a is reduced

ϕ increases

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

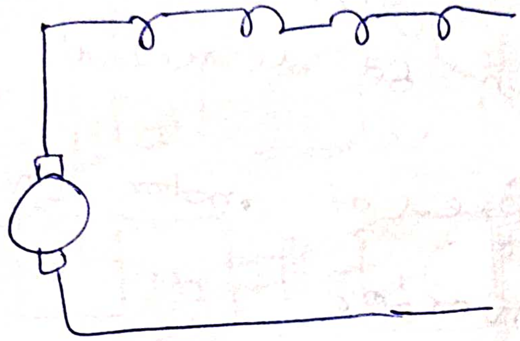
speed falls.

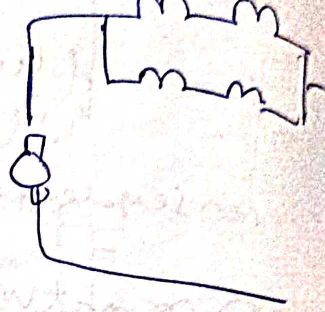
(c) Tapped field control :-



With full field the motor runs at its minimum speed which can be raised in steps by cutting some of the series turns.

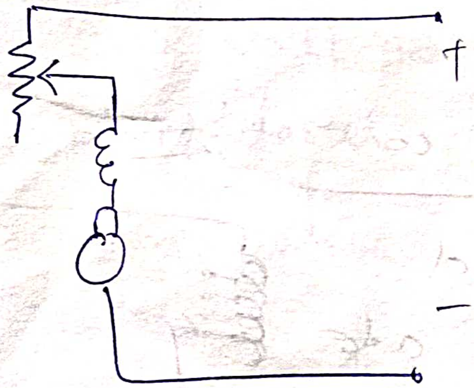
Paralleling field coils





Different speeds can be obtained by regrouping the field coils.

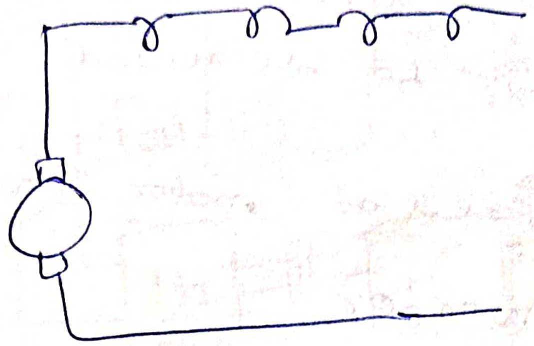
Resistance control or variable resistance in series with motor :-

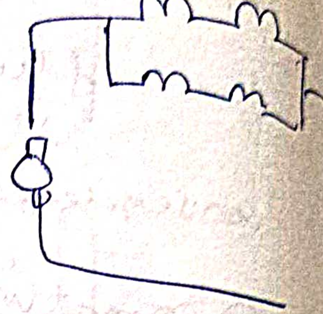


By increasing the resistance in series with the armature the voltage applied across the armature terminals can be decreased, & thus speed is decreased.

there is more power loss in this method.

Paralleling field coils





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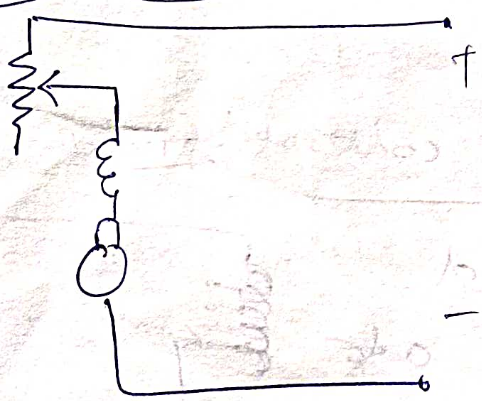
Resistance control or variable resistance in series with motor :-



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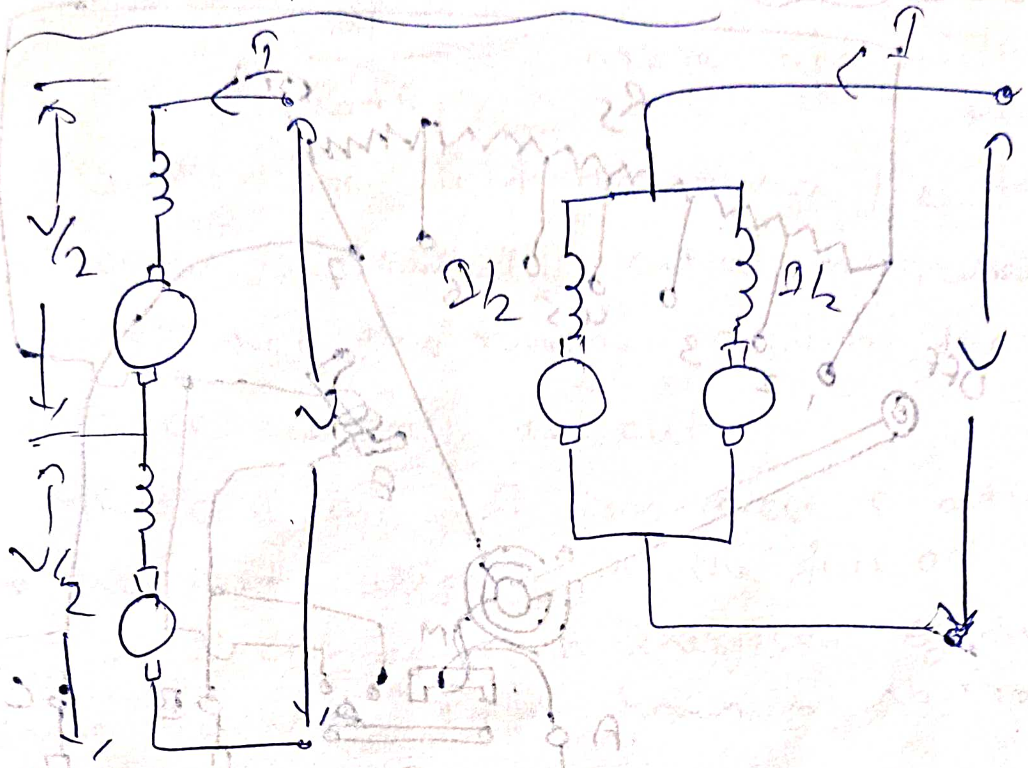
Series parallel control,



For series

$N \propto \frac{V/2}{I} \propto \frac{V}{2I}$

for parallel

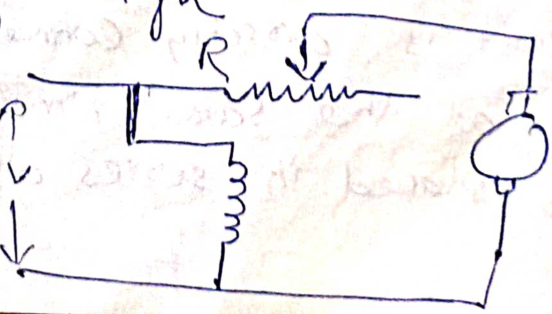
$\text{speed} \propto \frac{V}{I/2} \propto \frac{2V}{I}$

in parallel speed is 4 times compared to series.

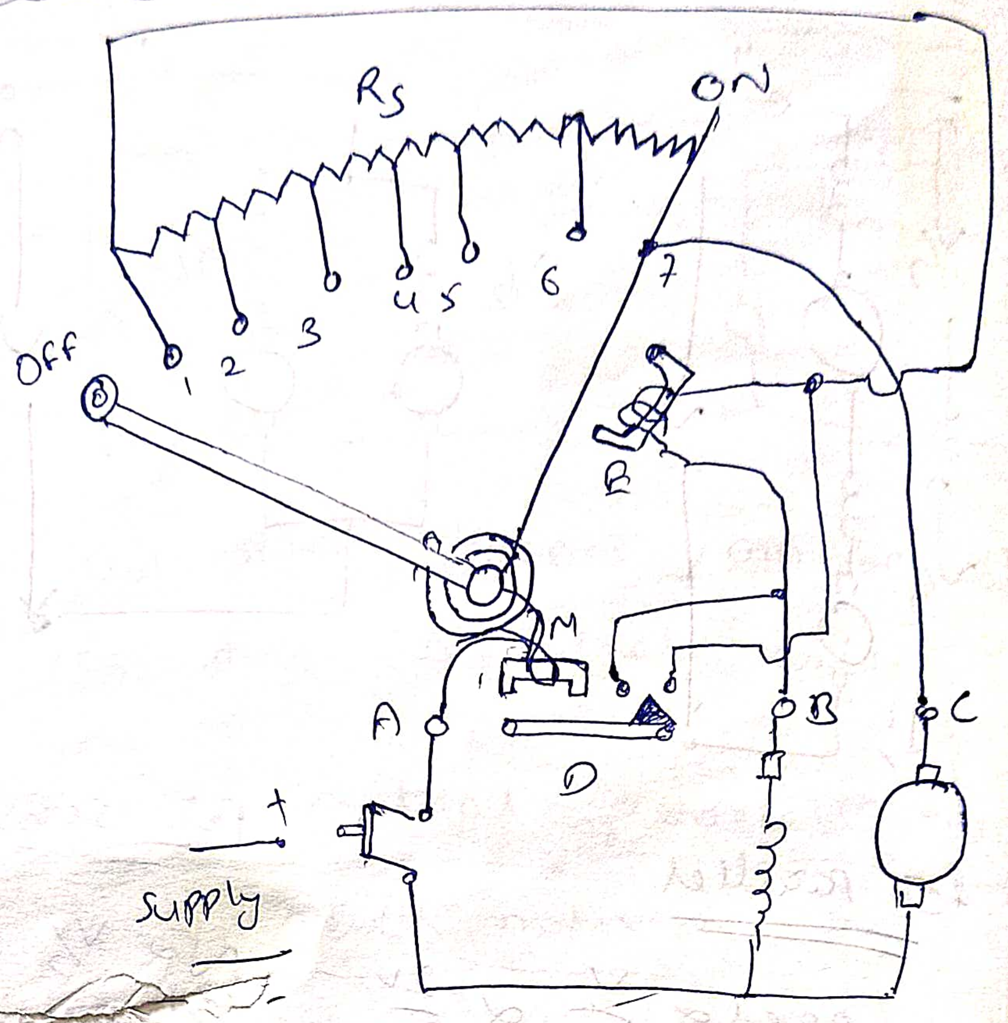
Necessity of a starter

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

At starting as $N=0$, $E_b = 0$ and V is full and R_a is small. So I_a will be very high



3 point starter :



Three terminals A, B, C

C is connected to armature

B to field & A is connected to line through overcurrent release.

To start the motor the main switch is first closed and then the starting arm is slowly moved to the right. As soon as the arm makes contact with stud No. 1 the field circuit is directly connected across the line and at the same time full starting resistance R is placed in series with the armature.

The starting current drawn by armature

$$= \frac{V}{R_a + R_s}$$ where R_s = Starting Resistance.

As the arm is further moved the starting resistance is gradually cut out till, when the arm reaches the running position, the resistance is all cut out.

There is a soft iron piece S attached to the arm which is in the full ON held by an electromagnet E energised by the shunt current. It is known as No-voltage release.

In case of failure or disconnection of the supply ~~for the~~ break in the field circuit ~~the~~ No voltage (Hold ON) release is deenergised, there by releasing the arm which is pulled back by the spring to the OFF position.

The overcurrent release consists of an electromagnet connected in the supply line. If the motor becomes overloaded beyond a certain predetermined value, the D is lifted and short circuits the electromagnet. Hence the arm is released and returns to OFF position.

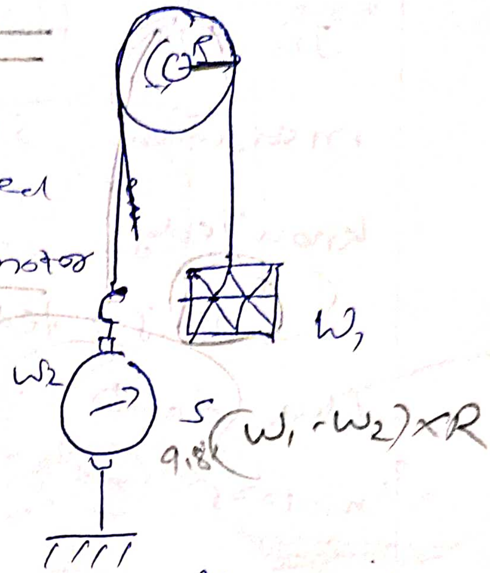
Limitation of 3- point starters

If it is desired to control the speed of the motor then field rheostat is connected in the field circuit. The motor speed can be increased by weakening the flux. But if too much resistance is cut in by the field reheostat, then field current is reduced very much so that it is unable to create enough electromagnetic pull to overcome the spring tension, Hence arm is pulled back to off position, so it is unsuitable for use with variable speed motors.

Brake test :

It is a direct method.

It consists of applying a brake to a water cooled pulley mounted on the motor shaft.



One end of the band is fixed to earth via a spring balance S and the other is connected to a suspended weight W_1.

W_1 = suspended weight in kg.

W_2 = Reading of spring balance in kg.

R = Radius of the pulley in metre

N = motor speed in R.P.S.

Shaft torque $= (W_1 - W_2) \times R$ kg-m

$$T_{sh} = 9.81 (W_1 - W_2) \times R \text{ N-m}$$

Motor output power $= T_{sh} \times 2\pi N$ watt

$$= 2\pi \times 9.81 N (W_1 - W_2) R \text{ watt}$$

$$= 61.68 N (W_1 - W_2) \times R \text{ watt}$$

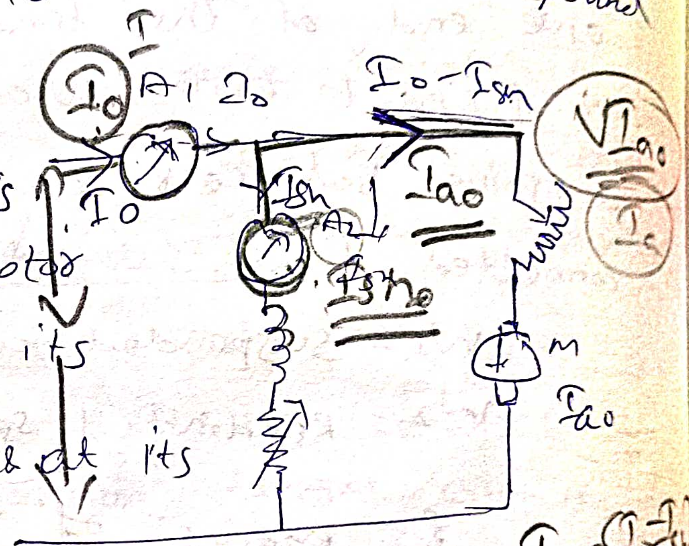
$$\eta = \frac{\text{output}}{\text{input}} = \frac{61.68 N (W_1 - W_2) R}{V I}$$

Swinburne's test (No-load test) (V)

In this method losses are calculated measured separately and from their knowledge efficiency

This test is applicable to const. flux device like shunt and compound motors.

The machine is running as a motor on no-load at its rated voltages at its rated speed.



$I_{a0} = (I_0 - I_{sh})$

No-load current by A_1 - I_0

Shunt field current by A_2 - I_{sh}

No load armature current $= I_0 - I_{sh} = I_{a0}$

Total input $= VI_0$

power input to armature $= VI_{a0} = V(I_0 - I_{sh})$

power input to shunt $= VI_{sh}$

armature power includes

(i) Iron loss in core

(ii) friction loss

(iii) windage loss

(iv) armature cu-loss $(I_0 - I_{sh})^2 \times R_a$

$I_{a0}^2 R_a$

If we subtract from total input no-load armature loss we get constant losses.

$$W_c = VI_0 - (I_0 - I_{sh})^2 R_a$$

for motor

Input = VI

Armature Cu loss = $I_a^2 R_a = (I - I_{sh})^2 R_a$

Const loss = W_c

$$\eta_m = \frac{\text{input} - \text{total loss}}{\text{Input}} \times 100$$

$$= \frac{VI - (I - I_{sh})^2 R_a - W_c}{VI} \times 100$$

for generator

Output = VI.

$$\eta = \frac{\text{output}}{\text{output} + \text{losses}} = \frac{VI}{VI + (I + I_{sh})^2 R_a + W_c}$$

Advantages :-

-> It is economical because power required to test a large machine is small

-> Efficiency ~~~~ can be predetermined at any load bcz const. losses are known

~~Disadvan~~

Disadvantages :

-) Change in iron loss from no load to full-load is not considered.

-) As the test is on no-load it is impossible to know whether commut would be satisfactory at full-load and whether temperature rise would be within the specified limits.

Applications of DC motors

Shunt

-) centrifugal pumps, machine tools, Blowers, fans etc.

Series

For traction, Trolley, cars., cranes hoists, etc.

Cumulative compound

Elevators, conveyors, Rolling mills, printing press, Air compressors etc.