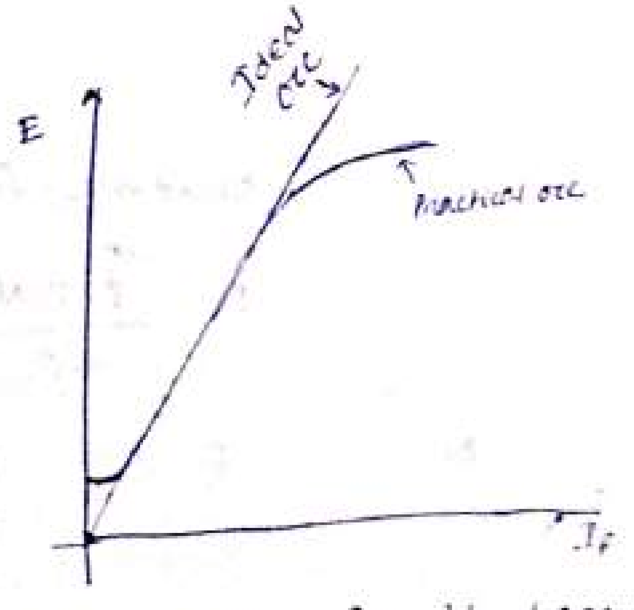
CHARACTERISTIC OF D.C GENERATOR :-

1. open circuit characteristic or magnetisation characteristic (OC
   E Vs I_f at N = constant
2. Load characteristic
   V Vs I_f / I_a = const, N = const
3. Internal cha ⇒ E_g Vs I_a / N = const
4. External characteristic . V vs I_L / N = const
5. Regulation curve ⇒ I_f Vs I_a / V = constant, N = const.

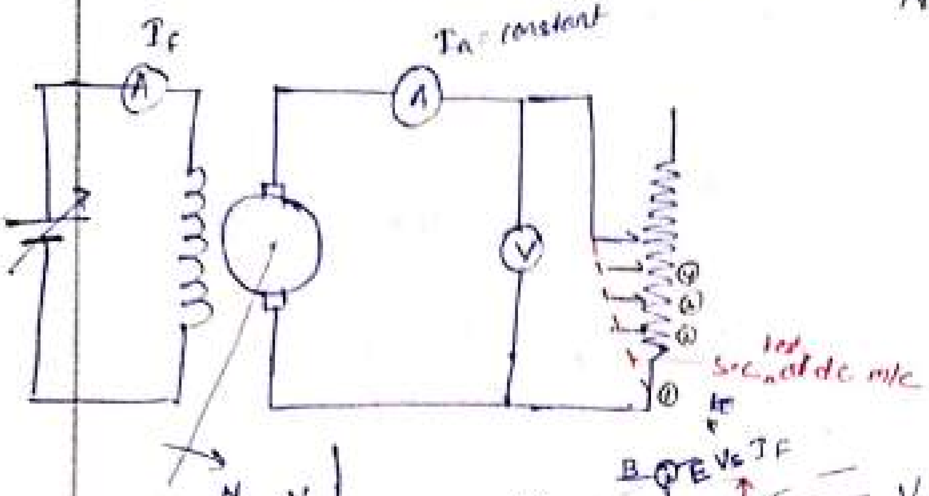
OCC :-



slope of ideal occ is critical field resistance.

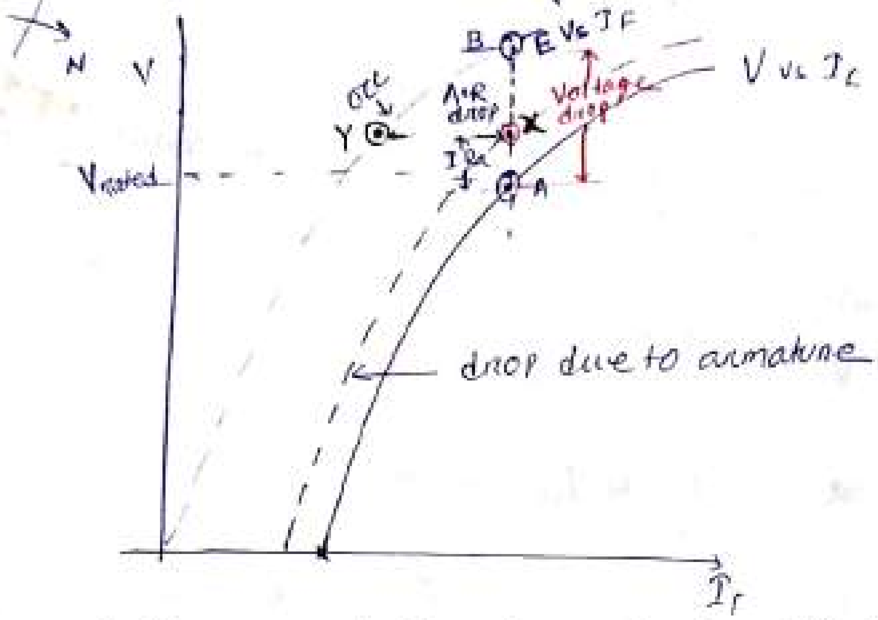
The slope of airgap line (ie ideal occ) = R_c (critical resistance)

Load characteristic :- V vs I_f | I_a = const, N = const



$I_a = 20\,A$

	I_f	V
①	2 A	0
②	3 A	20 V
	-	
	-	
	-	

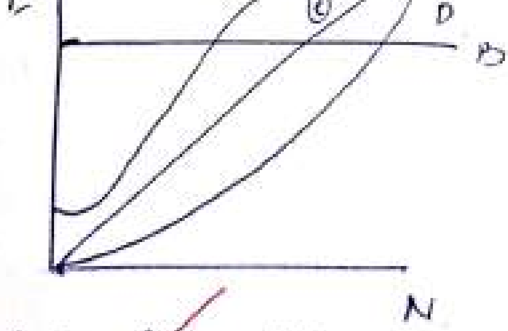


At short ckt load condition the field current exciting changes to get loaded to the rated load current in the ckt.

xy → field current to overcome the effect of A.R.

27/11/08

Which of the following characteristic represent the (Generator) voltage vs speed of a shunt m/c.



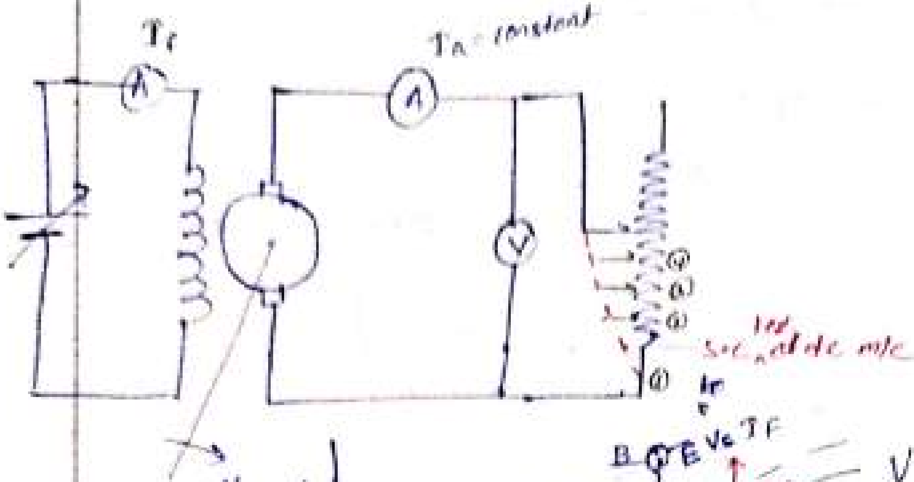
a) A b) B c) C ✓ d) D

Shunt m/c - flux constant

$$E = \frac{\phi Z N}{60}\left(\frac{P}{A}\right)$$

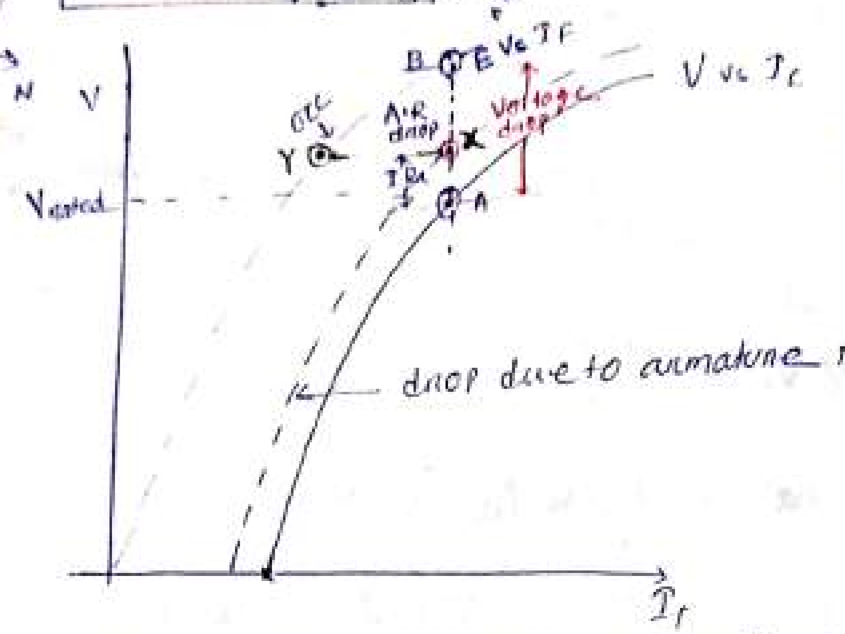
$E \propto N$ $N = 0$, $E = 0$

Load characteristic :- V vs I_f | I_a = const, N = const



I_a = 20 A

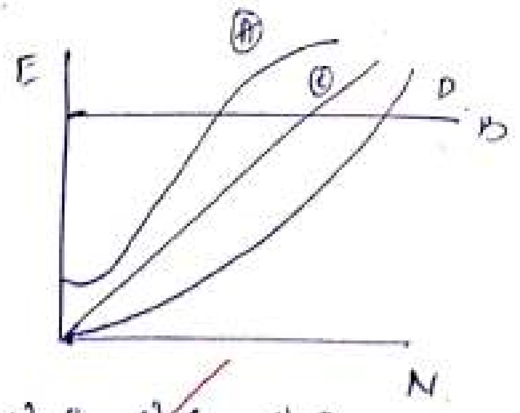
	I_f	V
①	2 A	0
②	3 A	20 V
	-	
	-	



At short ckt load condition the field current excitation changes to get load. to the rated load current of the ckt

xy → field current to overcome the effect of A.R.

Which of the following characteristic represent the Generator voltage E vs speed of a shunt m/c.



a) A b) B c) C ✓ d) D

Shunt m/c - flux constant

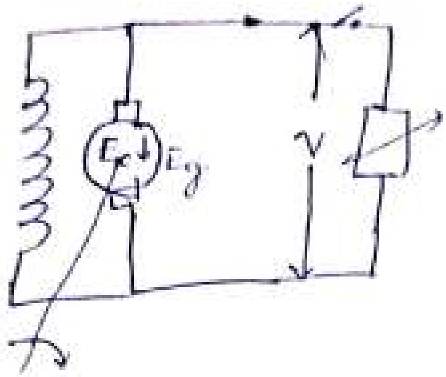
$$E = \frac{\phi Z N}{60}\left(\frac{P}{A}\right)$$

$E \propto N$ N = 0, E = 0

External characteristic :-

CAUSES FOR VOLTAGE DROP :-

1) Drop due to A R
2) Drop due to armature resistance $I_a R_a$
3) Drop due to reduction in field current due to reason (1) & (2)



$E_g = E$ - Armature ~~drop~~ Reaction drop

$E = E_g + AR$

no load generated voltage

~~$E = E_g + AR + R_a$~~

$E = V + I_a R_a +$ Drop due to A R

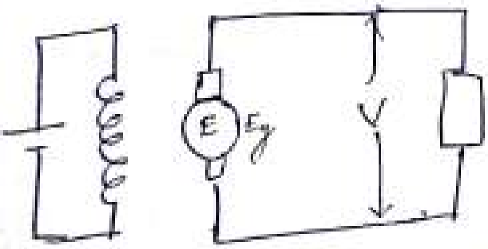
$E_g = V + I_a R_a$

$I_{sh} = \frac{V}{R_{sh}}$ - under load condition

E_g - generated voltage under loaded condition

$I_{sh} = \frac{E}{R_{sh}}$ - under no load condition

under ~~no~~ loaded condition, voltage reduces to V from E, so I_{sh} reduces so flux reduces the generated emf reduces. this is the drop due to 3rd condition.



In separately. drop due to field current does not exist, so reg is better drop is less regulated

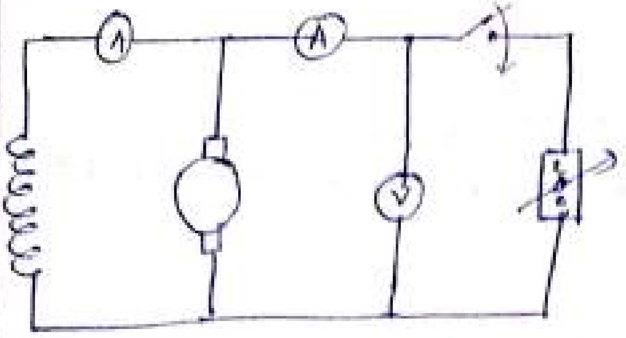
Q The voltage regulation of a shunt generator is 10% of the m/c is operated as separately excited generator with other thing remaining same the ~~ca~~ voltage regulation will be

(a) 10% (b) < 10% ✓ (c) m > 10% (d) none.

As drop in separately excited is less i.e absent of reduction in field ct loss so regulation is better i.e loss in magnitude than shunt generator.

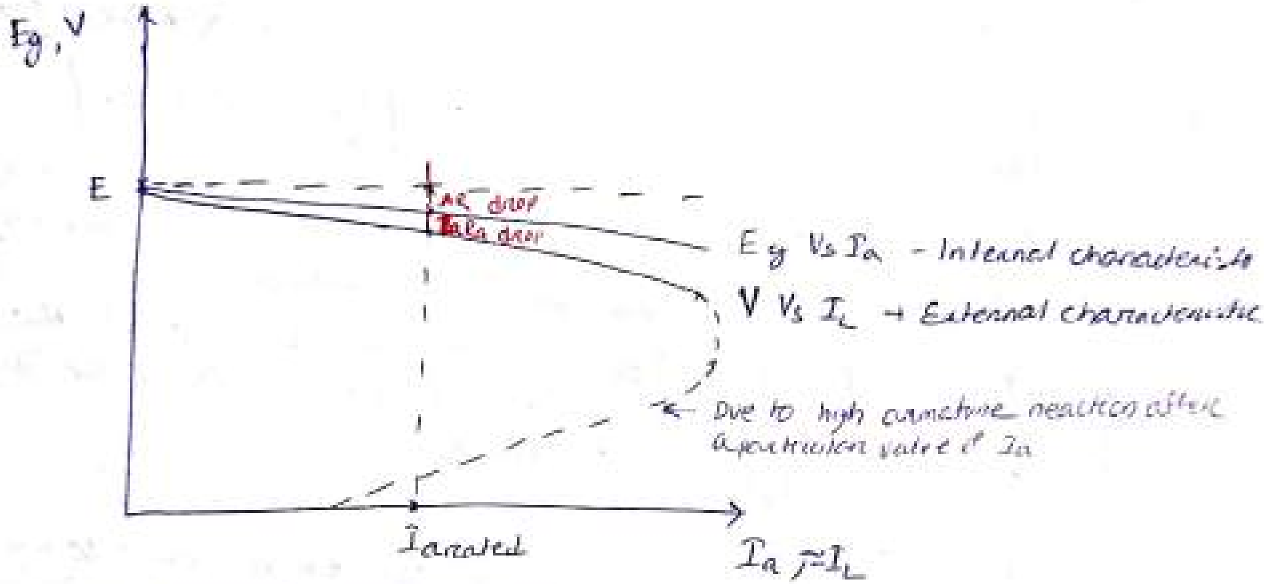
Scanned with CamScanner

Characteristic of DC shunt generator :-



$E_g = E -$ drop due to AR

$V = E_g - I_a R_a$



⇒ Drooping characteristic

Application :-

① It can be used as voltage source.

② As Battery charger

③ Exciter to synchronous m/c

Then terminal voltage is nearly constant therefore it can be used as

① Voltage source.

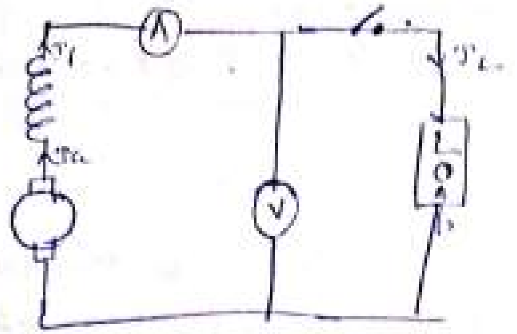
① ~~Acceta~~ Auxillary power supply

③ lightening.

④ Battery charger

⑤ As an exciter to excite the synchronous m/c.

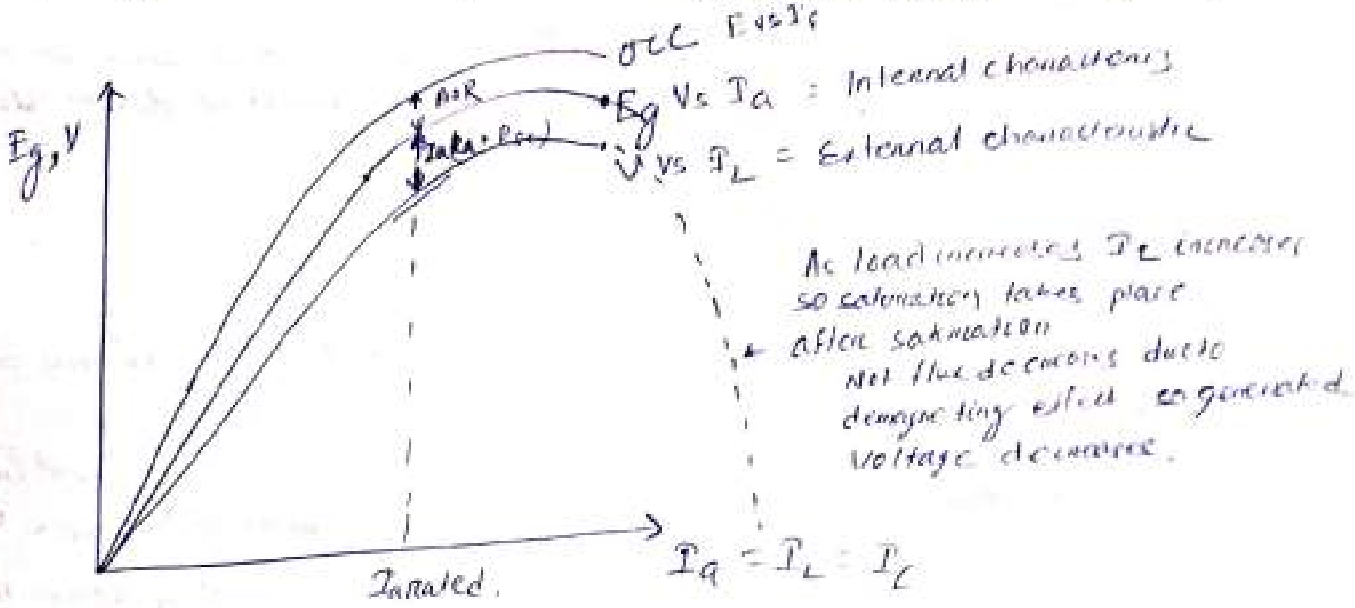
Series generator:-



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

$E_g \propto \phi \quad \because \phi \propto I_a$

$E_g \propto I_a$ so E_g Vs I_a is linear below saturation & non linear once the saturation begins.



⇒ RISING characteristic.

Series generators are used as booster in dc transmission line to maintain the voltage profile.

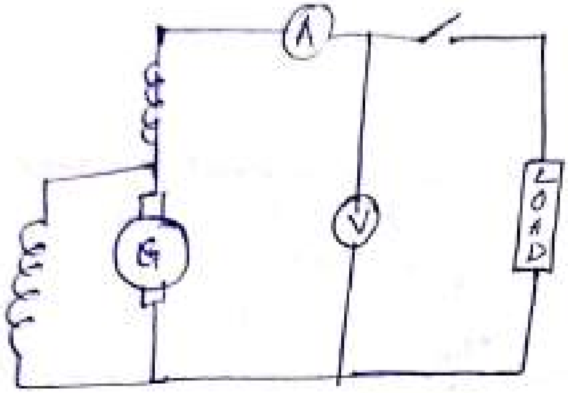
Series generator never be used as a voltage source bcoz as load increases its terminal voltage will increases.

Compound generator :-

1. Cummulative
2. Differential

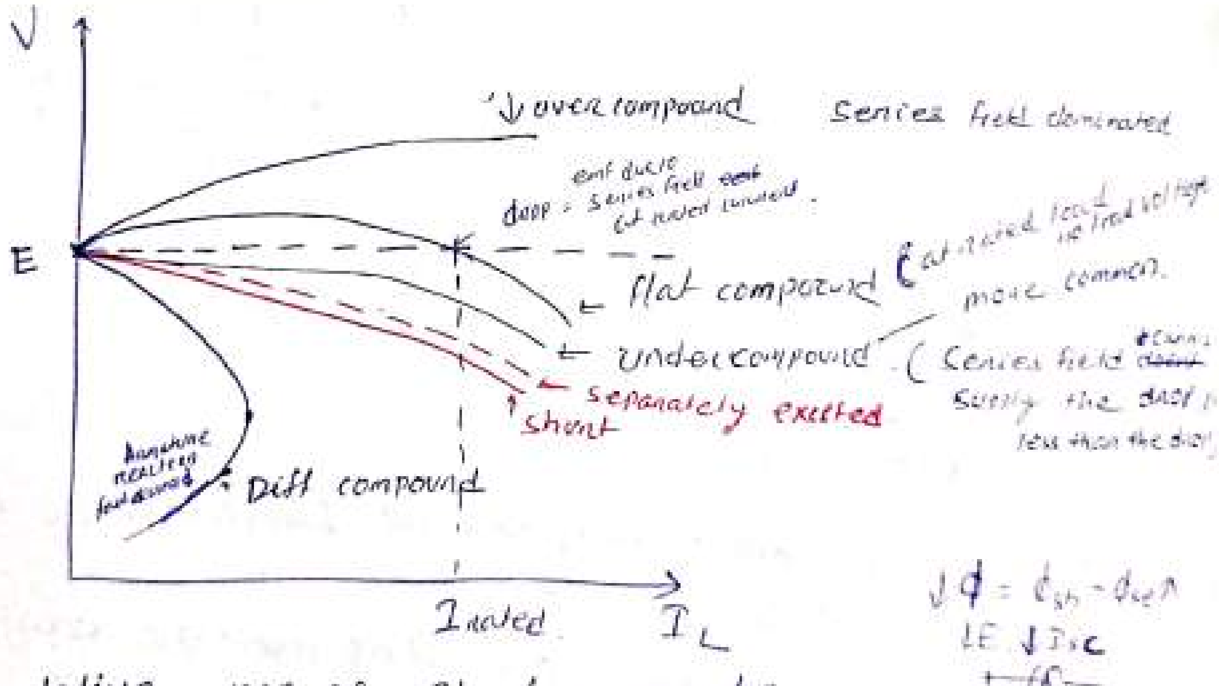
→ series field adds shunt field . $\phi = \phi_{se} + \phi_{sh}$ As load increases $I_a \uparrow$ $\phi_{se} \uparrow$ so $\phi \uparrow$ so generated voltage increases . terminal voltage increases.

→ $\phi = \phi_{sh} - \phi_{se}$. As load increases $I_a \uparrow$. $\phi_{se} \uparrow$ $\downarrow \phi = \phi_{sh} - \phi_{se} \uparrow$ so terminal voltage decreases . As generated voltage decreases



At no load some voltage will build up due to shunt field

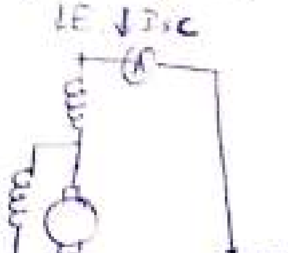
External characteristic :-



so cummulative uses as shunt generator.

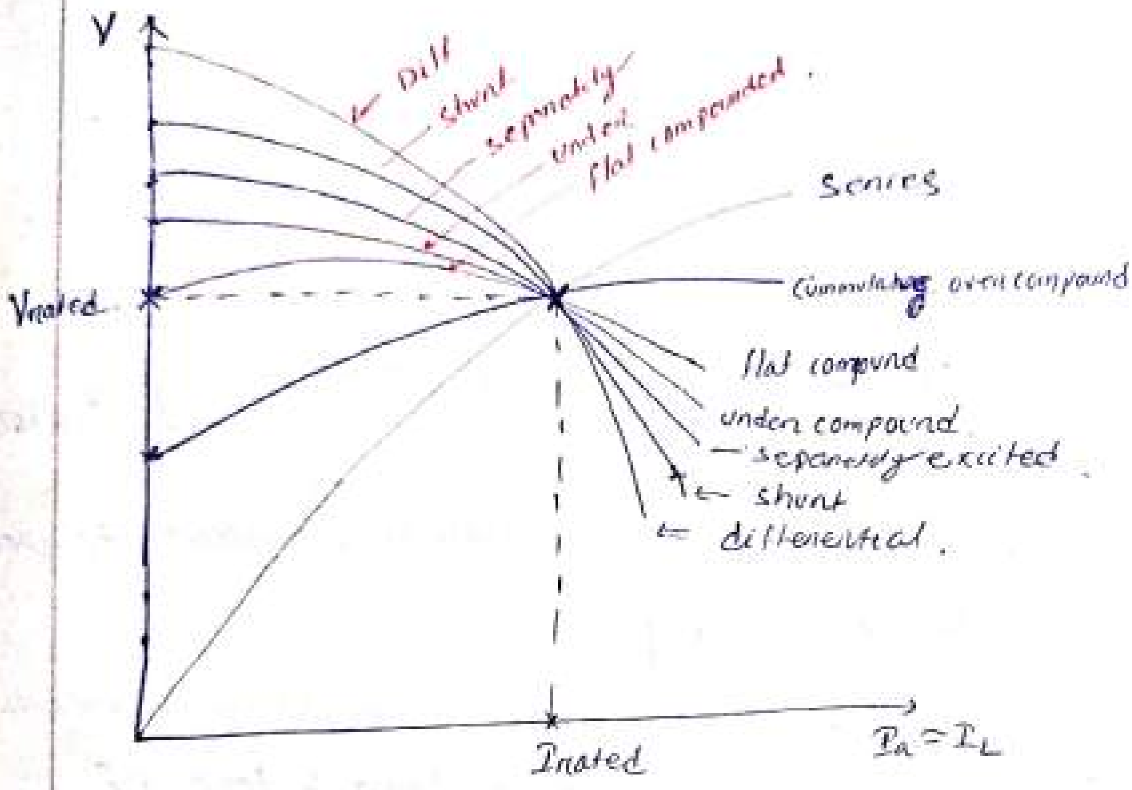
~~Differential compound generating~~

1. used as voltage source
2. Auxillary power supply
3. Battery charging
4. As an Exciter to excite the field of synchronous m/c.

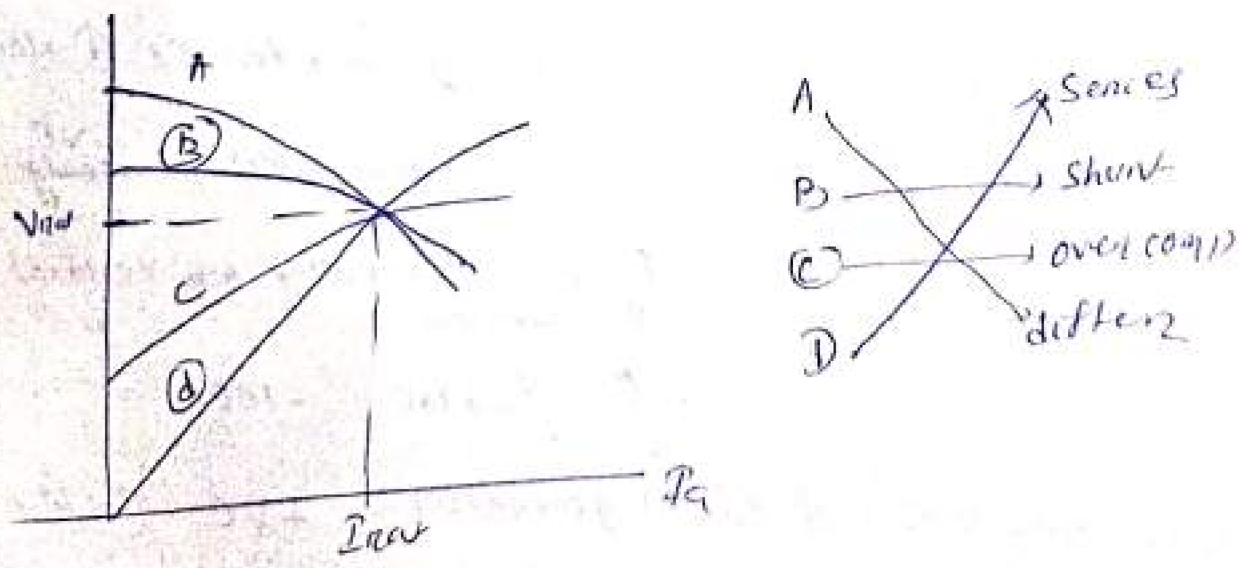


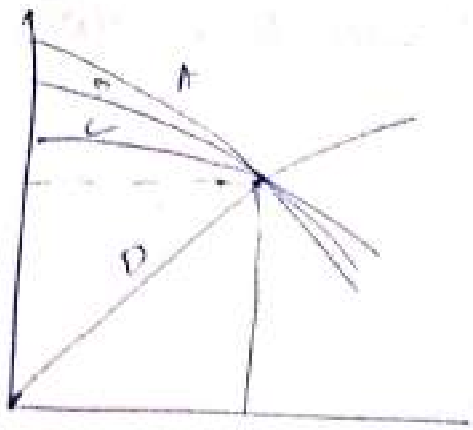
Differential comp generator:-

(1) used for ARC welding purpose since it limit the short ckt current during the welding process.



The following characteristic the V-I of DC Generators Match the following.





Shunt → B
Series → D
Diff → A
Cummulative → C

Voltage regulation :-

$$\frac{\text{No load voltage} - \text{f.L voltage}}{\text{f.L voltage}} = \frac{E-V}{V} \times 100$$

⇒ In dc generators the voltage regulation is proportional to speed

voltage regulation ∝ speed

⇒ But in synchronous Generator voltage regulation is independent of speed. depends only on magnitude of load & load P.f

Q. The voltage regulation of a shunt generator at 1000 rpm is 10%. the voltage regulation at 1250 rpm with other things remains same will be.

a) less than 10% (b) equal to 10% ✓(c) more than 10% (d) None

\# The voltage regulation for series generator is −ve ≃ −100% poorest

E = 0 neglecting residual
E = someless

$$\frac{0-V}{V} \times 100 = -100\%$$

\# voltage regulation of shunt generator = +ve (<10%)

\# Voltage regulation of separately excited = +ve

\# " " " overcompound = −ve

\# " " " under compound = +ve

Scanned with CamScanner

Voltage regulation of flat compound generator : zero.
Voltage regulation " differential compound gen = +ve. [positive voltage reg]

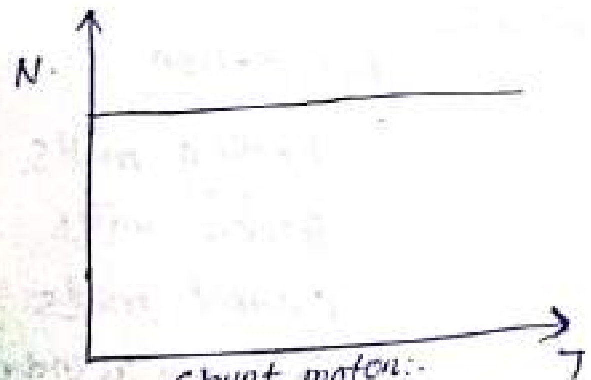
⇒ order of ~~voltage~~ magnitude of voltage regulation in descending order.

series > differential > over compound > shunt > separately > under > flat

Based on speed torque characteristic the types of drive

1. constant speed drive.
2. constant power drive
3. Adjustable speed drive.
   i) constant torque variable power drive.
   ii) constant power variable torque drive.

1. constant speed drive:-



Shunt motor:-

The speed is constant.
which is independent of torque.

Application - 1) fans
② Lathe m/c
③ centrifugal pump
④ Hydraulic pump
⑤ Air circulators
⑥ Line shafting.
⑦ Blower

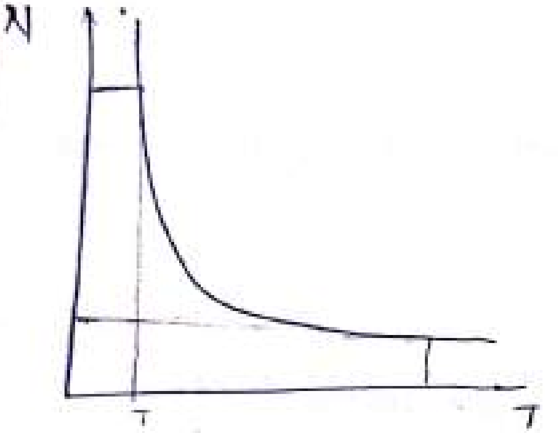
Constant power madrive :-

$P = \frac{2\pi N}{60} \times T \quad P \propto NT$ If P is const $\Rightarrow NT = const = k$

$N = \frac{k}{T} = N \propto \frac{1}{T}$.

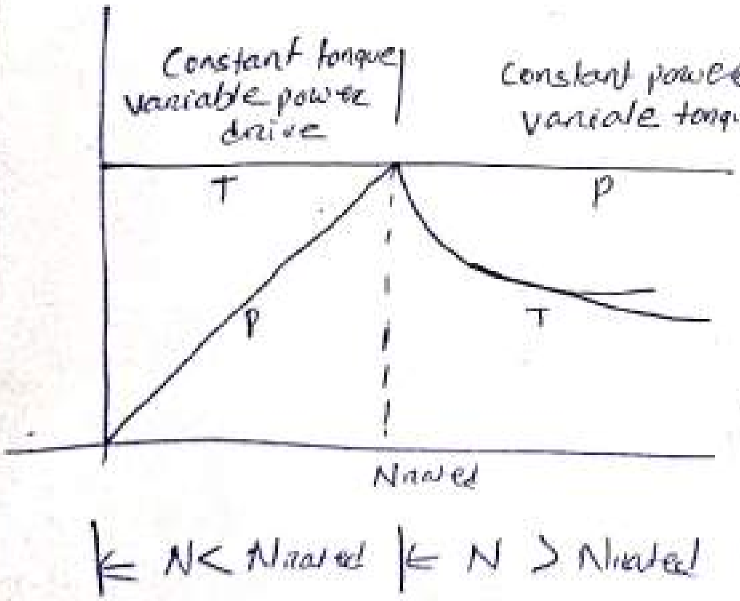
If one will increase other has to reduce to maintain constant power.

N vs T characteristic is a rectangular hyperbola.



Application :- ① Electric traction
locomotive (local train)
~~Chairs~~
Cranes
Lifts
hoists (vertical & horizontal movement ~~____~~ material lift)

Adjustable speed :-



Application :-

Rolling mills
Paper mills
Cement mills
Colliery winders.

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

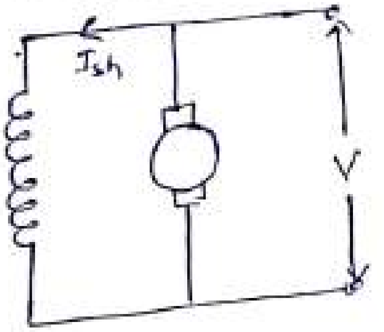
$$N \propto \frac{V - I_a R_a}{\phi}$$

$$T \propto \phi I_a$$

Characteristic of DC Motor :-

1. N Vs I_a characteristic
2. T Vs I_a characteristic
3. N Vs T characteristic

DC shunt motor :-



$I_{sh} = \frac{V}{R_{sh}} \simeq$ constant.

No residual flux required.

As V (supply voltage) is constant, & R_{sh} = consta

I_{sh} is constant

$\phi \propto I_{sh}$

$\phi \simeq$ constant

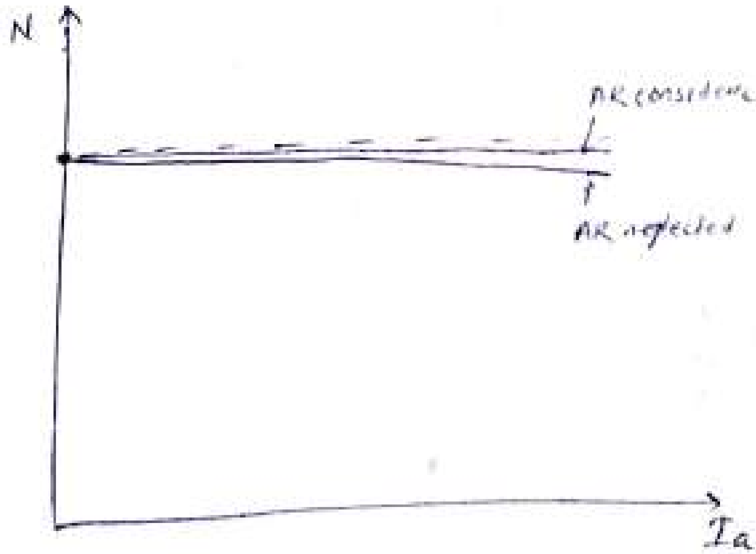
⇒ shunt m/c is a constant flux m/c.

1) N Vs I_a chara

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

$N \propto V - I_a R_a$ $\quad \phi$ ∴ constant

variation is only 10% due to $I_a R_a$ drop.

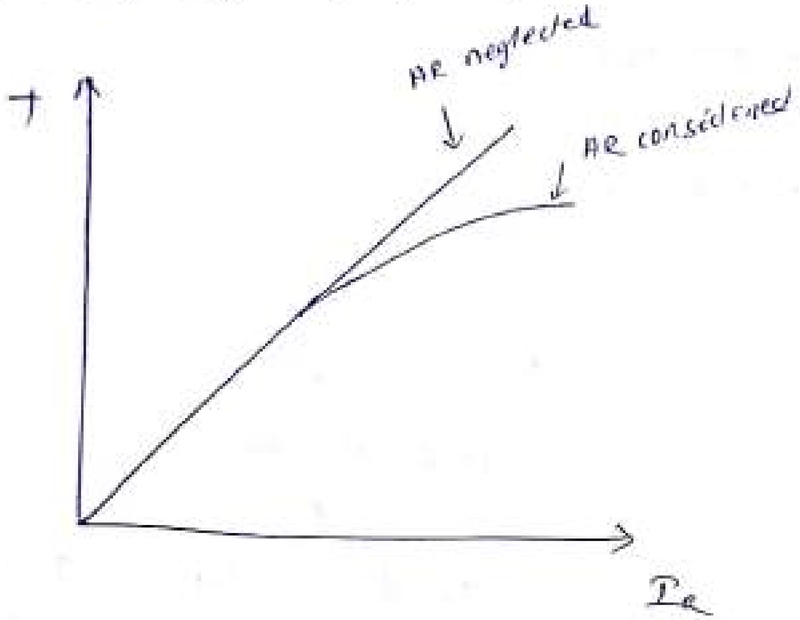


As load increases I_a increases due to armature reaction increases flux decreases so speed increases from AR neglected curve but not more than no load speed.

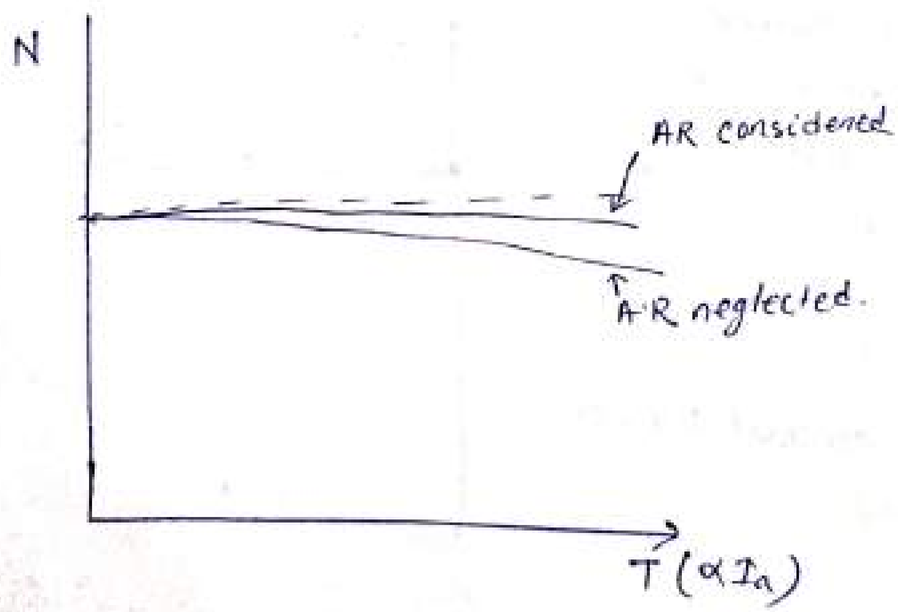
As load increases both numerator ($I_aR_a\uparrow$) decreases as well as denominator (AR due to I_a) decreases so speed is constant and speed regulation is nearly zero.

ii) T vs I_a characteristic

$T \propto \phi I_a \Rightarrow T \propto I_a$ T vs I_a char $\Rightarrow$ LINEAR.



iii) Speed Vs Torque (N vs T) characteristic:



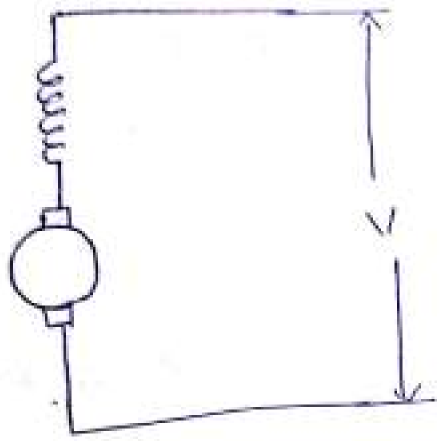
Scanned with CamScanner

Shunt motor is a constant speed m/c.

Applications:-

1. Fan, Lathe m/c, Air circulator, Centrifugal pumps, Hydraulic pumps.

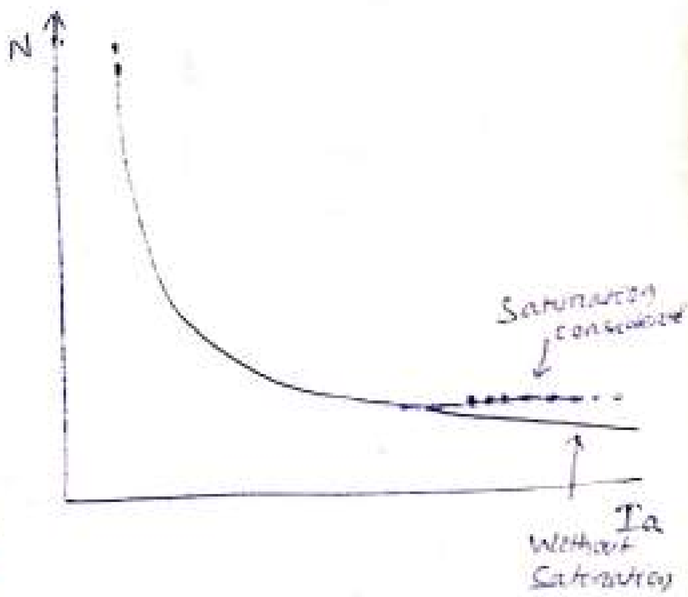
Series motor:-



$\phi \propto I_a$

⇒ Series m/c is a variable flux m/c.

1. N vs I_a Characteristic:-



$$N \propto \frac{V - I_a(R_a + R_{se})}{\phi}$$

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

As $I_a(R_a + R_{se})$ drops very small with respect to variation in ϕ.

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

N vs I_a = Rectangular hyperbola

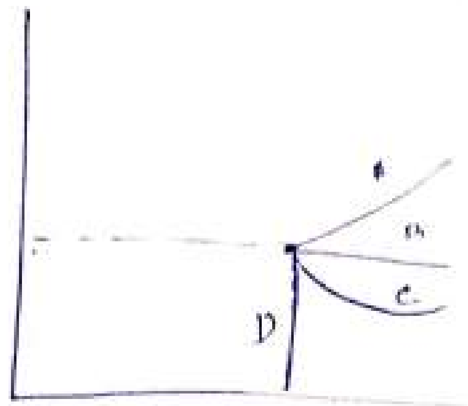
After saturation ϕ is constant

⇒ $N \propto V - I_a(R_a + R_{se})$

∴ N vs I_a characteristic are similar to characteristic of shunt motor i.e speed is nearly constant.

~~Q. The~~

Which of The following characteristic (N Vs I_a) represent ~~under~~ of a dc series motor under over load condition such that the field pole saturated



a) A
b) B
c) C
d) D

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

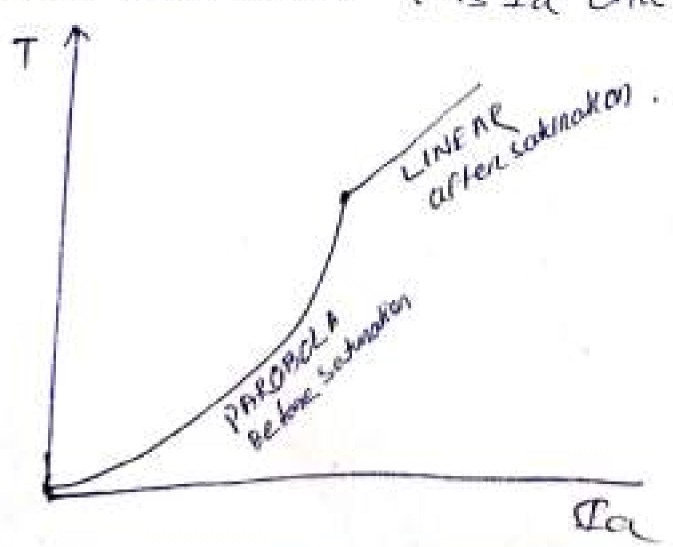
Series motor never be started under no load condition otherwise it will rotate dangeriously high speed. Generally series motor are connected permanent load like traction lifts etc. If An isolated series motor is attached with a suitablly design fly wheel to avoid dangeriously high speed.

ii) T vs I_a characteristic :-

$T \propto \phi I_a \propto I_a^2 \Rightarrow T \propto I_a^2 \Rightarrow$

so T vs I_a cha is - PARABOLA → Before saturation

But After saturation T vs I_a cha $T \propto I_a$ ⇒ T vs I_a LINEAR.



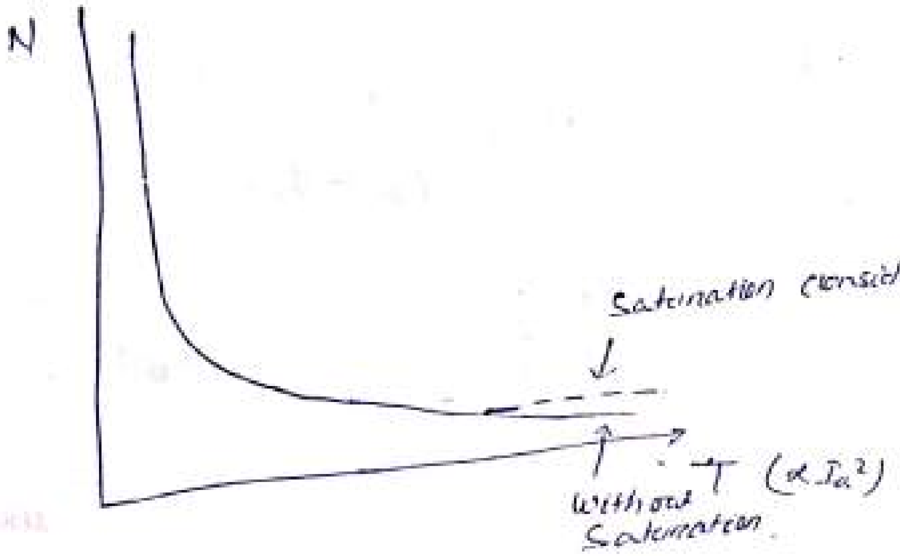
$T \propto I_a^2$

$I_{st} = (1.5 \text{ to } 2) I_{full}$

$T_{st} = I_{st}^2$

Series motor develop high starting torque, therefore these motors are best suited for ed
① Electric traction
② Locomotive
③ Lifting purpose.

III) N vs T characteristic:-



$N \propto \frac{1}{T}$.

$\Rightarrow NT \simeq$ constant

$P \propto NT$

$P \simeq$ constant

$\therefore$ Series motor is a constant power drive.

Application:-
① Electric Traction
② Locomotives
③ Cranes
④ hoist
⑤ lifts.

Characteristic of compound motor :-

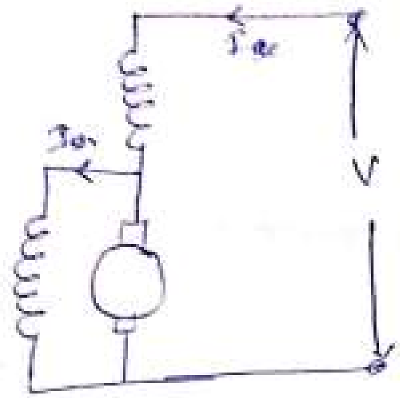
1. Cummulative → $\phi = \phi_{sh} + \phi_{se}$ → As load increases $I_a \uparrow$ $\phi_{se} \uparrow$

   $\uparrow \phi = (\phi_{sh} + \phi_{se})$ ∴ $N \downarrow$

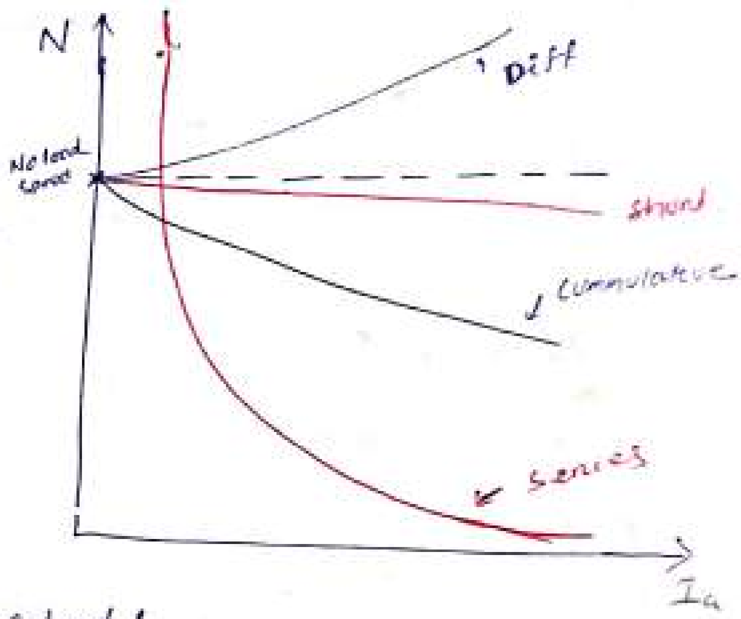
2. Differential → $\phi = \phi_{sh} - \phi_{se}$ → As load increases $I_a \uparrow$

   $\phi_{se} \uparrow$ → $\phi = (\phi_{sh} - \phi_{se}) \downarrow$ $N \uparrow$

N vs I_a characteristic



$$N \propto \frac{1}{\phi_{sh} \pm \phi_{se}}$$

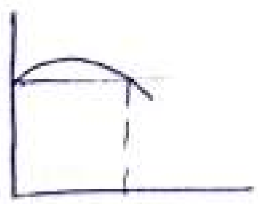


$\phi_{sh} > \phi_{se}$ - undercompound

cummulative compound motors are more common.

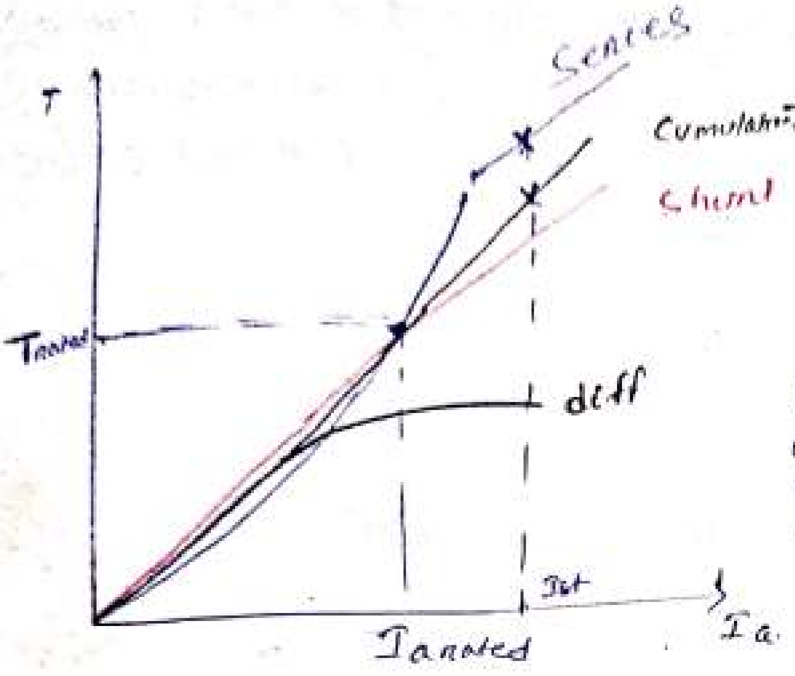
$$N \propto \frac{V - I_a R_a \downarrow}{\phi = (\phi_{sh} - \phi_{se}) \downarrow}$$

As load ↑



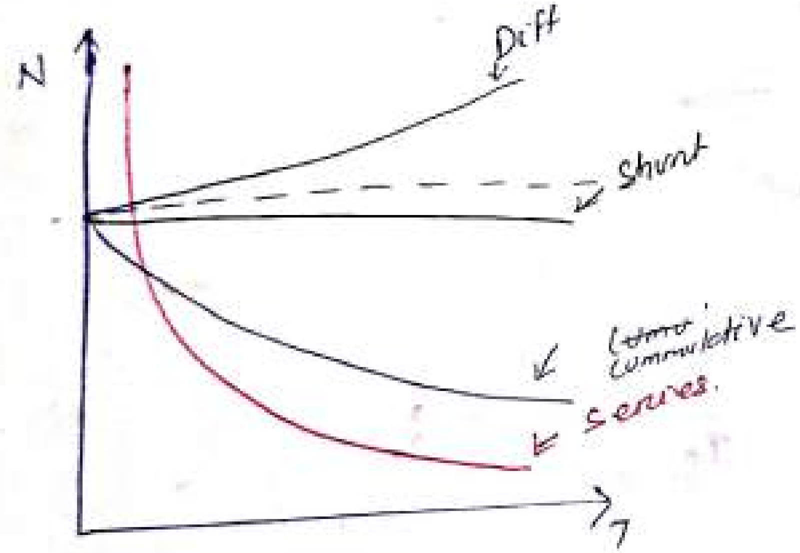
If ϕ_{se} more than ϕ_{sh} the ϕ = -ve so Torque will be -ve. so ~~dif~~ cummulative are rarely use.

II) T vs I_a characteristic.



Below rated value shunt is best. after rated value series is best suited then cummulative after series.

III) N vs T characteristic



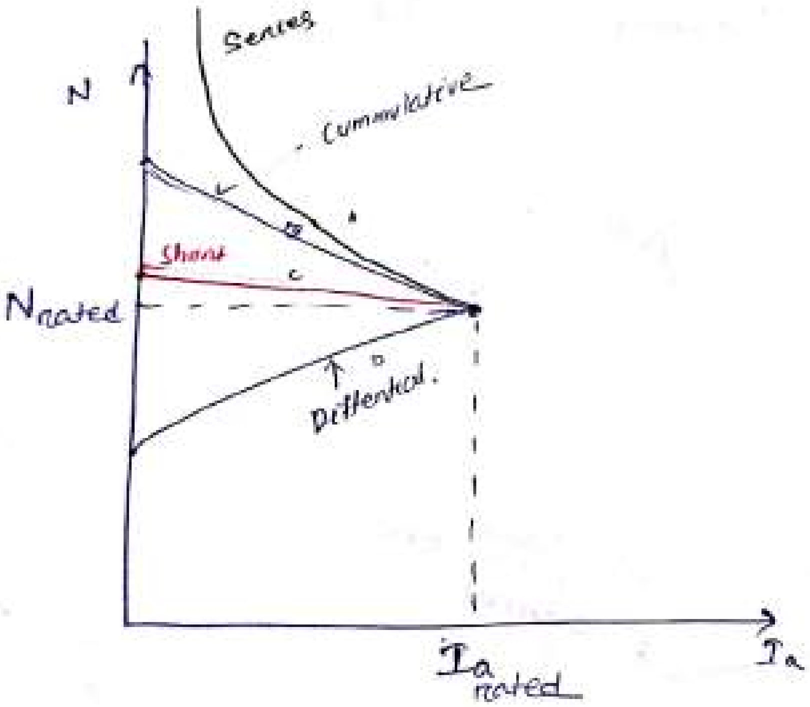
~~Commotative~~ C

Differential comp motor are rarely use because as load increases it's speed is increases. No application required this type of characteristic. If the m/c is over load speed is increases to dangeriously high speed.

With weaken series field flux a diff comp motor can be design so nearly with a constant speed.

Cummulative compound motors are more common because they will develop very good starting torque & limited no load speed. There fore these motors are used for intermittend load which consist a load and no load operation. Like ~~petchi~~

1. punching m/c
2. sewing m/c
3. Rolling mill
4. Crosser.
5. shearing machine.



Q//

	a	b	c	d
Series	A	B	A	A
Shunt	B	C	C	B
Cumulative	C	D	B	D
Diff	D	A	D	C

Speed regulation :-

$$\frac{\text{No load speed} - \text{f.L speed}}{\text{f.L speed}} = \frac{N_{NL} - N_{FL}}{N_{FL}} \times 100$$

⇒ Speed regulation of series motor is +ve & ≃ 60% → Poorest speed reg

⇒ " " " cummulative comp +ve & ≃ 20 to 50%

⇒ " " " shunt motor +ve & ≃ 0% (< 5% to 10%)

⇒ " " " Differential comp −ve

Speed regulation in descending order.

| Series > Diff > Cummulative > shunt |

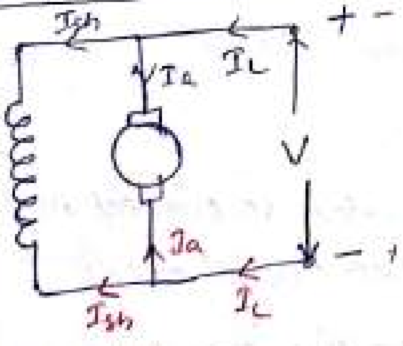
with stronger series field flux

$$N \propto \frac{1}{\phi_{sh} - \phi_{se}}$$

| Series > cummulative > Diff > shunt |

with weaker series field flux.

Shunt motor :-



The direction of rotation of a dc motor can be reverse either by changing field terminal or Armature terminal but not both.

By reversing the supply terminal there will be no change in direction of rotation.

$T \propto \phi I_a$

$T \propto (-\phi)(-I_a) = +ve$

Q. A shunt motor is running at rated speed. If the field cut opened then the motor will

(A) Dangerously high speed ✓ (B) rotate with same speed (C) reduced speed

D) will comes to stop.

$T \propto \phi I_a$

as open $\phi =$ zero $T =$ zero

but ϕ is not zero at open ckt condition.
due to residual flux. so speed is very high as residual flux is less.

Q. If shunt motor running under full load condition the field cut open then back emf reduces to maintain the load torque the motor will draw large armature current so armature winding will burn & motor will comes to stop.

Q. A shunt motor running at rated speed. If the armature cut open then the motor will

(a) reduce speed b) rotate with same speed (c) dangerously high speed.
d) motor would comes to stop. ✓

$T \propto \phi(I_a = 0) \Rightarrow T = 0$

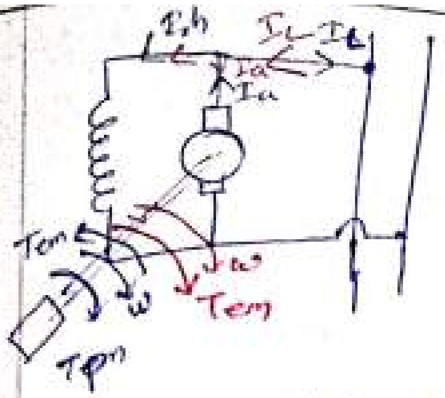
Q. A shunt motor running at rated speed if its field winding short ckted then the motor will

a) same speed b) dangerously high speed (c) rotate with reduce speed (d) motor comes to stop ✓

Here both armature & field will short cited so current will flow through short ckt. so no current so speed will zero

Q. A shunt generator supplying power to the DC busbar if the prime movers fail the m/c will behave as.

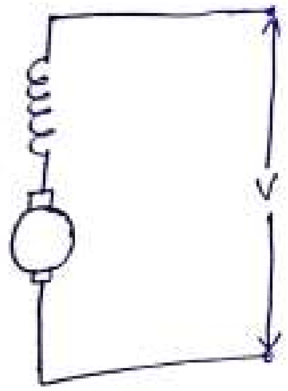
a) shunt motor, rotate in same direction ✓
b) " " rotate in opposite direction
c) " generator with reduced speed.
d) the m/c would comes to stop.



$T_{em} \propto \phi I_a \Rightarrow CCW$

$T_{em} \propto \phi(-I_a) = CW$

Series motor :-



① $T \propto \phi I_a = 0$

Q1 A series motor is running at rated speed. If the field ckt opens then the motor will

ⓐ same speed ⓑ rotate with reduced speed ⓒ rotate with dangerously higher

ⓓ The motor will comes to stop. $T \propto \phi I_a$, $I_a = 0$ so $T = 0$ stop.

Q. A series motor running at rated speed. If the field wind is short ckted the motor will

ⓐ same speed ⓑ Rotate with high speed ⓒ rotate with reduced speed

ⓓ motor would come to stop

only residual flux will there so $N \propto \frac{1}{\phi}$ high speed.

Q.3 Armature short ckted

ⓐ motor will stop

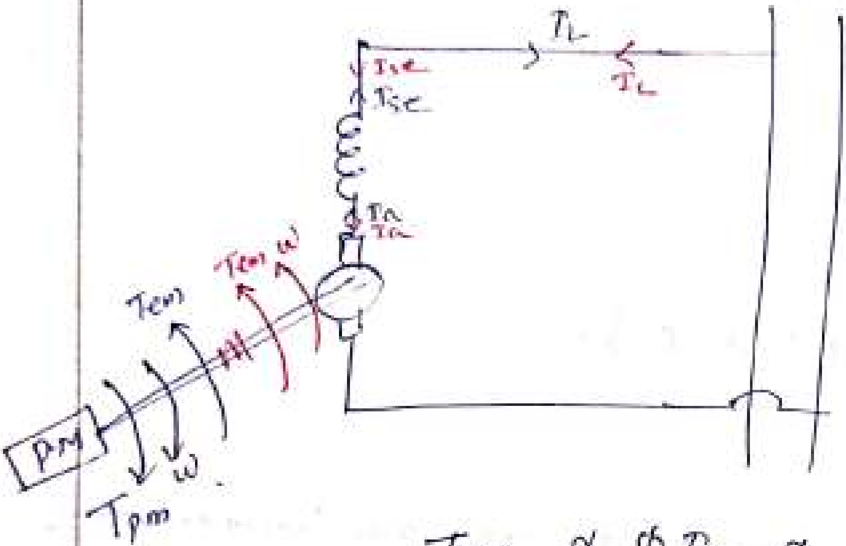
Q. A series generator supplying power to the dc busbar. If the prime mover fails then the m/c will behaves as .

a) series motor rotate in same direction.

b) Series motor rotate in opposite direction.

c) series generator rotate with reduced speed.

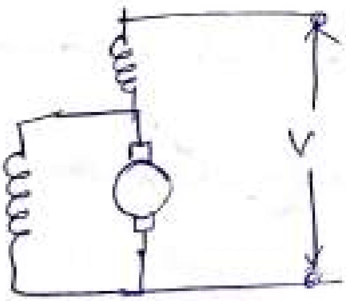
d) M/c would come to stop



$$T_{em} \propto \phi I_a \propto I_a^2 = CCW$$

$$T_{em} \propto (-\phi)(-I_a) = (-I_a)^2 = I_a^2 = CCW$$

Compound m/c



$$N \propto \frac{1}{\phi_{sh} \pm \phi_{se}}$$

+ → cumulative
− → differential.

Q. A cumulative comp running at rated speed. If the series field winding open then the motor would <u>stop</u>.

$I_a = 0$. stop

Speed control of DC Motor :-

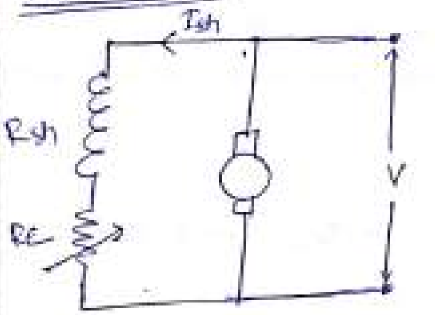
$$N \propto \frac{E_b}{\phi} \Rightarrow N \propto \frac{V - I_a R_a}{\phi}$$

Types of speed control :-

1. Flux control or field control
2. Armature resistance control
3. Armature voltage control.

1. Flux control method.

Shunt motor



$$\downarrow I_{sh} = \frac{V}{R_{sh} + R_C \uparrow}$$

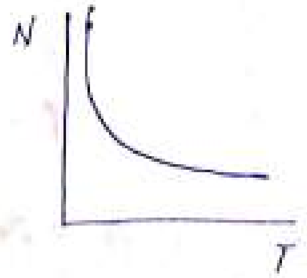
$$\downarrow \phi \propto I_{sh} \downarrow$$

By adding extra resistance in the field circuit the flux can be control below rated value. So by using this method speed can be controlled only above rated value.

In this method flux is below normal value therefore effect of A.R is more on weaker field flux so commutation is poor, sparking at the brushes.

$\phi\downarrow N\uparrow$; $\phi\downarrow, T\downarrow$ As flux decreases $N\uparrow$ $T\downarrow$

$\therefore N \propto \frac{1}{T}$



$NT \simeq$ constant

$P \propto \uparrow NT\downarrow$ ∴ $P \simeq$ constant

Any motor under flux control method

⇒ under flux control method any m/c will behave as constant power drive.

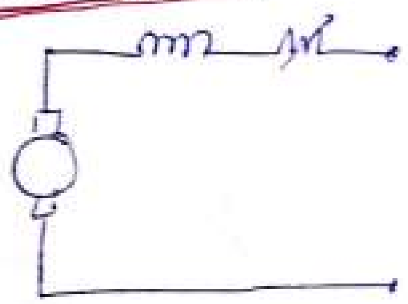
⇒ under flux control method the m/c will behave as constant power variable torque drive.

Shunt motor: $\frac{N_2}{N_1} = \frac{E_{b2}}{E_{b1}} \times \frac{\phi_1}{\phi_2}$

$$\boxed{\frac{N_2}{N_1} = \frac{E_{b2}}{E_{b1}} \times \frac{I_{sh1}}{I_{sh2}}}$$

If AR and saturation neglected.

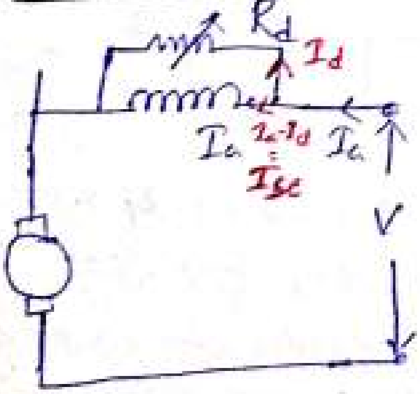
Series motor :-



It will be armature resistance control.

1. field diverter control
2. Tapped field control
3. series & parallel connection.

1. Field diverter :



$$I_{se} = I_a \times \frac{R_d}{R_d + R_{se}}$$

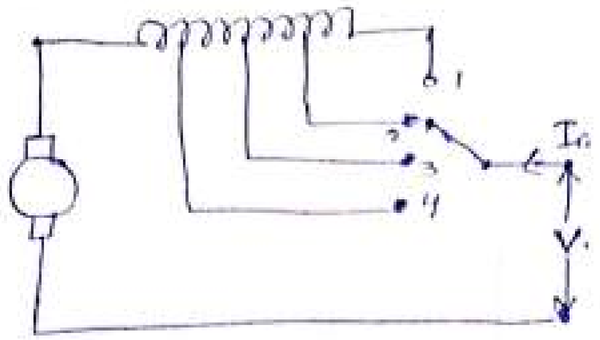
$$I_{se} \propto R_d$$

$$\frac{N_2}{N_1} = \frac{E_{b2}}{E_{b1}} \times \frac{\phi_1}{\phi_2}$$

$$\boxed{\frac{N_2}{N_1} = \frac{E_{b2}}{E_{b1}} \times \frac{I_a}{I_{se}}}$$

N_1 = without diverter
N_2 = with diverter.

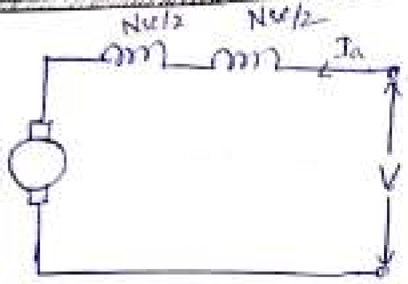
Tapped field control :-

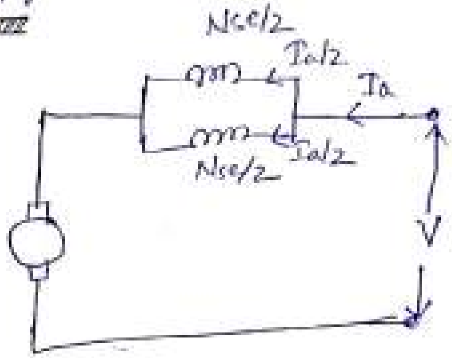


$N_4 > N_3 > N_2 > N_1$

N_1 : Rated speed.

Series and parallel connection :





$AT_{se} = \frac{N_{se}}{2} I_a + \frac{N_{se}}{2} \times I_a$

$AT_{se} = N_{se} \times I_a$

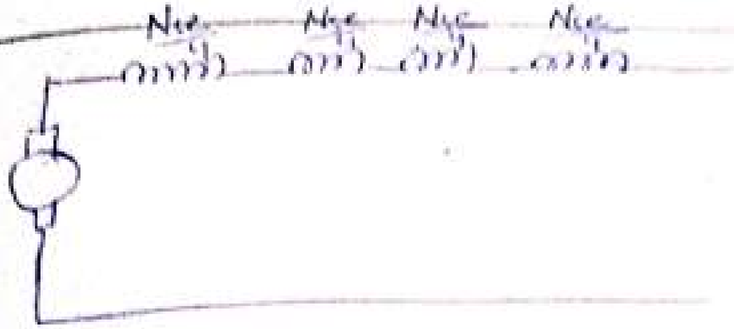
$AT_p = \frac{N_{se}}{2} \times \frac{I_a}{2} + \frac{N_{se}}{2} \times \frac{I_a}{2}$

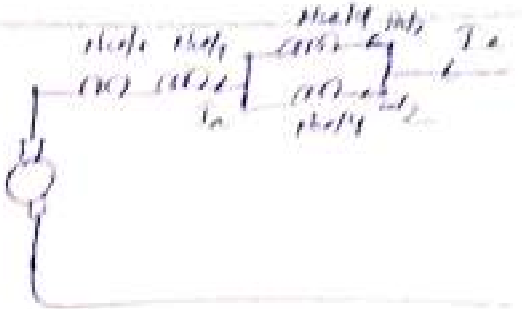
$= 2 \times \frac{N_{se}}{2} \times \frac{I_a}{2}$

$AT_p = N_{se} \times \frac{I_a}{2}$

so $AT_p = \frac{1}{2} AT_{se}$ $\therefore$ so $\boxed{N_p = 2N_{se}}$ As $\phi_p = \frac{\phi_{se}}{2}$

In a series motor series winding divided in 4 group.
If they all are connected in series speed is 1600 RPM
If two are connected in series, two are connected in parallel
both group connected in series then the speed will be ___ RPM.





$AT_1 = N_{se} I_a$ $AT_2 = \frac{3}{4} N_{se} I_a$

$$\frac{N_2}{N_1} = \frac{E_{b2}}{E_{b1}} \times \frac{AT_1}{AT_2} = \frac{AT_1}{AT_2}$$

$\because$ $I_a R_a$ neglected.
$E_{b1} = E_{b2}$

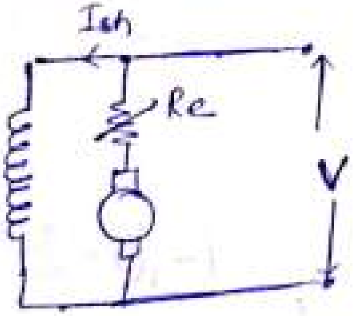
$E_{b2} \propto [\phi_2 N_2]$ = constant
or
$E_{b2} = V - I_{a2}(R_{se} - R_a)$ (neg)
= constant

$$\Rightarrow \frac{N_2}{N_1} = \frac{N_{se} I_a}{\frac{3}{4} N_{se} I_a} =$$

$\Rightarrow \frac{N_2}{N_1} = \frac{4}{3}$ $\Rightarrow N_2 = \frac{4}{3} \times 1000$

$N_2 = 1333$ rpm. Ans.

Armature resistance control :-



$N \propto \frac{V - I_a(R_a + R_e)}{\phi}$ = $N \propto V - I_a(R_a + R_e)$

$\Rightarrow$ As $R_e \uparrow$, $[V - I_a R_a + R_e] \downarrow$, $N \downarrow$

$\Rightarrow$ By using this method speed can be control below rated value.

$I_{sh} = \frac{V_{sh}}{R_{sh}}$ = constant

ϕ = constant

$\therefore$ Main field flux is normal value, therefore effect of A.R is normal, therefore commutation is good.

$I_a = \frac{V - E_b}{R_a + R_e}$, As $R_e \uparrow$ $N \downarrow$ $E_b \downarrow$, $V - E_b \uparrow$
$\therefore$ denominator increase, neumerator also increase so I_a is constant.

ϕ = constant, I_a = constant $\Rightarrow T \propto \phi I_a$ $\therefore$ T_a = constant.

$P \propto NT$: $P \propto N$. power is not fully utilized. power is reduced under armature ^resistance^ control method the m/c behave as constant torque Drive.

under armature resistance method the m/c behave as constant torque Drive variable power drive.

Power input is same but due to extra resistance, losses more so power o/p is not constant

so for shunt motor

$$\frac{N_2}{N_1} = \frac{E_{b2}}{E_{b1}} \times \frac{\phi_1}{\phi_2}$$

$$\frac{N_2}{N_1} = \frac{E_{b2}}{E_{b1}} \quad \because \phi_1 \approx \phi_2$$

$$\frac{N_2}{N_1} = \frac{V - I_a(R_a+R_e)}{V - I_aR_a}$$

N_1 = Rated speed without R_e

N_2 = Speed with R_e.

As $R_a << R_e$ so R_a can be neglected.

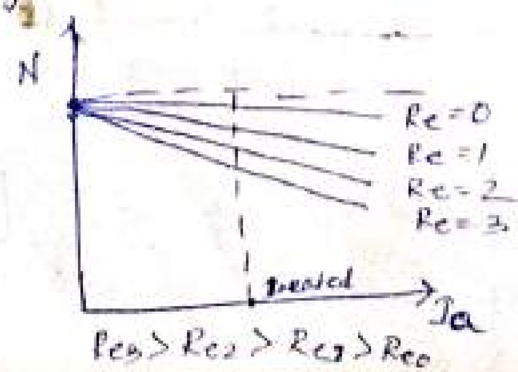
$$\frac{N_2}{N_1} = \frac{V - I_aR_e}{V} = 1 - \frac{I_aR_e}{V}$$

$\Rightarrow$ speed regulation $= \frac{N_1 - N_2}{N_1} = 1 - \frac{N_2}{N_1} = 1 - \left(1 - \frac{I_aR_e}{V}\right)$

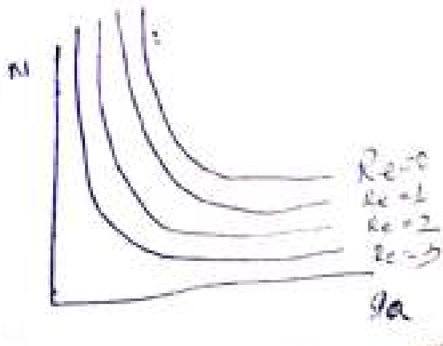
$$= \frac{I_aR_e}{V}$$

$\therefore$ speed regulation $= \frac{I_aR_e}{V}$

$\Rightarrow$ speed regulation depends on I_a & R_e.



$R_{e3} > R_{e2} > R_{e1} > R_{e0}$



$$\eta = \frac{P_m}{P_{in}} = \frac{E_b I_a}{V I_a} = \frac{E_b}{V} = \frac{V - I_a R_a}{V} = 1 - \frac{I_a R_a}{V} = \frac{N_2}{N_1}$$

$$\therefore \boxed{\eta = \frac{N_2}{N_1}}$$

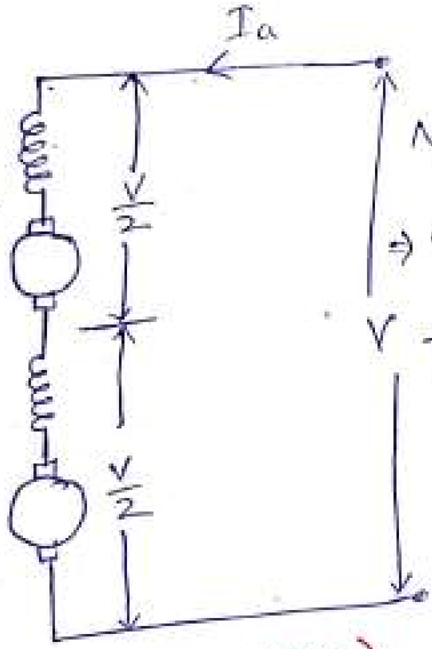
If $N_1 = 1000$ RPM If $N_2 = 700$ rpm then $\eta = 70\%$

If $N_2 = 500$ rpm then $\eta = 50\%$

$N_2 = 200$ rpm then $\eta = 20\%$

So By using this method wide range of speed control is not possi... only limited range, otherwise with lower speed result poor efficie...

Armature voltage control for traction motor :-

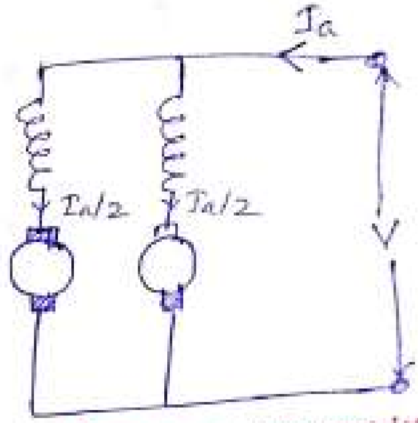


(During starting condition)

$N_{se} \propto \frac{V/2}{I_a}$

$\Rightarrow N_{se} \propto \frac{V}{2I_a}$

$T \propto I_a^2$



(During running condition)

$N_p \propto \frac{V}{I_a/2}$

$\Rightarrow N_p \propto \frac{2V}{I_a}$

$\Rightarrow T_p = \left(\frac{I_a}{2}\right)^2$

$N \propto \frac{E_b}{\phi}$ $\therefore E_b \simeq V$ $: \phi \propto I_f$

$N \propto \frac{V}{I_f}$

$$\frac{T_{se}}{T_p} = \frac{I_a^2}{\left(\frac{I_a}{2}\right)^2} = 4$$

$$\boxed{\frac{T_{se}}{T_p} = 4}$$

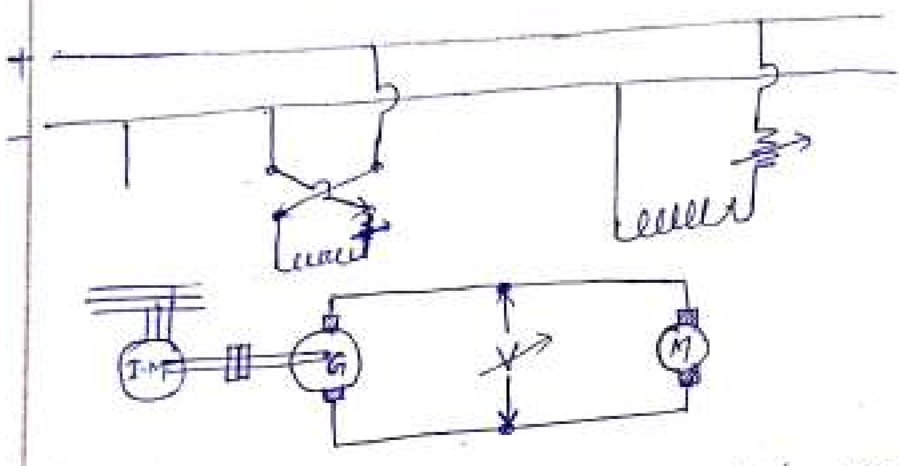
* $\boxed{T_{se} = 4T_p}$

$$\frac{N_{se}}{N_p} = \frac{\frac{V}{2I_a}}{\frac{2V}{I_a}} = \frac{1}{4}$$

$$\boxed{\frac{N_{se}}{N_p} = \frac{1}{4}}$$

* $\boxed{N_p = 4 N_{se}}$

Ward leonard speed control method.



for the speed required below rated value armature voltage control is used by varying the field Rheostat of generator. generator voltage can be control which is nothing but motor armature voltage control. By controlling the voltage below rated value the speed can be control below rated value.

Here ϕ = constant.

$$\uparrow N = \frac{\uparrow V - I_a R_a}{\phi}$$

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

$V\uparrow$, $N\uparrow$ $E_b\uparrow$ therefor $V - E_b$ = constant

I_a = can be maintain constant. $= \frac{\uparrow V - E_b\uparrow}{R_a}$ = constant

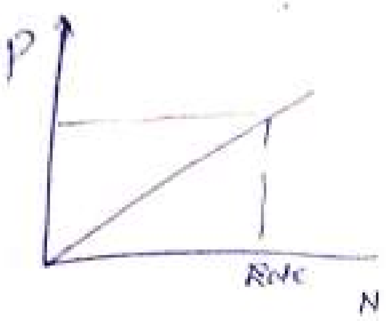
I_a = constant : ϕ = constant

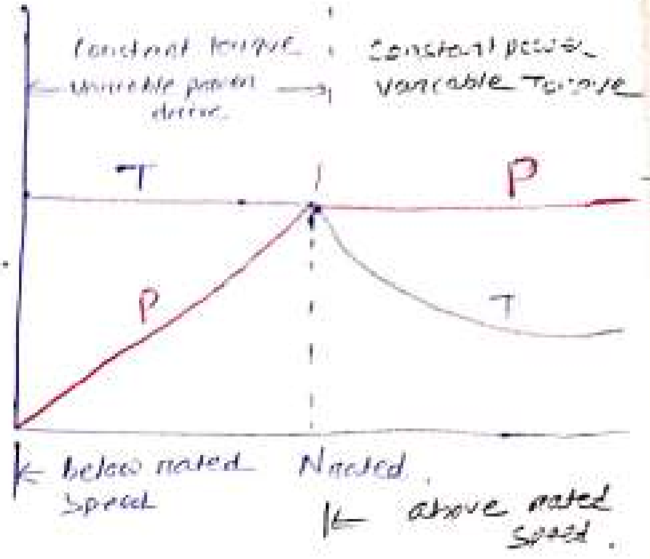
$T \propto \phi I_a \simeq$ constant

$\therefore T \simeq$ constant.

But $P \propto TN$

$\Rightarrow P \propto N$





Under this the m/c will behave as constant torque variable power drive.

At rated value of N, T & P are rated.

For above rated speed:-

V keep constant. by varying field Rheostat of motor flux will vary so speed will vary.

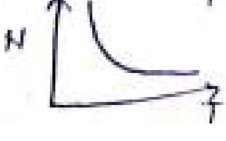
If the required above rated value flux control method is used. The voltage is kept at it's rated value by varying the motor field Rheostat, the flux can be control below rated ~~speed~~ value, thereby speed can be control above rated value.

$$\uparrow N \propto \frac{V - I_a R_a}{\phi \downarrow} \quad \therefore \phi \downarrow, N \uparrow$$

$$I_a = \frac{V - E_b}{R_a} \simeq \text{constant}$$

As. $E_b \propto \phi N$, $E_b \propto \phi \downarrow N \uparrow$

$\phi \downarrow, N \uparrow, T \downarrow$



$P \propto \downarrow T \cdot N \uparrow$ P = constant

Advantage:-

By using armature we can rotate at = 10:1

" field " " " " = 4:1

1 Wide range of speed control in either direction it is possible. By using both armature control, flux control the speed ranges 40:1

② High efficiency.

③ Simplicity.

Disadvantage:-

① High initial cost, bcoz two additional m/c of equal rating is required.

Application:-

1. Paper mill
2. steel mill
3. Rolling mill
4. cement mill
5. Colliery winders.
6. Printing m/c

Pb

A dc shunt motor driving a constant power load under rated condition the motor takes rated armature current and runs at rated speed. the speed and current for the following changes

① Armature terminal voltage is to halfed. I_f is unchanged.

ⓐ 2 PU, ·5 PU ⓑ 0·5 PU, 2 PU ⓒ 1 PU, 1 PU ⓓ 1 PU, 0·5 PU.

② V is unchanged I_f is halfed.

ⓐ 2 PU, 1 PU ⓑ 1 PU, 2 PU ⓒ 0·5 PU, 1 PU ⓓ ·5 PU, 2 PU.

3) both V & I_f are halfed.

a) 1pu, 0.5pu (b) 1pu, 2pu (c) 2pu, 1pu (d) 4pu, 4pu.

Soln: constant power load $P_1 = P_2$; under rated condition

$V_1 = 1pu$, $I_{a1} = 1pu$, $N_1 = 1pu$, $I_{f1} = 1pu$.

1) $V_2 = .5 pu$, $I_{f2} = 1 pu$ — constant power load. $P_1 = P_2$

$V_1 I_{a1} = V_2 I_{a2}$

$T_1 N_1 = T_2 N_2$

$I_{f1} I_{a1} N_1 = I_{f2} I_{a2} N_2$

$\frac{N_2}{N_1} = \frac{V_2}{V_1} \times \frac{I_{f1}}{I_{f2}}$

$V_1 I_{a1} = V_2 I_{a2}$

$1 \times 1 = .5 \times I_{a2} \Rightarrow I_{a2} = 2 PU$

$I_{f1} I_{a1} N_1 = I_{f2} I_{a2} N_2$

$1 \times 1 \times 1 = 1 \times 2pu\ N_2$

$N_2 = .5 pu.$

or $\frac{N_2}{N_1} = \frac{V_2}{V_1} \times \frac{I_{f1}}{I_{f2}}$

$= \frac{N_2}{1} = \frac{.5}{1} \times \frac{1}{2}$

$\Rightarrow N_2 = .5 pu$

2) $V_2 = 1$, $I_{f2} = .5$

$V_1 I_{a1} = V_2 I_{a2}$

$1 \times 1 = 1 \times I_{a2}$

$I_{a2} = 1 pu$

$I_{f1} I_{a1} N_1 = I_{f2} I_{a2} N_2$

$1 \times 1 \times 1 = .5 \times 1 \times N_2$

$N_2 = \frac{1}{.5} = 2 pu.$

3) $V_1 I_{a1} = V_2 I_{a2}$

$1 \times 1 = .5\ I_{a2}$

$= I_{a2} = 2$.

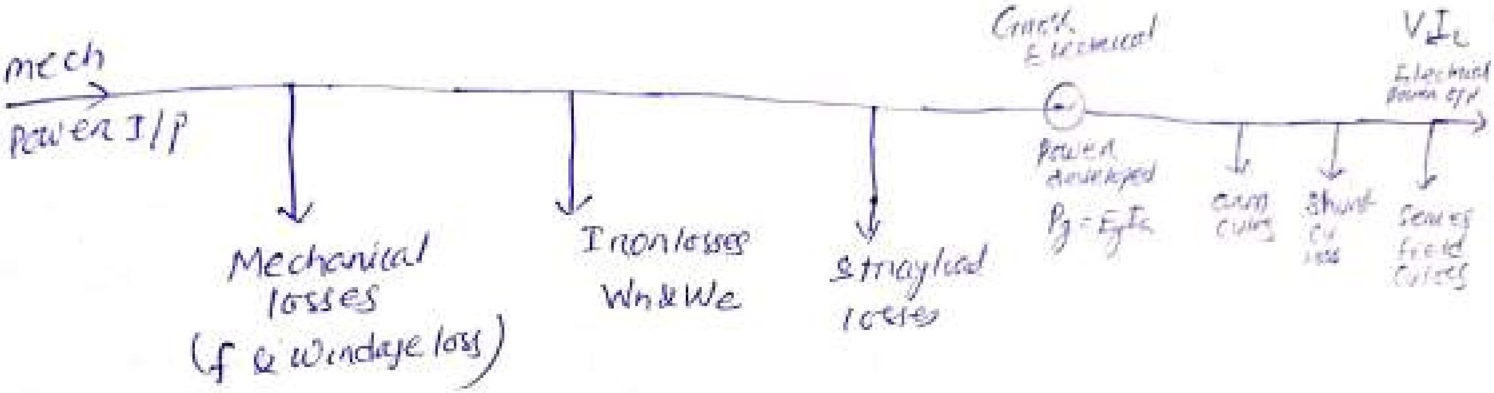
$I_{f1} I_{a1} N_1 = I_{f2} I_{a2} N_2$

$1 \times 1 \times 1 = .5 \times 2\ N_2$

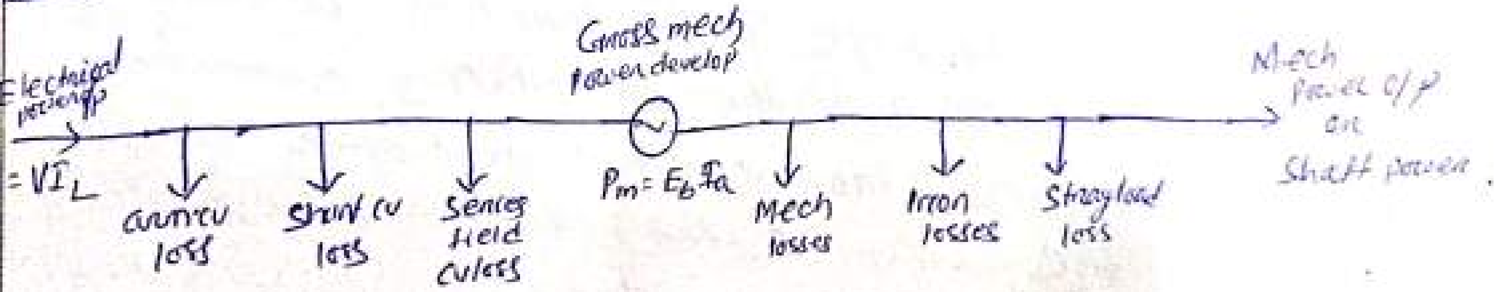
$N_2 = 1$ Ans

-: Power stages :-

Generator :



Motor



* Electromagnetic torque or Braking torque in gen $T_{em} = \frac{E_g I_a}{\omega}$

* E.m torque or gross torque develop in motor : $T_{em} = \frac{E_b I_a}{\omega}$

⇒ Shaft torque $= \frac{P_{out}}{\omega}$

Losses
- cu loss
  - Armature cu loss
  - Shunt cu loss
  - Series field cu loss
- → Iron loss
  - → Hysteresis losses $W_h = \eta B_{max}^{1.6} f \times V$ where $f \propto N$
  - → Eddy current loss $W_e = B_{max}^2 f^2 t^2$ $W_e \propto f^2 \propto N^2$
- → Mech loss
  - → Frictional losses at bearing & brushes
  - Air friction losses i.e. Air friction betn stator & rotor
- → Stray losses
  - → Stray Iron loss
  - → Stray cu loss

$$\boxed{W_h \propto f \Rightarrow W_h \propto N}$$

$$\boxed{W_e \propto f^2 \Rightarrow W_e \propto N^2}$$

Stray Iron loss:-

Due to the cross magnetising effect of armature reaction the maximum flux density increases, therefore iron losses increases these loss said to stray iron losses.

Stray load copper loss:-

Due to the self leakage in the armature conductor an emf is induced which will drive the circulating current or stray current, this stray current disturbed the current distribution. the current prefer to flow in outer periphery which is said to be Skin effect, Net effective area reduced Resistance increases, due to this additional cu loss. cu loss increase this loss said to be stray field culoss.

(Mech loss + Iron loss) + Stray load losses = Stray loss or Rotational loss,
no load ^ Rotational losses

Stray losses + shunt field cu losses = Constant losses

armature cu loss + series field culoss = Variable losses

condition for maximum efficiency is

Variable losses = Constant losses

this loss said to be stray field cu loss.

(Mech loss + Iron loss) + stray load losses = Stray loss or Rotational loss,
no load ^ Rotational losses

stray losses + shunt field cu losses = <u>Constant losses</u>

armature cu loss + series field cu loss = <u>Variable losses</u>.

condition for maximum efficiency is

$$\boxed{\text{Variable losses} = \text{Constant losses}}$$

Q.1

A dc <u>series</u> motor driving an electric train a constant a power load it is running at rated speed at rated voltage, if the speed has to brought down to ·25 p.u the supply voltage has to be approximately brought down to.

a) ·75 PU ✓b) 0·5 PU c) ·25 PU d) ·125 PU.

Soln $P_1 = P_2$

$$V_1 I_{a1} = V_2 I_{a2}$$

$$T_1 \times N_1 = T_2 N_2$$

$$I_{a1}^2 \times N_1 = I_{a2}^2 N_2$$

$$1 \times 1 = I_{a2}^2 \times \cdot 25$$

$$I_{a2} = 2 \text{ pu}$$

$V_1 I_{a1} = V_2 I_{a2}$ $\Rightarrow 1 \times 1 = V_2 \times 2 = V_2 = \cdot 5 \text{ PU}$

Q-2

A 240 V dc series motor takes 40 Amps when giving it's rated o/p at 1500 rpm. His resistance is ·3 Ω the value of the resistance which must be added to obtained rated torque at 1000 rpm is

a) 6 Ω b) 5·7 Ω c) 2·2 Ω d) 1·9 Ω

Sol^n

240 V, $I_{a1} = 40\,A$ $N_1 = 1500$ rpm $R_a = ·3\,\Omega$

$R_e = ?$ $N_2 = 1000$ rpm Rated torque.

$T_1 = T_2 \Rightarrow I_{a1}^2 = I_{a2}^2$

$\Rightarrow I_{a1} = I_{a2} = 40\,A$

$E_{b1} = V - I_{a1}R_a = 240 - 40 \times ·3 = 228\,V$

$E_{b2} = V - I_{a2}(R_a + R_e) =$

$$\frac{N_2}{N_1} = \frac{E_{b2}}{E_{b1}} \times \frac{\phi_1}{\phi_1} \Rightarrow \frac{E_{b2}}{E_{b1}} \times \frac{I_{a1}}{I_{a2}} = \frac{E_{b2}}{E_{b1}}$$

$$\frac{1000}{1500} = \frac{E_{b2}}{228} \Rightarrow E_{b2} = \frac{1000}{1500} \times 228 = 152\,V$$

So $152 = 240 - 40(·3 + R_e)$

$R_e = 1·9\,\Omega$

Q

A 50 kW DC shunt motor is loaded to draw rated armature current at any given speed when driven

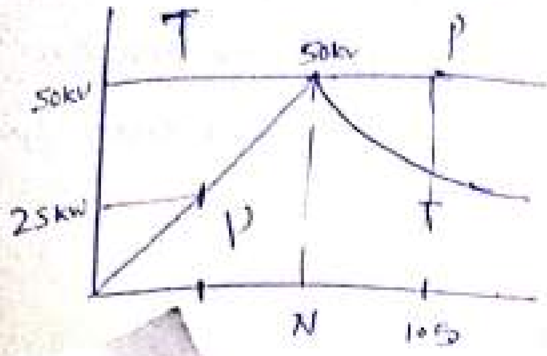
① Half the rated speed by armature voltage control.

2) 1·5 times the rated speed by field control.

Scanned with CamScanner

the respective power deliver by motor are resp

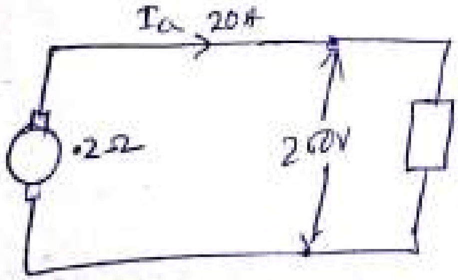
(a) 25 kW, 75 kW (b) 25 kW 50 kW (c) 50 kW 70 kW (d) 50 kW, 50 kW

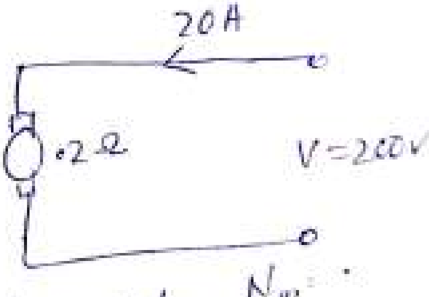


P_a = constant throughout the ~~speed control~~.

Q. A 220V dc m/c supplies 20 A at 200 V as a generator. The armature resistance is .2 Ω if the m/c is now operated as motor at same terminal voltage & current but flux increased by 10%. The ratio of motor speed to generator speed is.

a) .87 b) .95 c) .96 d) 1.06





N_g =

N_m =

$\phi_m = 1.1\,\phi_g$

$E_g = V + I_a R_a$
$= 200 + 20 \times .2 = 204$

$E_m = 200 - 20 \times .2 = 196$

$$\frac{N_m}{N_g} = \frac{E_b}{E_g} \times \frac{\phi_g}{\phi_m}$$

$$\frac{N_m}{N_g} = \frac{196}{204} \times \frac{1}{1.1} \Rightarrow .87$$

Q. A separately excited dc generator having armature resistance of 0.1 Ω supplied 4kW at a terminal voltage of 200V. If the m/c is now operated as a motor at the same terminal voltage & same armature current with flux per pole being increased by 10%, the ratio of generator speed to motor speed will approx be.

a) 0.09 b) 0.11 c) 1.04 d) 1.12 ✓

Sol

$$I_a = \frac{4000}{200} = 20\,A$$

$$E_g = 200 + 20 \times .1 = 202$$

$$E_m = 200 - 20 \times .1 = 198$$

$$\frac{N_g}{N_m} = \frac{202}{198} \times \frac{1.1}{1}$$

$$= 1.12$$

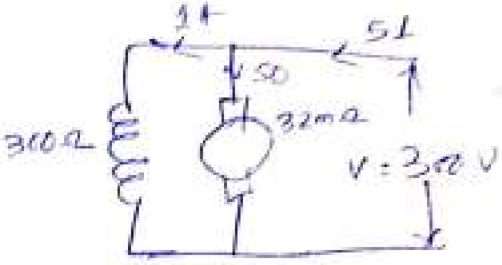
Q. A separately excited dc generator rotating at 3000 RPM produces an emf of 157 volts and delivers a current of 20A. The braking torque excited by armature is

a) .17 Nm b) 10 N·m ✓ c) 12 N·m d) 12.5

$$T_{em} = T_b = \frac{157 \times 20}{2 \times \pi \times \left(\frac{3000}{60}\right)} = 10\ N\cdot m.$$

Q. A 300 V dc shunt motor draws a line current of 51 amp. The armature & field resistances are 32 mΩ & 300 Ω respectively. Assuming 1 hp = 746 watt the mech power developed by the motor is

a) 20 hp b) 20.1 hp c) 20.4 hp d) 20.5 hp.



$P_m = E_b \times I_a$

$E_b = V - I_a R_a$

$I_a = I_L - I_{sh} = 51 - \frac{300}{300} = 50A$

$E_b = 300 - 50 \times 32 \times 10^{-3} = 298.4 V$

Mech power = $E_b \times I_a$

$= 298.4 \times 50$ watt

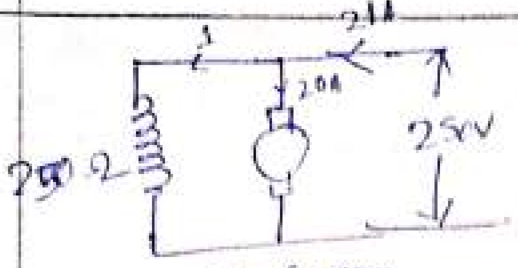
$= \frac{298.4 \times 50}{746} = 20 HP$

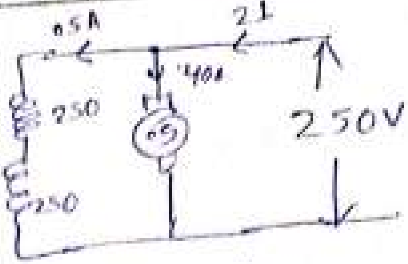
Q. A 250V DC shunt motor has an armature resistance of .5 Ω and field resistance of 250 Ω when driving a constant torque load at 600 rpm the motor draws 21 amp the new speed of motor if additional 250 Ω resistance is connected in series in field ckt.

Sol^n $E_{b1} = 250 - 20 \times .5 = 240$

$E_{b2} = 250 - 20.5 \times .5 = 239.75$

$\frac{N_2}{N_1} = \frac{E_{b2}}{E_{b1}} \times \frac{I_{sh1}}{I_{sh2}} = \frac{239.75}{240} \times \frac{1}{.5} =$





$N = 600$ RPM

$T_1 = T_2$

$N_2 = ?$

$I_{f1} I_{a1} = I_{f2} I_{a2}$ $\quad T \propto \phi I_a$

$I_{sh1} I_{a1} = I_{sh2} I_{a2}$

$1 \times 20 = .5 \times I_{a2}$

$I_{a2} = 40A$

$E_{b1} = 250 - 20 \times .5 = 240$

$E_{b2} = 250 - 40 \times .5 = 230V$

$$\frac{N_2}{N_1} = \frac{E_{b2}}{E_{b1}} \times \frac{I_{sh1}}{I_{sh2}}$$

$$\frac{N_2}{600} = \frac{230}{240} \times \frac{1}{.5} =$$

$N_2 = 1150$ rpm.

Q) A dc series motor driving a fan load when the load torque is proportional to N^3 the resistance of armature and fields $1\,\Omega$ & motor takes 10 A at 1000 rpm when operating from 200 V supply, the value of resistance to be inserted in series with the armature to reduce the operating speed 500 rpm.

a) $12.75\,\Omega$ b) $11.74\,\Omega$ ✓ c) $13.74\,\Omega$ d) $14.75\,\Omega$

Scanned with CamScanner

$T \propto N^3$, $R_a + R_{se} = 1\Omega$ $I_a = 10A$ $N = 1000$ rpm $V = 200V$

$R_e = ?$ At to reduces the speed $N_2 = 800$ rpm.

$T \propto N^3$

$I_a^2 \propto N^3 \Rightarrow \frac{I_{a1}^2}{I_{a2}^2} = \frac{N_1^3}{N_2^3}$

$\Rightarrow \frac{I_{a1}}{I_{a2}} = \sqrt{\frac{N_1^3}{N_2^3}}$

$\frac{10}{I_{a2}} = \sqrt{\frac{1000^3}{800^3}}$

$I_{a2} = 7.15 A.$

$E_{b1} = V - I_{a1} \times 1 =$

$= 200 - 10 \times 1 = 190$

$E_{b2} = 200 - 7.15(1 + R_e)$

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

$\frac{800}{1000} = \frac{E_{b2}}{190} \times \frac{10A}{7.15}$

$E_{b2} = 108.76 V$

$108.76 = 200 - 7.15(1 + R_e)$

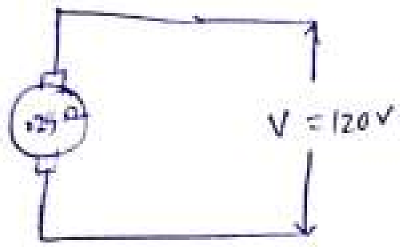
$R_e = 11.74 \Omega$

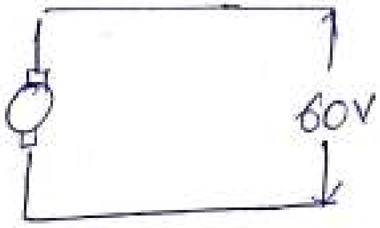
Q5

A permanent magnetic dc commutator motor has no load speed is 6000 rpm when connected to 120V dc supply. the armature resistance is 0.5 Ω & other losses maybe neglected. the speed of the motor with supply voltage of 60 V developing a torque .5 N-m. is

a) 3000 rpm b) 2673 rpm c) 2836 rpm d) 5346 rpm

Soln





$N = 6000\ rpm$

$T = 0.5\ N\text{-}m$

$N_2 = ?$

$E_{b1} = V$ $I_a = 0$ (as losses neg., No load)

As permanent mag so flux = constant

$$E_{b1} = 120 = \frac{P\phi Z N}{60A} = 120\ A$$

$$= \frac{\phi Z P}{60A} = \frac{120}{6000} = 0.02$$

$$\frac{\phi Z P}{A} = 0.02 \times 60 = 1.2$$

$$T = \frac{E_{b2} I_{a2}}{2\pi \frac{N}{60}} = \frac{\frac{\phi Z N_2}{60} \times \frac{P}{A} \times I_{a2}}{2\pi \frac{N_2}{60}} = \frac{\phi Z P}{2\pi A} \cdot I_{a2} = .5$$

$$\Rightarrow \frac{1}{2\pi}(1.2)\ I_{a2} = .5$$

$$I_{a2} = 2.61\ A$$

$E_{b2} = V - I_{a2} R_2$

$= 60 - 2.61 \times 2.5$

$= 53.47$ V

$\frac{N_2}{N_1} = \frac{E_{b2}}{E_{b1}}$ $\because \phi_1 = \phi_2$

$\frac{N_2}{6000} = \frac{53.47}{120} = N_2 = 2673$ RPM.

6) A 230V, 250 rpm, 100 amp seperately excited dc motor has an armature resistance of 0.5 Ω the motor is connected to 230V dc supply and rated dc voltage applied to the field winding. it is driving a load whose torque speed characteristic given by $T_L = 500 - 10\omega$, where ω is the rotational speed expressed in rad/sec. & T_L load torque in N-m. find the steady state speed at which the motor drives the load and armature current drawn by it from the source, neglect the rotational losses of the m/c.

Sol^n A 230V, 250 rpm 100 A sep excited dc motor $R_a = .5\,\Omega$ V = 230V

$T_L = 500 - 10\omega$

$T_{em} = J\frac{d\omega}{dt} + B\cdot\omega + T_L$ (steady state $\frac{d\omega}{dt}$ = 0; loss neglected so it is zero.)

$T_{em} = T_L$

At rated condition i.e 250 RPM.

$E_b = 230 - 100 \times .5 = 180$ V

$E_b = K \times \omega$

for seperately excited & shunt m/c

$$E_b = k\omega$$

$$T = k I_a$$

$$T = \frac{E_b I_a}{\omega} = \frac{k\omega I_a}{\omega} = k I_a$$

$$E_b = \frac{\phi Z N}{60}\left(\frac{P}{A}\right)$$

$$E_b \propto N \propto \omega$$

$$k = \frac{E_b}{\omega} = V/rad/sec$$

$$k = \frac{T}{I_a} = N\text{-}m/Amp$$

Soln

$$E_b = k\omega$$

$$k = \frac{E_b}{\omega} = \frac{180}{2\pi \frac{N}{60}} = \frac{180}{\frac{250}{60}} = 6.87 \; V/rad/sec$$

ω_m = actual speed of motor.

$$T_{em} = \frac{E_b I_a}{\omega_m} = \frac{k\omega_m I_a}{\omega_m} = k I_a = k\left[\frac{V - E_b}{R_a}\right]$$

$$T_e = k\left[\frac{V - k\omega_m}{R_a}\right] = T_L = 500 - 10\omega_m$$

$$\Rightarrow 6.87\left[\frac{230 - 6.87 \times \omega_m}{0.5}\right] = 500 - 10\omega_m$$

$$\omega_m = 31.5 \; rad/sec = 31.5 \times \frac{60}{2\pi} = 301 \; RPM.$$

$$I_a = K\left[\frac{V - E_b}{R_a}\right]$$

$$= (0.5)\left[\frac{230 - 6.37 \times 31.5}{0.05}\right] = 26.7\ A \text{ Ans}$$

$- 27.1\ A$ Ans

Q A 250V DC series motor has armature & series field resistance of $\cdot 25\Omega$ & $\cdot 15\Omega$ respectively. the current for th developing 80N-ms at 1200 rpm is

a) 86.4 Amp b) 43.2 A c) 21 A d) 13 A

$T = 80$ N-m

$$T = \frac{E_b I_a}{\omega} = \frac{(V - I_a R_a) I_a}{\omega}$$

$$T_{em} \times \omega = E_b I_a$$

$$80 \times \frac{2\pi \times 1200}{60} = [250 - I_a(\cdot 4)] I_a$$

$$80 \times 2\pi \times 20 = 250 I_a - I_a^2(\cdot 4)$$

$$I_a = 43.2\ A$$

Scanned with CamScanner