19.2.25

E.M.F Equation of DC Generator:-

Let ϕ = Flux/Pole
P = No. of poles
N = R.P.M
Z = Total conductor
A = No. of parallel path.

⇒ Now, for one revolution, flux $= P\phi = d\phi$ (say)

$\therefore$ $\boxed{\text{Time} = \left(\frac{60}{N}\right) = dt \text{ (say)}}$

⇒ Induced e.m.f from the conductor is:

$$\boxed{e = \frac{d\phi}{dt} = \frac{P\phi}{\left(\frac{60}{N}\right)} = \frac{PN\phi}{60}}$$

⇒ Induced e.m.f for Z-conductor, $\boxed{E = \frac{PN\phi}{60}}$

$\therefore$ Now effective conductor/parallel path $= \frac{Z}{A}$

⇒ Induced e.m.f for Z-conductor is $\boxed{E = \frac{PN\phi}{60}\left(\frac{Z}{A}\right)}$

⇒ Now, Induced e.m.f. for Lap winding, $\boxed{E = \frac{PN\phi}{60}\left(\frac{Z}{P}\right)}$

Induced e.m.f for wave winding, $\boxed{E = \frac{PN\phi}{60}\left(\frac{Z}{2}\right)}$

* Depending factor of induced e.m.f, $e = Blu$

D = Diameter of Armature
L = Length of Armature

* Cross-section area $= \pi DL$

$\boxed{B = \frac{P\phi}{\pi DL}}$, $e = Blu$, $\boxed{u = \frac{\pi DN}{60}}$

$$\boxed{E = \frac{PN\phi}{60}\left(\frac{Z}{A}\right)}$$

Here; P, Z and A ~~do~~ are constants.

$\Rightarrow E = KN\phi$

$\Rightarrow$ (i) $E \propto \phi$ Again, $\phi \propto I_f$

(ii) $E \propto N$ $\Rightarrow E \propto I_f$

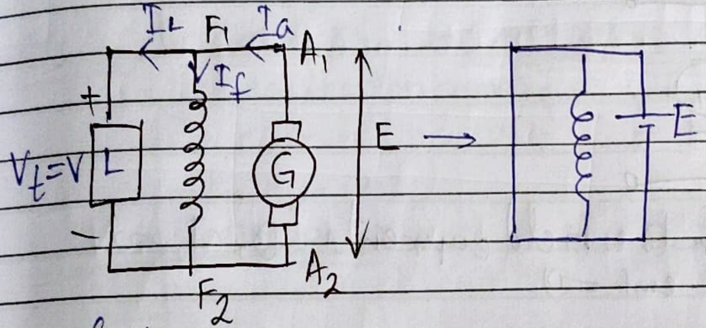
Now, for $N_1, \phi_1 \Rightarrow E_1 = KN_1\phi_1$

$N_2, \phi_2 \Rightarrow E_2 = KN_2\phi_2$

$$\frac{E_1}{E_2} = \frac{N_1\phi_1}{N_2\phi_2}$$

Again, if $\phi_1 = \phi_2 = \phi = \text{constant} \Rightarrow \boxed{\frac{E_1}{E_2} = \frac{N_1}{N_2}}$

Some other equation for Generator:



(Shunt Generator)

Here, $I_a = I_A$

$\boxed{I_a = I_e + I_f}$ — (i)

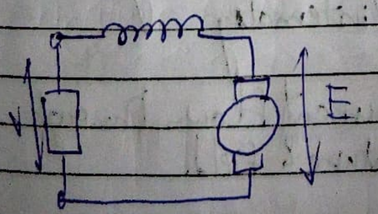
$I_f = I_{sh}$

In KVL equation:-

$E = I_aR_a + \underbrace{I_LZ_L}_{V}$, $\boxed{E - I_aR_a = V}$ — (ii)

$\boxed{V = I_fR_f}$ — (iii)

(Series Generator)



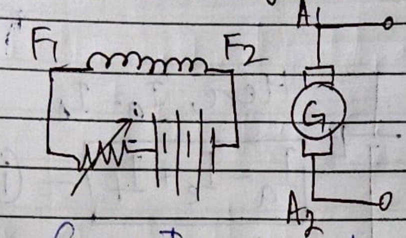
Characteristics of DC Generator:

1. No-load or Open-circuit Characteristics
2. External or Load Characteristics
3. Internal characteristics.

No-Load →

⇒ $E = KN\phi$ ⇒ $E \propto \phi$ for const. N.
But $\phi \propto I_f$ ⇒ $E \propto I_f$

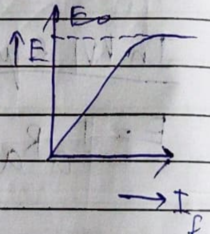
① # Separately Excitated Generator →



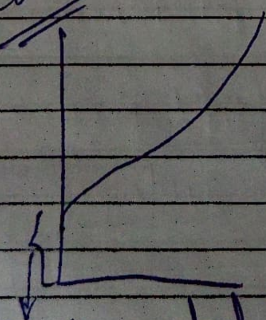
Case I: When the field current is 0, $I_f = 0$
∴ $E = 0$ (ind. emf = 0)

Case II: When the field current (I_f) increases, ϕ (↑)
'E' also increases (E ↑)

Case III: When the field current (I_f) decreases, ϕ (↓), 'E' also decreases (E ↓).



Case I



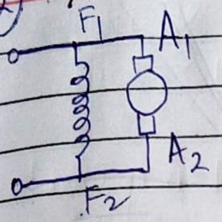
due to residual magnetism.

→ Armature wdg & field wdg are connected internally.

→ So, same current flows through both armature & field.

28.2.25

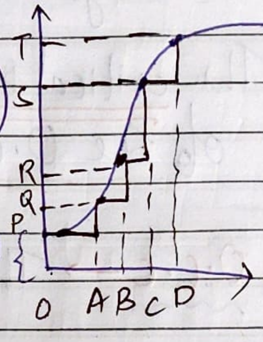
② # Shunt Generator



We know that $E = KN\phi$.
$\therefore$ For emf N, $E \propto \phi$
but $\phi \propto I_f \Rightarrow E \propto I_f$.

Case I: When $I_f = 0 \Rightarrow E = 0$ (ind. emf = 0) ×
(emf. is directly prod.).
Initially generator has some induced e.m.f., which is possible when residual magnetism.

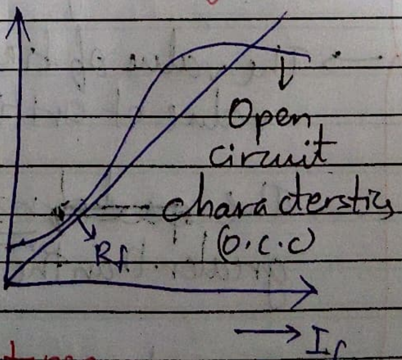
Case II: (value of Mag. field increase when excitation current increases)
(ind. current increases)
(emf. increases)
upto saturation point.



→ When dipoles all are aligned perfectly, no more magnetisation increase happen → saturation occurs at some point.

Condition: Some residual volt. is req. at the beginning to make some induced e.m.f and operate the generator

$\frac{E}{I_f}$ - Appox. value of field resistance + (val. of arm resistance).



Note: For a particular generator the field resistance is always lower than O.C.C resistance.

Effect of Field Resistor:-

Consider two field resistance R_{f1} and R_{f2}.

$R_{f1} \rightarrow$ Original field resistance

$R_{f4} > R_{f3} > R_{f2} > R_{f1}$

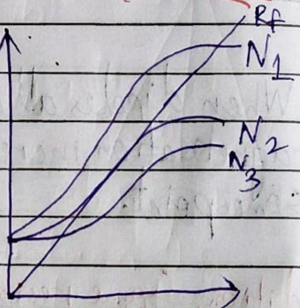
* Critical Field Resistance

→ The maximum value of the field resistance which can build up the voltage for a given value of I_f.

If the value of field resistance > Critical resistance it can't generate any voltage

- This critical field resistance is the tangent of the O.C.C. (Open ckt characteristics)

* O.C.C → The graph of E vs. I_f for const. N.



$N_1 > N_2 > N_3$

* Condition of Voltage Building:-

→ There must be a residual magnetism.

→ The value of field resistance must be less than value of critical field resistance.

→ The ~~speed of~~ rotation of the armature must be greater than the critical speed.

→ The polarity of the field and rotation of the armature must be in proper sequence.

if oppo. polarity → Then it destroys the residual magnetism present.

?. Process of volt. buildup → (O.C.C) explanation

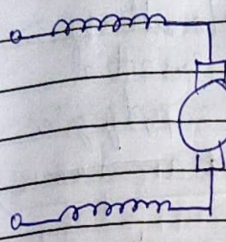
Justify for shunt gen. there must be resid. mags (O.C.C) explanation

(after mid-term)

19.3.25

O.C.C

Series Generator



We know that $E = KN\phi$

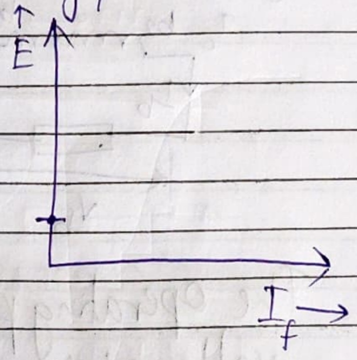
$\therefore$ For constant N, $E \propto \phi$.

But $\phi \propto I_f$ $\Rightarrow E \propto I_f$.

Case I: $I_f = 0$ $\Rightarrow E = 0$ (ind. emf = 0).

Case II:

(e.m.f is directly produced)



26.3.25

Internal Characteristics -

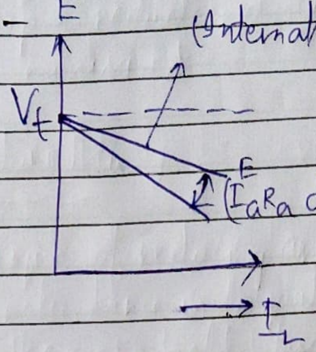
$\therefore E = V_t + I_a R_a$

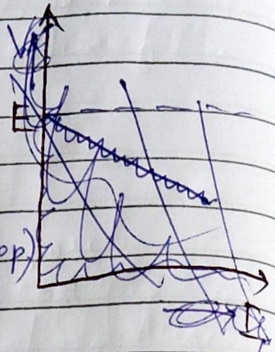
E vs. I_a

Shunt Generator -

$E = V_t + I_a R_a$

$\Rightarrow$



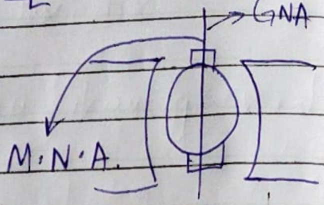


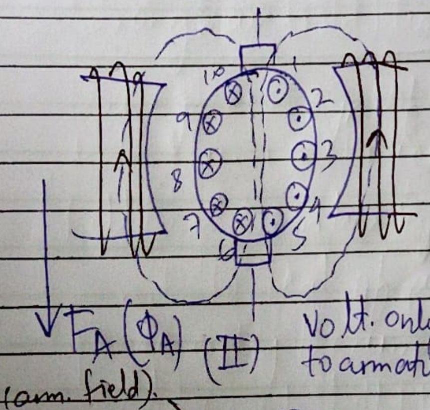
Armature Reaction -

GNA $\Rightarrow$ Geometrical Neutral Axis

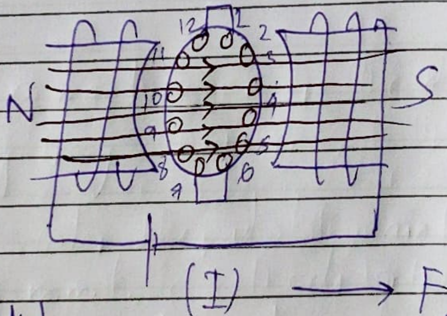
MNA $\rightarrow$ Magnetical Neutral Axis.

* Brush is always placed in MNA.

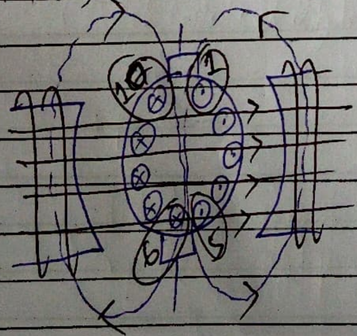




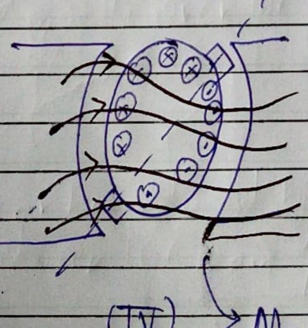
(II) Volt. only applied to armature wdg.



(I) $\longrightarrow F_m (\Phi_m)$ (main mag. field)



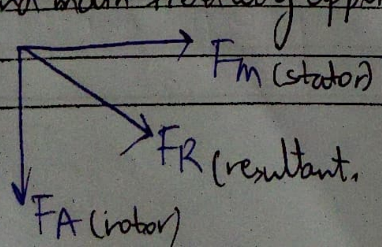
(III)



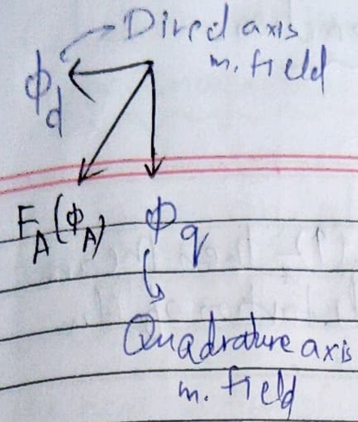
(IV) $\rightarrow$ Magnetic neutral axis will also change

$\rightarrow$ Brush also change

Both volt. to armature and main field wdg applied



* Dir^n of the armature mag. field is always ~~perpendicular~~ along the MNA or brush axis.



Direct axis → Polar axis
Axis in between the main pole.
* Main mag. field is always along the d. axis or polar axis

$\perp^r$ to direct axis = Quadrature axis

* Dir^n of Φ_d is directly oppose the main field path.

⇒ Value of main field decreases.

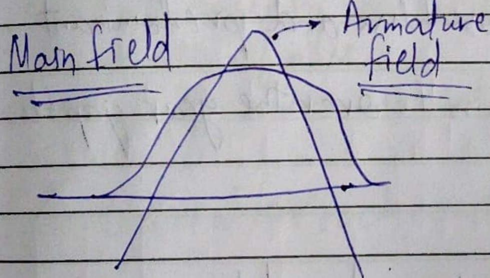
Effect of Armature Reaction:-

Effect of Φ_d on the main mag. field is called as Demagnetisation (Volt$_{Term}$ is reduced)

Φ_q ⇒ Directly cross the main mag. field
(Cross magnetisation effect).

Physically → Sparking and Brush contact is observed.
Electrical → Distortion of mag. main field.
↳ Harmonic effect is obs. in sine wave

Hostelwork
Waveforms of Field wave, Arm. wave;



Detrimental Effect of Armature rxn

↓

1. The iron loss will be increased (depends on flux density)
2. There is a problem on commutation. (earlier 1⊙ then 1⊗, 6⊗ then 6⊙)
3. Sparking excessively can be observed and
4. Cost of the Field wdg increases; To maintain volt. const. we need to reduce more arm. rxn.

Method of Limiting the effect of Armature Reaction-

① **By High reluctance pole tip**

If the reluctance of the pole tip is (↑), then the arm. of the mag. flux tip is reduced and distortion of flux density is also be minimised.

② **Reduction in Armature Flux-**

Another const. Technique of reducing arm. ~~flux~~ cross mag. flux is to create more reluctance in the path of arm. flux without reducing the main field flux.

This is achieved by doing field pole having several rect. pole punched in together.

③ **Strong main field flux -**

During the design of the DC machine, ensure the main field flux is sufficiently strong in comparison to the full load arm. flux ~~by~~. Greater the ratio of main field m.m.f. to that of arm. m.m.f., less the distortion produces by the armature cross flux and predominant could be control of the field m.m.f. over the year gap flux.

④ **Interpoles-**

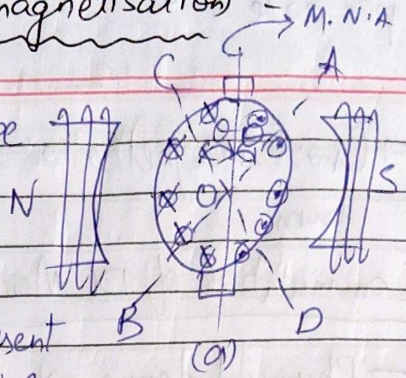
The effect of arm. rxn can be reduced by using interpoles Soft poles between the main pole.

⑤ **Compensating wdg-**

The effect of arm. rxn can be reduced by using compensating wdg

Easily improve.

Calculation of Armature Ampere-Turn
(for demagnetisation & cross-magnetisation)



- Due to arm. rxn, let the M.N.A be shifted ahead by an angle θ, which is shown in fig.

The new position of M.N.A is represent by the line AB. Draw another line CD making the same angle 'θ' with G.N.A., but in opposite dir^n which is shown in fig.

→ It may be obs. that all the conductor lying btw AOC and BOD carry current in such a dir^n, the m.m.f. produced by them is opposite to the main m.m.f. This conductor cause demagnetisation effect and this ~~term~~ turn are called as demagnetising turn.

→ All other turn lying between AOB & COD produce the cross magnetisation effect and turns are called as cross magnetising turn.

Let Z = No. of conductor,
A = No. of parallel path
(mech) θ = Angle by the shifted m.m.f. to the G.N.A.
P = No. of pole
I_A = Armature current

$$I_C = \text{Current for each conductor} = \frac{\text{Arm. current}}{\text{No. of parallel path}} = \frac{I_A}{A}$$

⇒ Total ampere turn $= \left(\frac{Z}{2}\right) I_C = \left(\frac{I_C Z}{2}\right)$

⇒ ~~Total~~ ampere turn per pole $= \left(\frac{I_C Z}{2P}\right)$

Demagnetising ampere turn (m.m.f.) - Ampere turn line between AOC & BOD = m.m.f AOC + m.m.f BOD $= \frac{I_C Z}{2}\left(\frac{2\theta + 2\theta}{360}\right)$

$$= I_C Z \left(\frac{2\theta}{360}\right)$$

Demagnetising ampere turn per pole $= I_c$

⇒ Cross-magnetisation ampere turn $= \frac{I_c Z}{2P} - I_c Z \frac{\theta}{360}$

Commutation of DC Machine-

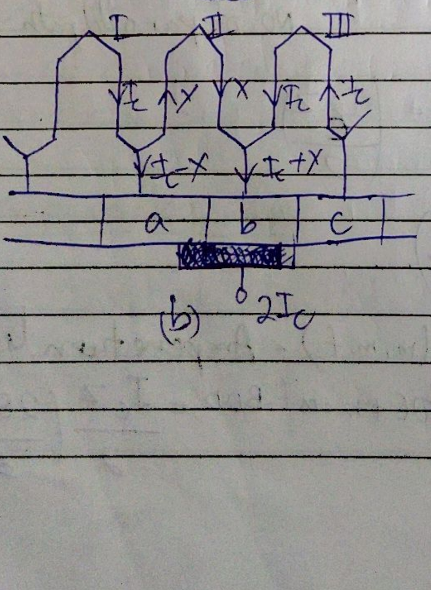
→ Physical device which helps to convert AC to DC or DC to AC.

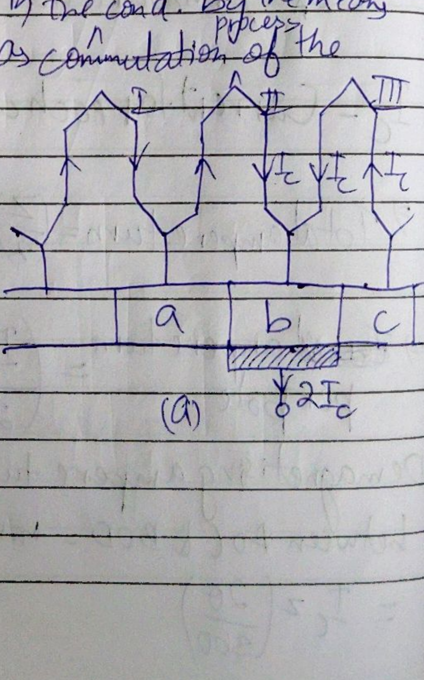
→ The arm. conductor that are under the influence of the north pole carry current in 1 direction and that under the south pole carry current in oppo. direction

→ Therefore, if the current in the conductor ~~carry in oppo. dir^n^~~ under the influence of north pole come under the influence of the south pole, the dir^n^ of the current of the conductor will change.

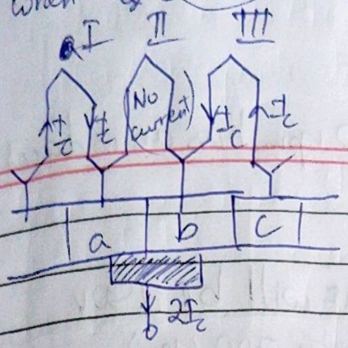
Current in these conductors change from +I to 0 and then from 0 to -I. Similarily change occur when the cond. under the influence of south pole come under the influence of the north pole. The current in this conductor change from -I to 0 and then from 0 to +I.

Therefore the reversal of current in the arm. cond. by the means of brush & commutator is called as commutation process of the DC machine

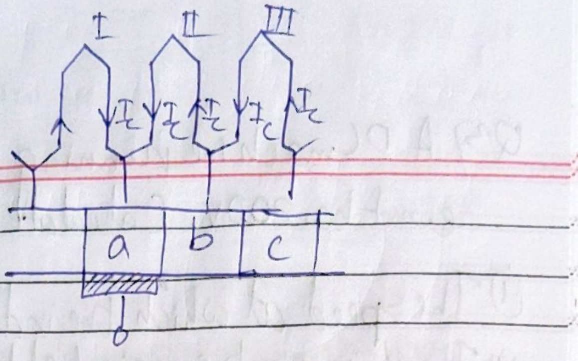




when $X=0$



(C)



(d)

28.3.25

Ex I: A 4-pole DC Machine has 144 slots in the armature with two coil side per slot and each coil has 2 turn. The flux per pole is 20 mWb, the armature is lap wound and it rotate at 720 rpm. What is the induced emf:

(i) Across the armature (ii) Across each parallel path

Ans: (i) $E = \frac{PN\phi}{60}\left(\frac{Z}{A}\right)$ [Across the armature].

$Z = 144 \times 2 \times 2$, $A = P = 4$, $N = 720$, $\phi = 20 \times 10^{-3}$

$E = 138.24V$.

Ex II: A DC generator carry 600 conductor and lap winding. The generator have 8 pole with 0.06 Wb useful torque. What will be the induced emf at the terminal if the generator rotate at 1000 rpm. Also determine the speed at which it should be driven to induce the same volt. with wave connection. – 250 rpm

Ans: (i) $E = \frac{PN\phi}{60}\left(\frac{Z}{A}\right) = \frac{8 \times 0.06 \times 1000 \times 600}{60 \times}$

Q3) A DC machine running at 750 rpm has an induced e.m.f has 200V. Calculate

(i) The speed at which the induced EMF will be 250V.
(ii) The % inc in the main field flux (with 700 rpm)

Ans: $\frac{E_1}{E_2} = \frac{N_1 \phi_1}{N_2 \phi_2}$ (here $\phi_1 = \phi_2$, nothing mention by default).

(i) $\Rightarrow \frac{E_1}{E_2} = \frac{N_1}{N_2} \Rightarrow \frac{200}{250} = \frac{750}{N_2}$

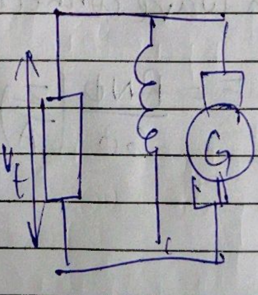
$\Rightarrow N_2 = 937.5$ rpm

(ii) 1.34% % increase 34%

$\frac{E_1}{E_2} = \frac{N_1 \phi_1}{N_2 \phi_2} \Rightarrow \frac{200}{250} = \frac{750}{700} \times \frac{\phi_1}{\phi_2}$. $\Rightarrow \frac{\phi_1}{\phi_2} = 1.34$

Q4) A 2-pole DC shunt generator with lap connected has field and armature resistance of 50Ω and 0.1Ω

A generator is supplying a load 2.4 kW at 100V. Calculate the armature current and current in conductor and generated e.m.f.



Ans: $E = V_t + I_a R_a$

$I_a = I_l + I_f$

$V = I_f R_f \Rightarrow I_f = \frac{100}{50} = 2.$

$P = 2.4$ kW, $V = 100$, $I_L = 24$.

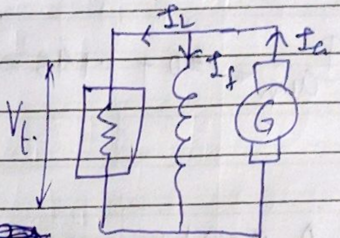
$E = 100 + 26 \times 0.1 = 102.6$V.

$P_L = V^2 R \Rightarrow 2.4 \times 10^3 = (10^2)^2 R \Rightarrow R = 24 \times 10^{-2} \Omega$

$P_L = (100)^2 (24 \times 10^{-2}) = 2400 W.$

Q5) The armature of a 4-pole shunt DC Generator has wave connected 378 conductor. The arm. & shunt wdg resistances are 1Ω and 100Ω.
Flux per pole = 0.02 Wb. If load resist. is 10Ω is connected across the arm. terminal & gen. is driven at 1000 rpm, calculate the power abs. by the load.

Ans: $P = I_L^2 R_L = V_L I_L$



$E = \frac{PN\phi}{60} \times \frac{Z}{A} = \frac{4 \times 1000 \times 0.02}{60} \times \frac{378}{2}$
$= 252 V.$ ~~252~~

$V_t = E - I_a R_a$ $\qquad V_t = 227 V$

$I_L = I_a - I_f$, $\left(I_a = I_L + I_f = \frac{V_t}{10} + \frac{V_t}{100} \right)$

$I_L = \frac{227}{10} = 22.7$, $I_f = \frac{227}{100} = 2.27$ $\Rightarrow I_a = 24.97 A.$

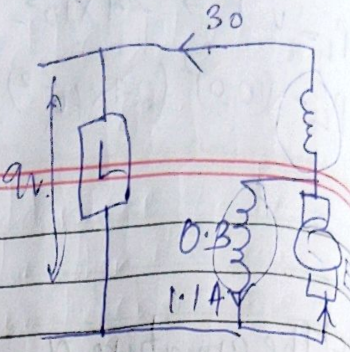
$P_L = 5.153 kW$ $\left(P_L = V_t I_L = 227 \times 22.7 \right)$
$= 5152.9 W$

$I_a = I_f + I_L$
$= \frac{V_t}{R_f} + \frac{V_t}{R_L}$

Q6) A short shunt compounded DC Gen. deliver 30 A, 220 V. The resistance of the arm and ~~shunt~~, field and shunt resistance is 0.05Ω, 0.3Ω and 200Ω.
Calculate the ind. emf and armature current allowed 1 V of brush ~~of~~ contact drop.

Ans: $E = V_t + I_{a} R_{a}$ + Brush contact drop.

$I_l = 30A$



$I = \frac{V}{R} = \frac{220}{200} = 1.1A$

$E - 2 \times 1V = O_t + I_a R_a$

Volt. drop across series field $= 30 \times 0.3 = 9V$

— — — — shunt field $= 220 + 9 = 229V$

$I_{sh} = \frac{229}{200} = 1.145$

$I_{arm} = 30 + 1.145 = 31.145$

$E = 232.56$

Q) A 250 kW, 500V, 4 pole arm wound armature has 720 conductor. It is given a brush lead of 3° mechanical from the geometrical neutral axis. Calculate the demag. and cross mag. tising amp. turn per pole.

Ans. Demag. ~~and~~ amp. Turn $= I_c Z \frac{\theta}{360}$

Cross magnetising amp. Turn $= I_c Z \left(\frac{1}{2P} - \frac{\theta}{360} \right)$. Mag. degree

Neglect the shunt field current.

$I_c = \frac{I_A}{A}$, $I_A = \frac{250 \times 10^3}{500} = 500A$, $A = 4$.

$\Rightarrow I_c = 125 \left(\frac{500}{4} \right)$, $Z = 720$, $\theta = 3°$.

$\therefore$ Demag. amp turn $= 125 \times 720 \times \frac{3}{360} = 750$

Cross mag. amp. Turn $= 125 \times 720 \left(\frac{1}{8} - \frac{1}{120} \right)$

$= 10500$

Q) A 250V, 10 KW, 8 pole DC Generator has single turn coil. The armature is wave wound with 90 commutator segment. If the brush is shifted by 2 commutator segment at full load, calculate:

i) The total armature rxn amp. Turn
ii) Demagnetizing amp. Turn   iii) cross-magnetising amp. Turn

Ans: $I_L = 40A = \frac{10\,kW}{250V}$, $I_f = 0$ (neglected), $I_a = I_L$.

$$\text{Total} = \frac{I_c Z}{2P} = \frac{I_a}{A} \cdot \frac{Z}{2P} = \frac{\cancel{40}^{20}}{\cancel{2}} \times \frac{(90\times\cancel{2})}{\cancel{2}\times 8}$$

→ single turn
↳ 2 parallel path
↳ (90 com. ×2)

i) ⇒ Total arm rxn amp. Turn = 225 A

(ii) $\theta = \frac{\text{No. of brush}}{\text{Total com. seg}} \times 360 = \frac{2}{\cancel{90}} \times \cancel{360}^{4} = 8°$

$I_c = \frac{I_A}{A} = 20$, $Z = 90 \times 2$

~~I~~ Deg. amp turn = 80

(iii) Cross mag. amp. Turn = $20 \times 180 \left(\frac{1}{16} - \frac{8}{360}\right) = 145$.

Q) Plot the O.C.C for the 375 rpm and determine the volt. to which the machine will excite if the field circuit resistance is 40 Ω.

The following data are given for the DC generator at 300 RPM

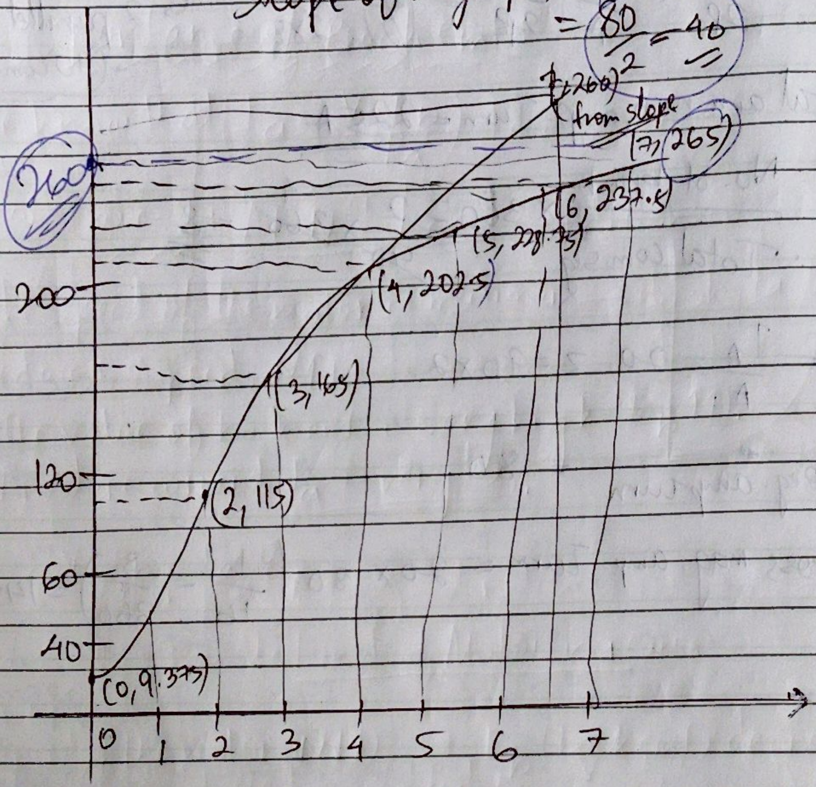
I_f	0	2	3	4	5	6	7
Arm. volt.	7.5	92	132	162	183	190	212.
New arm. volt.	9.375	115	165	202.5	228.75	237.5	265

(i) What additional Resist. should be added to the ckt to reduce the volt. to 200 V at 375 rpm.

(ii) Without these additional rest., determine the load current supplied by the generator when its terminal voltage is 200V. Assume that the armature resistance is 0.5 Ω.

Ans: $\left(\frac{E_1}{E_2} = \frac{N_1}{N_2}\right) \Rightarrow E_2 = \left(\frac{N_2}{N_1}\right)E_1 = \left(\frac{375}{300}\right)E_1$

Slope of the graph, where it's linear mostly $= \frac{80}{2} = 40$



* For the field current 7 Amp and shunt field 40 Ω, speed 375 rpm from the graph, the induced EMF. is (260 A).

The field current is (to get 200 V) 3.9 A

→ Therefore shunt field resist. $= \frac{200}{3.9} = R_{sh} = 51.28$ Ω

Elevation 11.28 Ω   Earlier = 40 Ω

arm. resist = 0.4 Ω $E = V_t + I_a R_a$

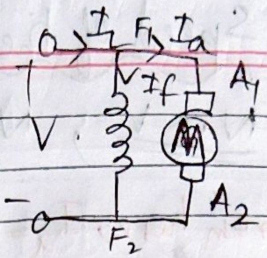
$\Rightarrow I_a = 71.875$ A $= 228.75 = 200 + I_a R_a$ 0.4

Load current = 66.29

2.4.25

DC Motor

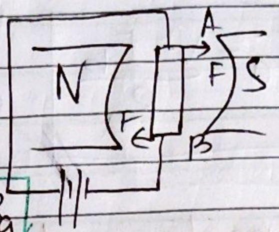
Basic Principle:



$I_L = I_a + I_f \Rightarrow \boxed{I_a = I_L - I_f}$

$\boxed{E_b = \frac{PN\phi}{60}\left(\frac{Z}{A}\right)}$ → Back emf

$= E_G$



$\boxed{V = E_b + I_a R_a} \Rightarrow \boxed{E_b = V - I_a R_a}$

* $(I_{aG} = I_L + I_f)$ $\boxed{E_G = V + I_a R_a}$

→ Motor → DC Machine which draws current from the supply

Generator → DC Machine which supplies current to the load.

* Busbar → source of constant voltage (supplies infinite current)

Torque Equation of DC Motor–

$E_b \cdot I_a = P_{Elect}$ Now, $P_{mech} = \tau \cdot \omega = \tau \cdot \frac{2\pi N}{60}$

* (Neglecting the loss), $(P_{ele.} = P_{mech})$

$\Rightarrow E_b \cdot I_a = \tau \cdot \frac{2\pi N}{60}$. Also, $E_b = \frac{PN\phi}{60}\left(\frac{Z}{A}\right)$

$\Rightarrow \tau \cdot \frac{2\pi N}{60} = \frac{PN\phi}{60}\left(\frac{Z}{A}\right) I_a$

$\Rightarrow \boxed{\tau = \frac{PZ}{2\pi A}\phi I_a = K_t \phi I_a}$, where, $K_t = \frac{PZ}{2\pi A}$

* $\tau \propto \phi$, $\tau \propto I_a$.

$F = BIl$

$B = \frac{P\phi}{2\pi r l}$

$\tau = F \cdot r$
$= F \cdot r \cdot z$

Speed Equation:

$\because E_b = V - I_a R_a \Rightarrow kN\phi = V - I_a R_a \Rightarrow N = \frac{V - I_a R_a}{k\phi}$

* Speed of the motor depends

$N \propto V$, $N \propto -I_a R_a$, $N \propto \frac{1}{\phi}$

From here, I_a = Armature current = $\frac{V - E_b}{R_a}$

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

* Importance of Back emf:

We know that $\left(I_a = \frac{V - E_b}{R_a}\right)$

Now, Case-I: At No-Load condition:-

→ The speed of the motor is maximum → no obstacle to reduce the speed. $(N\uparrow\uparrow)$.

→ The value of back emf is very high $(E_b\uparrow\uparrow)$.

→ Armature current I_a is very less.

when $V \approx E_b$, $I_a = 0$.

Case-II: When the Load of Motor increases

* Speed of the motor $(N\downarrow\downarrow)$ * E_b (back emf) decreases.
* Armat. current increases $(I_a\uparrow\uparrow)$.

Motor will draw more current from supply.

Case-III: When the Load of Motor decreases.

* Speed of the motor $(N\uparrow\uparrow)$ * E_b (back emf) increases.
* Armature current decreases $(I_a\downarrow\downarrow)$.

Motor will draw less current from supply.

→ (Back EMF works as governor of the DC Motor)

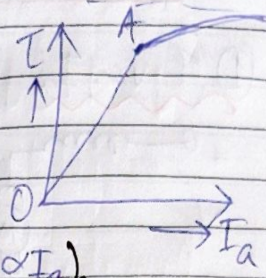
* Characterstics of the Motor–

① Torque vs Armature Current (τ vs. I_a).

② Speed vs Armature Current (N vs. I_a).

③ Speed vs. Torque (N vs. τ).

DC Shunt Motor–



① (τ vs I_a)

$\because$ ($\tau = k_f \phi I_a$) Therefore for (constant ϕ, $\tau \propto I_a$).

Case I: At no load condⁿ of motor.

⇒ I_a (Arm. current) → 0, * ($\tau = 0$)

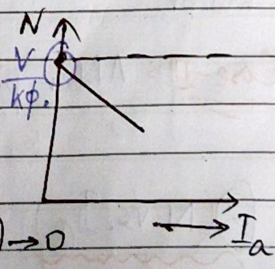
Case II: When the load of the motor inc. (↑).

* I_a (Arm. current) ↑↑ inc. * (τ also increase τ(↑))

⇒ Case III: After point A, arm. rxn takes place

⇒ Graph has demag. process, non-linear increase

⇒ will reach saturation pt.



② (N vs I_a)

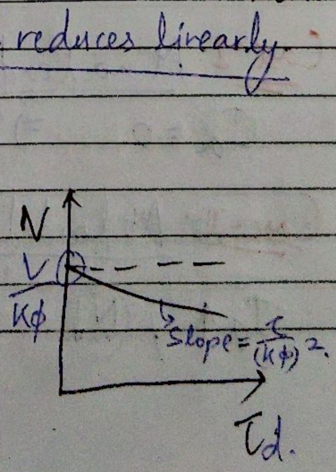
$$N = \frac{V - I_a R_a}{k\phi} \Rightarrow N \propto (-I_a R_a).$$

Case I: At no-load condⁿ, I_a (Arm. current) → 0

$N = \frac{V}{k\phi}$ Maximum value.

Case II: When the load of motor inc. (↑↑), I_a (arm. current) ↑↑ increases

but $N \propto (-I_a R_a)$ ⇒ So, speed reduces linearly.



③ (N vs τ_f)

$$\tau = k\phi I_a, \quad N = \frac{V - I_a R_a}{k\phi},$$

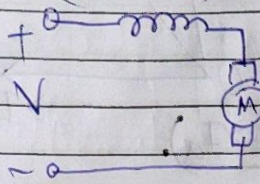
$$\Rightarrow N = \frac{V - \left(\frac{\tau}{k\phi}\right) R_a}{k\phi} = \left(\frac{V}{k\phi} - \frac{\tau}{(k\phi)^2} R_a\right)$$

$\tau_d \rightarrow$ Developed Torque $\rightarrow$ equivalent to Mech. Torque which can be applied to the shaft of the motor.

4.25
3.

DC Series Motor -

① (τ vs. I_a)



We know that $\tau = K_t \phi I_a$

But $\phi \propto I_f$

$\Rightarrow \tau = K_{t1} I_f I_a$

Again for series Motors:-

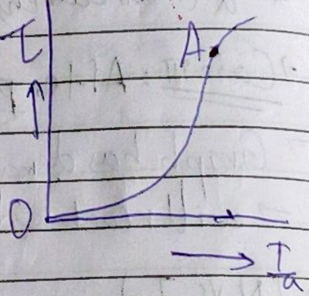
$I_a = I_f$

$\tau = K_{t1} I_a^2$

$\tau \propto I_a$

Case-I: At no-Load condition:-

$I_a = 0$. or $I_a \approx 0 \rightarrow \tau = 0$.

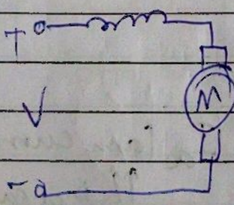


Case-II: At loaded condition:-

Load of motor (↑), then I_a (↑) ($\tau \propto I_a$)

Case-III: After point A $\rightarrow$ Saturation curve $\rightarrow$ Arm. rxn

② (N vs. I_a)



We know that $N = \dfrac{V - I_a R_a}{K\phi} = \dfrac{V - I_a R_a}{K_1 I_f}$

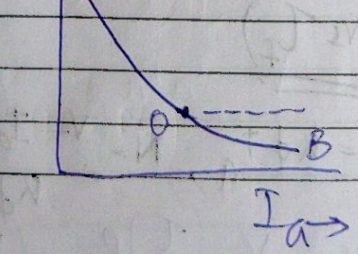
$\Rightarrow N = \dfrac{V - I_a R_a}{K_1 I_a}$ $\quad [\phi \propto I_f$.

Case-I: At no-load condition -

$I_a = 0 \quad \Rightarrow N \rightarrow \infty$

Case-II: At loaded condition -

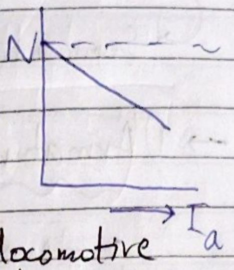
$I_a \uparrow$, $N \downarrow$



* If we turn the N very high → mech. breakdown of the ball bearing. → series motor can't run at (no-load condition)

Case-III: at very high I_a, (N almost constant)
↓
* DC motor is considered as constant speed driver

③ (N vs. T)



DC series motor is used in transution device → locomotive device.

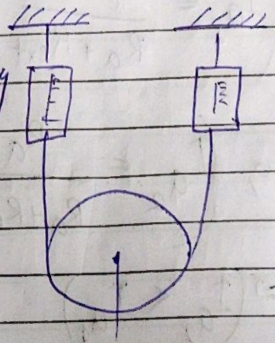
① No chance of off-load condⁿ (always mech. connected)

* Torque of the motor $\propto I_a^2$.

② Starting torque $(T_{st}) \propto I_a^2$

At starting, arm. current is always very high. (for any motor).
→ To overcome the inertia of rest (more driving thrust).
Series motor has more starting Torque than shunt motor.

(Transuction / Locomotive) Alternative to applying Load to the Motor (always) ⟶ Belt-Pulley System



Q) *** Why it is dangerous to run series motor by belt-pulley arrangement?

Ans: Aging effect of belt due to cont. friction of rotating pulley → Belt may break down unlike train
↳ Mech. breakdown due to no-load

Characteristics of separately excited shunt motor:

Cummulative motor → in between shunt & series motor.

Speed Control- $N = \frac{V - I_a R_a}{k\phi}$

$\Rightarrow N \propto V$

$N \propto -I_a R_a$

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

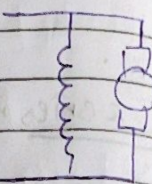
① Armature control : Arm. resistance control.

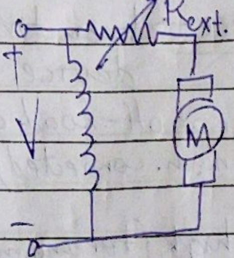
② By field current control

③ By supply voltage control : (very impractical to change supply voltage in household devices)

→ Semiconductor device

→ 1) Armature Resistance control - (Shunt motor)





→ Without Rext.

$$\left(I_{a_1} = \frac{V_t - E_b}{R_a} = \frac{V_t - k\phi N_1}{R_a} \right) \qquad E_b = k\phi N_1$$

* With Rext

$$\left(I_{a_2} = \frac{V_t - E_b}{R_a + R_{ext}} = \frac{V_t - k\phi N_2}{R_a + R_{ext}} \right).$$

So, $\left(I_{a_2} = \frac{R_a}{R_a + R_{ext}} I_{a_1} \right)$ when $\underline{(N_1 = N_2)}$ (ϕ is const. but $\tau \propto \phi I_a$)

$\Rightarrow \left(I_{a_2} < I_{a_1} \right)$ ⇒ Torque of developed motor is reduced.

For a particular Load Torque, and developed Torque is dec.

⇒ Speed of Motor reduced.

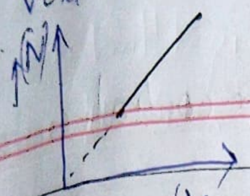
→ Back emf of Motor decrease → Arm current increased till the original current of I_{a_1}.

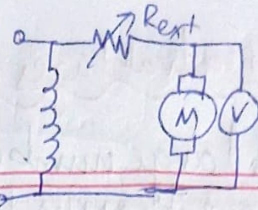
* Further, $N_2 = \frac{V_1 - I_{a_1} R_a}{k\phi}$, $N_2 = \frac{V - I_{a_2}(R_a + R_{ext})}{k\phi}$

but, $(I_{a_1} = I_{a_2})$.

So, $\boxed{N_2 = \frac{V_t - I_a (R_a + R_{ext})}{V_t - I_a R_a} N_1}$ $(N_2 < N_1)$

Volt. of the armature will change (V_a)





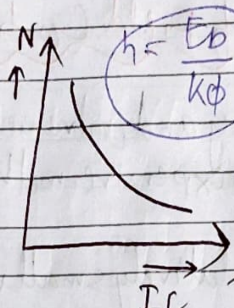
($V_a \rightarrow$) (Arm. voltage vs speed) → Speed is Linear characteristic

* we can't draw the characteristic from origin → Motor has initial speed.

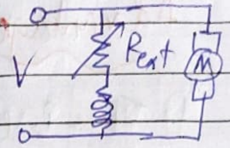
2) → Field control (shunt motor)

- By applying external resistance in series with the field circuit.

$N_1 = \frac{V_t - I_a R_a}{k\phi_1}$, $N_2 = \frac{V_t - I_a R_a}{k\phi_2}$



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



$\frac{N_2}{N_1} = c\frac{\phi_1}{\phi_2}$ ⇒ $\left(N_2 = c.\frac{\phi_1}{\phi_2} N_1\right)$

Therefore $(N_2 > N_1)$

But, $I_{f_1} = \frac{V_t}{R_f}$ and $I_{f_2} = \frac{V_t}{R_f + R_{ext}}$ $(I_{f_2} < I_{f_1})$

A.A.25 Armature control :-

$$\frac{N_2}{N_1} = \left(\frac{V_t - I_a(R_a + R_{ext})}{V_t - I_a R_a}\right) = \frac{(E_b + I_a R_a) - I_a R_a - I_a R_{ext}}{(E_b + I_a R_a) - I_a R_a}$$

$$\Rightarrow \left(\frac{N_2}{N_1} = \frac{E_b - I_a R_{ext}}{E_b}\right) \quad \boxed{V_t = E_b + I_a R_a}$$

* When $R_{ext} = 0$, the speed will be maximum.

Base speed → Rated speed or Maximum speed of the Motor.

* Two mode of ways to control speed of Motor

1) Constant Torque of the Motor (driving Torque)
2) Constant Power drive, $P = T\omega = KTn$, $T = k_t \phi I_a$ & $n = \frac{E_b}{k\phi}$

$\boxed{\Rightarrow P = E_b I_a \text{ (constant)}}$

Armature resistance's working principle

Field control's working principle.

Disadvantages of Armature Resistance:-

1) A large number of power is lost in the control resistance since it carries full armature current.

2) The speed varies widely with the load since the speed depends on the volt. drop in the control resistance.

3) The output & efficiency of the motor are reduced.

4) This method result in poor speed regulation (No load - Full load speed

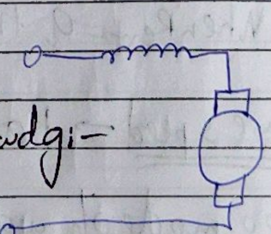
Advantage of Field Control Technique

1) This is easy and convenient method.
2) It is an inexpensive method since very little power is lost due to relatively small value of the field current.
3) The speed control exercised by this method is independent of the load of the machine.

Disadvantage of Field Control Technique:

1) Only speed higher than the normal speed can be obtained.
2) There is a limit to the maximum speed obtainable by this method.

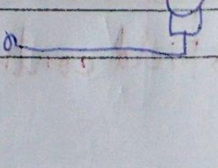
Series Motor:-



Ways in which we can change current in field wdg:-

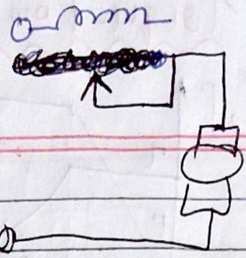
1) Field diverter circuit:-

Diverter is a variable resistance which is connected in parallel to the series field.

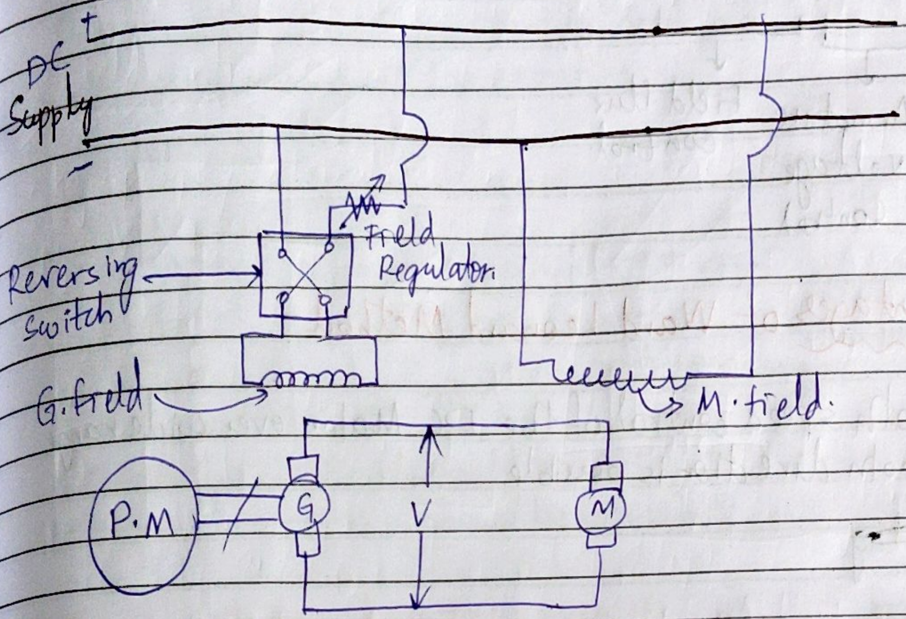


2) Tapped field control:-

→ In a field coil, if there is provision to connect multiple slots, we can tap at diff. places to obtain variable no. of turns.



Ward Leonard Method of Speed Control :-



* In the combined armature and field control technique by which speed ~~of~~ and field control is done.

Here the DC motor armature is fed from a variable voltage and adjustable polarity supply. The variable voltage and adjustable polarity supply is feed from the generator. The generator is driven by a prime mover.

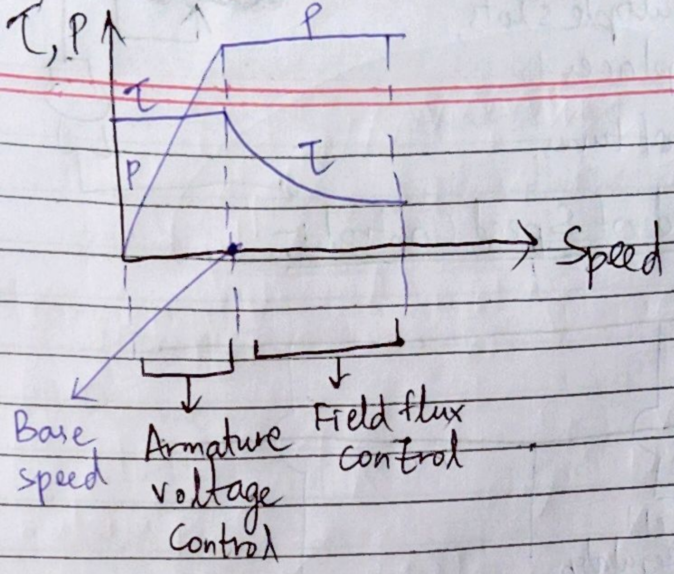
The field of both generator & motor are both separately excited. Here the P.M may be a DC Motor or 3-ϕ Induction Motor.

- Acc. to the diagram, the G.field is to be controlled

Generator voltage can be increased by :- (2 way).

1) Changing the speed of the P.M.
2) Changing the field current of the motor.

Torque-Power Characteristics:-



Advantages of Ward Leonard Method -

1) Smooth speed control of the DC Motor over wide range in both direction is possible.

~~2) The lag~~

Disadvantages of Ward Leonard Method -

1) Cost of the instrument is more.
2) 3 Motor → More Power consumption → Low efficiency. (Power Loss)
3) Large space required to accomodate 3 motors.

Starter
Loss Efficiency
Test
Parallel operation

~~Breaking~~ X

Starter -

Need of starter -

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

Now at starting, $E_b = 0$ [$N = 0$, $E_b = Kn\phi$.

Therefore the starting current of Motor, $\left(I_{st} = \frac{V}{R_a}\right)$

But the supply voltage, V = 220V (in general) and R_a (armature resistance) ≃ 1Ω. Therefore;

starting current = $\frac{220V}{1\Omega}$ = 220A → It goes through the terminal of motor.

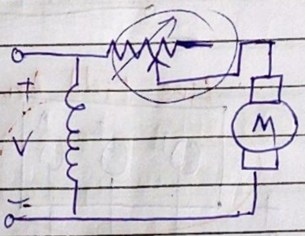
* Heat loss = I^2R → very high power generated (melting of arm/field resistance)

* To limit the starting current by applying ext. resistance in series ~~which~~ with the armature circuit.

$$\left(I_{st} = \frac{V}{R_a + R_{ext}}\right)$$

After running the motor, the armature current is prominent with E_b ↑↑, no need of ext. Resistance
→ If we still apply R_{ext}, then additional power loss will occur, and efficiency will be reduced.
* The value of R_{ext} should be 0 after starting period.
* The nature of R_{ext} should be variable.

* We cannot use rheostat, even if it is just like it since we have to manually change the value of resistance everytime power switch ON & OFF.



Starter →

→ Starting device of DC motor which has a variable resistance and this variable resistance can connect in this series with armature circuit to limit the starting.

or (i) Starter protect the armature from burn
(ii) To ~~pro~~ limit the starting current.

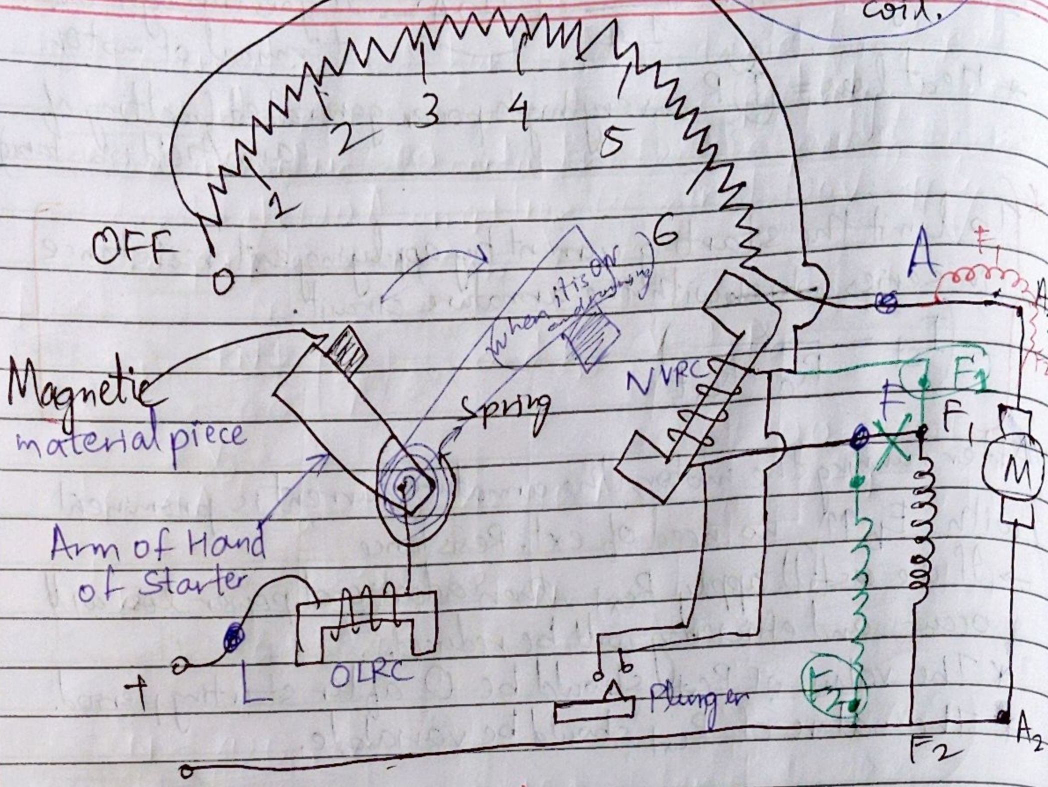
Types of Starter

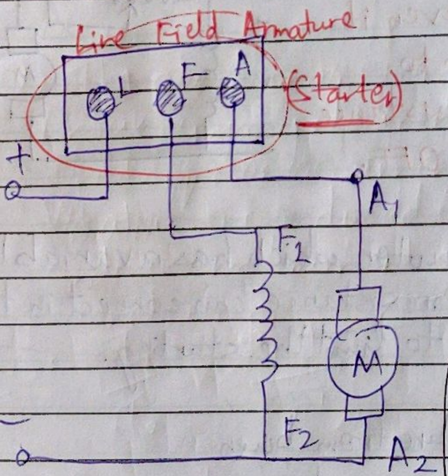
Three Point | Four point.

* Operating principle of 3-point Starter :-

OLRC
OverLoad Release coil.

NVRC
No voltage Release coil.





Function of NVR

(i) To keep the starter at OFF through spring. (Spring pull > mag. pull)

(ii) To provide the no-load protection to the starter.

Function of OLR:

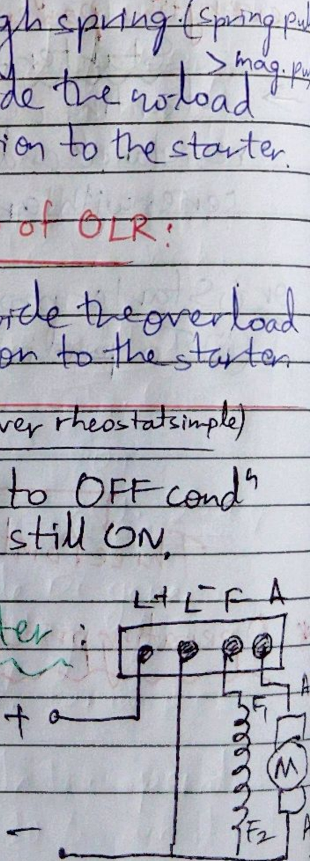
(i) To provide the overload protection to the starter.

(Advantage over rheostat simple)

Drawbacks of Starter:-

* Speed control may sometimes lead to OFF condⁿ of the starter while the motor is still ON.

→ Minor changes for 4-point starter:



Two point starter-

Loss on DC Machine:-

- Constant Loss
  - Iron Loss
    - Hysteris Loss
    - Eddy Loss
  - Mechanical Loss
    - Windage Loss
    - Friction Loss
- Variable Loss (stray Load Loss)
  - Armature Copper Loss
  - Field Copper Loss
  - Brush Contact

Efficiency of DC Machine-

1. The ratio of output to input of the motor is called as commercial efficiency. $= \left(\frac{O/P \text{ of Motor}}{I/P \text{ of Motor}}\right)$

2. The ratio of mechanical power output to the power developed at the armature is called as Mechanical Efficiency.

$$= \frac{\text{Mech power O/P}}{\text{Mech power developed in arm.}}$$

3. The ratio of electrical power developed in the armature to the ele. power input. is called as Electrical Efficiency.

$$= \frac{\text{Elec. power developed in arm.}}{\text{Elec. power Input}}$$

Let V = (Supply voltage / Terminal voltage), I_L = ~~Rated cu~~ Load current subjed to the Load

Power input = Power output + Loss (variable + const.)

Power input = $(VI_L) + (I_a^2 R_a + P_c)$

$$* \boxed{\text{Efficiency} = \left(\frac{VI_L}{VI_L + I_a^2 R_a + P_c}\right)}$$

, Maximum efficiency when (var. loss = Const. loss)

$$I_a^2 R_a = P_C.$$

8.4.25

Q1) The armature and shunt field resistance of a 4-pole DC shunt gen. is 0.05Ω and 25Ω respectively. If the armature contain 500 conductor, find the speed of the motor when it take 120 A current from DC main of 100V supply. Flux per pole = 2×10^{-2} Wb

Ans:

$E_b = \frac{PN\phi}{60}\left(\frac{Z}{A}\right)$ and $E_b = V - I_a R_a$

$I_f = \frac{V}{R_f} = \frac{100}{25} = 4A$, $I_a = 120 - 4 = 116$ A.

$\Rightarrow 100 - \cancel{116}^{29}(0.25)$
$= 71.$

$71 = E_b = \frac{4\times 2\times10^{-2}\times 500}{60\times 4}\times N.$

$\Rightarrow N = 426$ rev.

Q2) The electromag. Torque der. in a DC machine 80Nm And an armature current of 30 A, What would be the torque for a current of 15A? Assume const. flux What is the induced EMF at a speed of 900rpm. and an arm. current of 15A.

Ans: $\frac{T_1}{T_2} = \frac{\cancel{\phi_1} I_1}{\cancel{\phi_2} I_2}$ $(\phi_1 = \phi_2)$. $E_b I_a = \omega T_2$

$\omega = \frac{2\pi N}{60}$

(Elec.) (Mech.) energy

$\frac{T_1}{T_2} = \frac{I_1}{I_2} \Rightarrow T_2 = 40$ Nm.

$\Rightarrow E_b = \frac{2\pi N T_2}{I_a \cdot 60} = \frac{2\pi \cancel{900}^{15}}{\cancel{15}\times 60}$

$= 80\pi$

$= 251.3274$ V

Q3) The armature resist. of a 2-pole DC gene. is 0.4Ω delivering 4kW at rated voltage of 220V. The machine is operated as a motor. Draw the same arm. current from same voltage. In this operation if the flux per pole is increased by 20%, what will be the ratio of the speed from generator to motor

Ans: For Generator →

$I_{LG} = 18.1818A$, $I_{aG} = 18.1818A$

$E_G = V + I_{aG_2} R_a = 220 + 18.182(0.4) = 227.2728\,V.$

$E_b = 220 - 18.182(0.4) = 212.727\,V.$

Q4) A DC shunt motor run at 1000 RPM at 220 V. Armature and Field Resistance are $0.5\,\Omega$ and $110\,\Omega$ respectively. Total current taken from supply is 26 A. It is desired to reduced the speed to 750 RPM, keeping the field and armature current same, what resistance should be inserted in the armature circuit.

$I_f = \frac{220V}{110\,\Omega}$

$I_a = 24A.$

$I_a + I_f = 26A$

Ans: $E_b = V - I_a R_a = V - I_a(R_a + X).$

$$\frac{1000^{4}}{750_{3}} = \frac{E_{a1}}{E_{a2}} = \frac{220 - 24(0.5)}{220 - 24(0.5 + X)} = \frac{4}{3}$$

$$\Rightarrow \cancel{208} \times \frac{3}{4} = \cancel{220 - 12} - 24X \qquad \Rightarrow X = \frac{52}{24}\,\Omega$$

$104 \quad 52 \quad 208.52$

$= 156$

$\Rightarrow X = 2.1667\,\Omega$

$E_{b_1} = 240 + 12 = 252V$

$E_{b_2} = 240 + 24(0.5 + 2.167) = 240 + 64.008\,\Omega$

$= 304\,\Omega$

Q5) Field winding & arm-winding resistance of a 240 V DC shunt motor is $120\,\Omega$ and $0.02\,\Omega$ respectively. It draws 24 A at a rated voltage and run at 1000 rpm. Find the value of additional resistance required in the armature to reduce the speed to 800 rpm when:-

(i) Load Torque is proportional to the speed and

(ii) Load Torque vary as square of the speed.

Ans: $I_f = \frac{240V}{120\,\Omega} = 2A.$, $I_L = 24A$, $I_a = I_L - I_f = 22A$

(i) $$\frac{T_1}{T_2} = \frac{N_1}{N_2} = \frac{\cancel{\phi_1} I_{a_1}^{\,24}}{\cancel{\phi_2} I_{a_2}} = \frac{1000}{800} \Rightarrow I_{a_2} = 17.6\,A$$

(ii) $\frac{T_1}{T_2} = \left(\frac{N_1}{N_2}\right)^2 = \left(\frac{\cancel{1000}^{5}}{\cancel{800}_{4}}\right)^2 = \frac{\cancel{\phi} \cancel{22} I_{a_1}}{\cancel{\phi} I_{a_2}}$ 24 A.

$\Rightarrow I_{a_2} = 22 \times \left(\frac{4}{5}\right)^2 = \cancel{15.36 A}$ 14.08 A

(i) $\frac{E_{b_2}}{E_{b_1}} = \frac{N_2}{N_1} = \frac{\cancel{1000}^{5}}{\cancel{800}_{4}} = \frac{V - I_{a_2}(R_a + R_{ext})}{V - I_{a_1} R_a} = \frac{5}{4}$.

$A \Rightarrow \frac{5}{4} = \frac{240 - 14.08(}{240 - 17.6(}$

Q6) The field and armature resistance of 500 V DC series motor is 0.2 Ω and 0.3 Ω respectively. The motor run at 500 RPM, and draw a current of 40 A from the supply. If the load Torque vary as a square of the speed, determine the value of the external resistance to be added in series with the armature to run the motor at 450 RPM. Assume linear magnetisation.

Ans: $I_f = \frac{V}{R_f} = \frac{500}{0.2} = 2500 A,$

$\left(\frac{N_1}{N_2}\right)^2 = \frac{T_2}{T_1} = \frac{\cancel{\phi_2} I_2}{\cancel{\phi_1} I_1} = \frac{I_2^2}{I_1^2} \Rightarrow \frac{450}{500} = \frac{I_2^2}{I_1^2} = \frac{I_2^2}{40^2}$

~~$\Rightarrow I_2 = 14.4185 A$~~ $\cancel{I_2 = \sqrt{\frac{40^2 \times 450}{500}} = 37.94 A}$

$\Rightarrow \frac{N_1}{N_2} = \frac{I_1}{I_2} \Rightarrow I_2 = \frac{40 \times 45}{50} = 36 A$

$\Rightarrow \frac{500 - 36(0.5 + R_{ext})}{500 - 49 \times 0.5} = \left(\frac{36}{49}\right)^2$

$\frac{E_{b_1}}{E_{b_2}} = \frac{N_1 \phi_1}{N_2 \phi_2} = \frac{N_1 I_1}{N_2 I_2} = \left(\frac{N_1}{N_2}\right)^2$

$\Rightarrow 500 - 18 - \overset{36}{\cancel{\ }} R_{ext} = 475.5 \times \left(\frac{36}{49}\right)^2 = 256.66$

$\Rightarrow R_{ext} = \cancel{\ } \ \underline{6.259\,\Omega}$

Q7) A DC shunt gen. supply $\overset{I_L =}{}$ 195A at 220V. The arm resistance is 0.02 Ω and shunt resistance is 44 Ω. If the iron and friction loss is 1600 Watt, find

(i) e.m.f generated
(ii) copper loss
(iii) b.h.p of the engine driving the gen.
(iv) commercial, mechanical and electrical efficiency

Ans: (i) $E = V + I_a R_a = 220 + 0.02(200)$
$= 224V$

$I_f = \frac{220V}{\cancel{0.02}\ 44} = 5A.$

$\Rightarrow I_a = I_f + I_L$
$= 195 + 5$
$= \boxed{200A}.$

(ii) Armature copper Loss $= I_a^2 R_a = 800W$
Shunt field copper Loss $= I_f^2 R_f = 1100W$
Total copper Loss $= 1900W$

(iii) O/P of the Generator $= VI_L = 42900W.$
I/P of the Generator $= 46400W.$

B.H.P of the engine (HP) $= \frac{I/P\ watt}{735.5} = \underline{63.086\ HP}.$

(iv) Commercial efficiency $= \frac{42900W}{46400W} \times 100\% = \underline{92.457\%}$ $\left(\frac{O/P}{I/P}\right)$

Mechanical efficiency:
Power developed in armature $= EI_a = 224(200) = 44800W.$

So, Mech. eff. $= \frac{\text{Mech. devel}}{I/P\ watt} \times 100\% = \frac{42900}{49800} \times 100\% = 95.758\%$

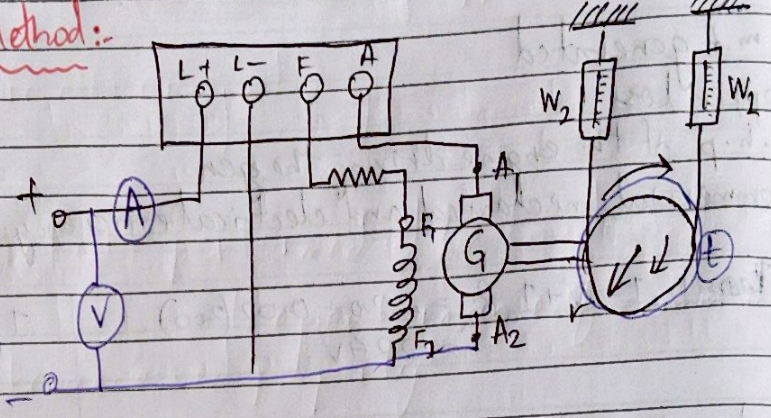
Elec. eff. $= \frac{O/P\ power}{Ele.\ power\ developed} = \frac{44800}{46400} \times 100\% = 96.55\%.$

8.4.25

TEST ON DC M/C:-

Direct Method — Indirect Method — Regenerative Method

1. Direct Method:-



Let the spring balance on the tight side be W_1 kg and loose side be W_2 kg and motor speed is N. The radius of the pulley is R and thickness of the belt is T.

Therefore, motor output $= \underbrace{(W_1 - W_2)\left(r + \frac{t}{2}\right)}_{\tau} \times \underbrace{\left(\frac{2\pi N}{60}\right)}_{\omega}$

$= (W_1 - W_2)\, r \left(\frac{2\pi N}{60}\right)$ kg × 9.8

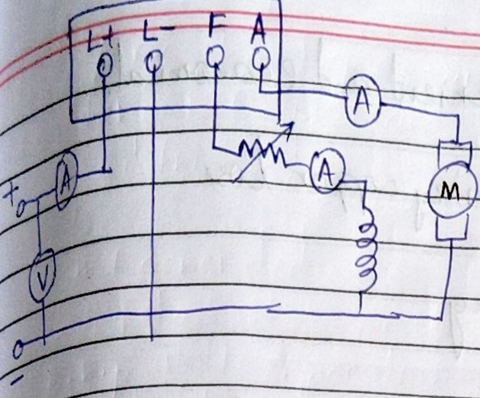
Power drawn by the motor from the supply = VI (Input Power)

Brake Test method.

Drawbacks:-

1) We cannot determine the efficiency of the large machine the mech. arrangement of the load is tendious for large machine.
2) The output measured by this method is not accurate because the belt is not offering a constant load.

2. Indirect Method – Calculate the efficiency at no-load cond^n without any load. (Swinburne's Test)



From this circuit diagram, loss of the motor at no-load –

1) Iron Loss in the core
2) Mech. (windage and frictional) Loss
3) Shunt field copper Loss
4) Arm. copper loss at no-load current (but it is very small in amt.).

Let V = supply voltage, I_0 = No load current, I_{sh} – Shunt current.

No load armature current = $I_{a_0} = I_0 - I_{sh}$

∴ Therefore no-load power input = (VI_0)

→ $I_{sh}^2 R_f$ [Shunt field Loss] or $I_{sh} V$.

→ Armature copper Loss = $I_{a0}^2 R_a$

$P_c = VI_0 - (I_{sh} \cdot V + I_{a0}^2 R_a)$

After determing the constant loss, the efficiency of the machine when it is working as a motor or a generator can be calculated for any load

* (As a motor) –

$I_a = I_L - I_{sh}$, variable armature copper Loss = $I_a^2 R_a$

∴ Total Loss = $P_c + I_a^2 R_a$

* Input Power to the motor = VI_L.

O/P of the motor = I/P power – Loss = $VI_L - P_c - I_a^2 R_a$

* (As a generator) – $I_a = I_L + I_{sh}$

Copper Loss = $I_a^2 R_a$, Total Loss = $P_c + I_a^2 R_a$ (core)

Input Power = $VI_L + I_a^2 R_a + P_c$

Output Power = VI_L.

Advantages:-

1) The method is very convenient and economical.

2) The constant loss and stray copper loss

Therefore efficiency at any

1) Since the test is performed at no-Load condition the performance of commutator cannot be accessed properly

2) This test cannot be performed with DC series motor

3) The change in iron loss from no-Load to full-Load are no accounted for, although this change is prominent due to armature reaction.

Q)1 A 250 V, 15 kW motor has a maximum efficiency of 80% and at a speed of 700 RPM, when delivering 80 % of its rated output. The resistance of shunt field is 100 Ω. Determine the efficiency & speed when the motor draw a current of 78 A from the main.

Ans: Efficiency (commercial) $= 80\% = \frac{O/P}{I/P} = \frac{15\times10^3}{15\times10^3 + \text{Loss}} = 0.8$

$\Rightarrow \frac{15\times10^3}{0.8} - 15\times10^3 \Rightarrow$ ~~Loss = 3750 watt~~

$\Rightarrow$ ~~Input power = $15\times10^3 + 3750 =$ 18750 watt.~~

for max^n efficiency, $P_c = I_a^2 R_a = \frac{3750}{2}$

$\Rightarrow$ Armature Loss $=$ 1875 watt.

$\Rightarrow$ Armature Current $= I_a = \sqrt{\frac{I_a^2 R_a}{R_a}} = \sqrt{\frac{1875}{100}} = 4.33\,A$ X

Actual O/P = 15 kW

but here efficiency 80% here, → 12 kW.

$\Rightarrow$ ~~Loss $= \left(\frac{1}{\eta} - 1\right)$ O/P $=$ 3000 watt.~~

$I/P = \underbrace{12000\,kW}_{O/P} + \text{Loss} = 15000$

$I_L = \frac{I/P}{Volt.} = \frac{15000}{250} = 60\,A.$

$I_a^2 R_a = 818$

Loss $= P_c + I_a^2 R_a$
$= 1636.$

$\Rightarrow I_a^2 (0.302) = 818$

$\Rightarrow I_a = 52.1\,A$

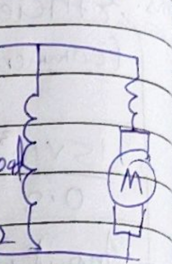
Total Loss = 2536 W

Efficiency = 86.96 %

Total O/P = 78×250 = 19500 watt, I/P = 22036 watt

Now, $\frac{E_{b1}}{E_{b2}} = \frac{N_1}{N_2}$ (ϕ const) $= \frac{250 - I_a R_a}{250 - I_{a_2} R_a} = \frac{N_1}{N_2}$

Q2) A 50 KW, 250 V long shunt compound motor take a current of 9 A while running on no-load at rated voltage and speed. The shunt field current is 5A. The resistance of the winding are 0.1, 0.07, and 0.03 Ω of armature, series field and interpole. The brush drop is 2V. ~~Determine the motor output and efficiency when the motor intake is 155 A.~~



Ans: Constant Loss at no-load cond^n = Rating at no Load power − Var. Loss

$I_L = 9A,\ I_f = 4A$ So, $I_a = 5A$

~~Variable Loss~~ $= I_{ao}^2 (R_{series\ eff.})$ + Brush drop Loss $= (4)^2 (0.1 + 0.07 + 0.03) + 2$
(no load current)

$= 16(0.2) + 2$

$= 3.2 + 2 = 11.2$

Rating at Full Load Power $= 50 \times 10^3$,

~~(250×9)~~

Arm. current = 155A, var. loss $= I_a^2 (R_{series})$ + Brush Loss

$= (155)^2 (0.1 + 0.03 + 0.07) + 2 = \underline{4807\ W}$

Motor output = Motor input + Loss = $\underline{31.7\ KW}$

~~Motor input~~

~~Efficiency = 81.82 %~~ $= \frac{O/P}{I/P}$

Q3) The result of 2 hoculus Test on 2 DC machine are as follows:- 250 V, 23 A → generator arm. current,

20 A → motor arm. current

~~0.4A → genent field~~

0.3 A → motor field

Arm. resistance for each machine → 0.5 Ω. Calculate the efficiency of each generator and motor.

Input current ~~power~~ Line = ~~A~~Motor I/P current − Generator I/P current $= (23 + 0.3) - (20 \frac{}{0.4})$

$= 23.3 - 19.6$

$I_L = (3.7 A)$

Power = 925 watt →

Total Cu Loss = 639.5 watt
(arm. and shunt field) → Volt. x shunt field current (shunt current)

Arm. cu Loss motor = 263.5 w
200 watt
motor field =
gene field = 100 watt.
} 639.5 watt

stray power Loss = 925 (I/P of mach) − Copper Loss = 925 − 639.5
= 285.5 watt

stray power loss per each machine = ½ for gen & motor
= 142.75 watt.

I/P power
(23.3) x V) 23.3 x 250 = 5825 watt | Motor Efficiency = 91.72%

Generator out/put = 4900 w | Efficiency = 94.44%
Total ge. Loss = 21

Q4 A 230 V DC shunt motor as an armature res. of 0.4Ω & field res. of 115 A. This motor is driven by const. torque Load & takes a constant Load of Torque. 20 A with 800 RPM

Motor speed (800 RPM ⟶ 1000 RPM) by decreasing the field current.
Find the resistance that must be inserted in the shunt field cht.
Assume for linear magnestisation

Ans: $T \propto \phi I_a$ $(T_1 = T_2)$

$\frac{T_1}{T_2} = \frac{\phi_1 I_{a_1}}{\phi_2 I_{a_2}} \Rightarrow \phi_2 I_{a_2} = \phi_1 I_{a_1} \Rightarrow I_{a_2} = \frac{\phi_1 I_{a_1}}{\phi_2} = k I_{a_1}$

$= 20$ A.

For 800 RPM $\rightarrow E_{b_1} = V - I_a R_a = 230 - 8$

For 1000 RPM $\rightarrow E_{b_2} = V - I_{a_2} R_{a_2} = 230 - 8k$

$$\Rightarrow \frac{E_{b1}}{E_{b2}} = \frac{N_1 \phi_1}{N_2 \phi_2} = k\left(\frac{N_1}{N_2}\right) k\left(\frac{800}{1000}\right) \Rightarrow k^2 - 28.75k + 34.67 = 0$$

$$\Rightarrow k = 27.49$$
$$k = 1.26$$

Relation of ϕ_1 & ϕ_2 are relative to each other in similar value, so $k \neq 27.49$.

$K = 1.26$

$\Rightarrow \cancel{I_{a_2} = 20A \propto I_{a_1} = k I_{a_2} = 20 \times 1.26 =}$

$$\frac{\phi_1}{\phi_2} = \frac{I_{f_1}}{I_{f_2}} \Rightarrow I_{f_1} = 2, \ I_{f_2} = \cancel{1.5087A}$$

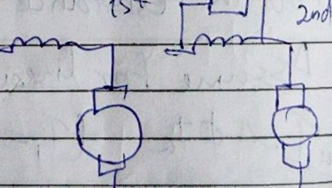
$$\frac{V_1}{R_{f_1}} = \frac{230}{115} = 2.$$

$$\Rightarrow I_{f_2} = \frac{V_2}{R_{f_2}} = \frac{230}{145} = \cancel{1.587A}$$

$R_{f_2} = 145 \Omega$

Q) A DC series motor turning a 50 cs Load at 1000 RPM, ~~for~~ take 40 A current from a supply $R_f = 0.2\Omega$, $R_a = 0.2\Omega$. A divertor of 0.3Ω parallel with series field, find the motor speed.

Ans:



Ans: 1285 RPM

Parallel operation of DC ~~Motor or~~ Generator -

nothing important (Load are pratically connected in parallel)

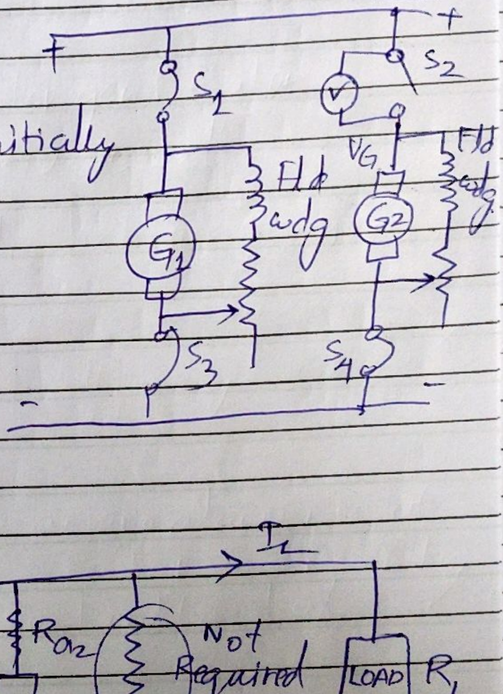
1. Continuity of the supply.
2. Mantainance and repairment.
3. ~~Efficiency~~ of the totalsystem is improved.
4. Future expansion of demand.
5. Cost effective.

Condition of the parallel operation of the DC Generator -

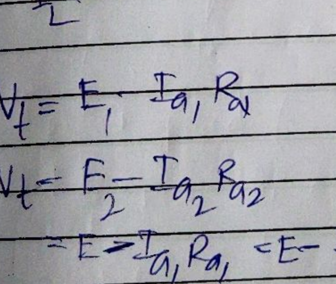
1. ~~They have same emf value and~~ polarity of the DC generator is same.
2. Voltage terminal of the generator is equal $V_t = V_b$

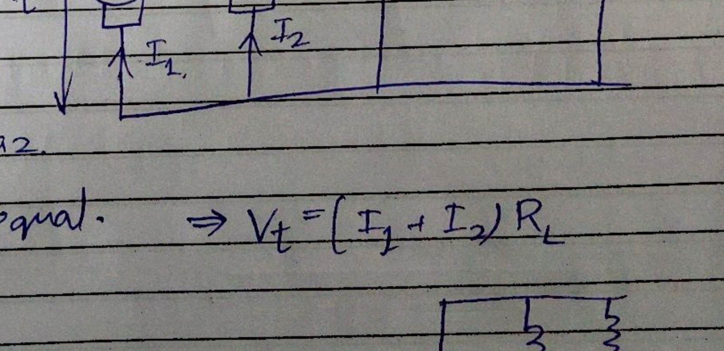
DC shunt generator -

1) In this diagram, the generator is initially connected to



Characteristics of parallel shunt DC generator :-





$V_t = E_1 - I_{a_1} R_{a_1}$

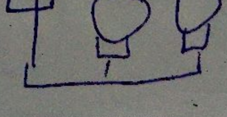
$V_t = E_2 - I_{a_2} R_{a_2}$

$= E - I_{a_1} R_{a_1} < E - I_{a_2} R_{a_2}$

* If E_1 and E_2 are not equal. $\Rightarrow V_t = (I_1 + I_2) R_L$

$$I_c = \frac{E_1 - E_2}{R_1 + R_2}$$

* Now for series generator in parallel,



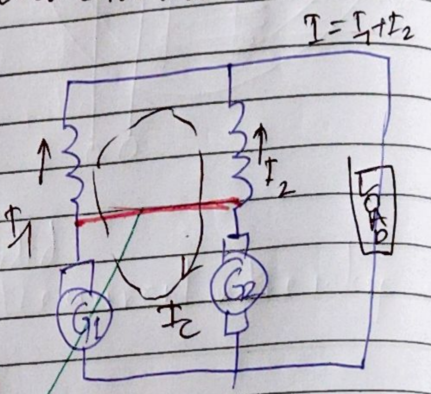
16.4.25

Parallel operation of 2 series Generator

· If the ind. emf for the generator G_1, i.e., E_1 increase due to any reason, there will be immediately a current flow in between generator G_1 and G_2.

* This current is called circulating current.
Therefore current of the gen. G_1, i.e., (I_1) will increase
current of the gen G_2, i.e., (I_2) will decrease

→ The series gen. have voltage increasing with the increament of armature current, E_1 will increase further.



* Thus there is cumulative effect on the circulating current.
Ultimately, it will settle with deadly short circuit, i.e., E_2 and I_2 will get reversed and the circulating current will be

$$\underset{\text{(initial)}}{I_c} = \frac{E_1 \sim E_2}{R_1 + R_2}$$ but $$I_c = \frac{E_1 + E_2}{R_1 + R_2}$$

* If there is no fuse / protection any other in ckt, the 2 machine will be damaged at instant.

So, the series gen. can't be run at parallel to each other.

Precautions:-

* Arm. of the 2 gen. are connected with pure conductor / copper (Thick) → Low resistance.

Accd. to the fig., due to the increament of the E_1, circulating current will flow ~~through~~ between generator & thick Cu wire, so no current will flow through field of the both gen.

That's why there is no chance to inc. /dec. the ind. emf of the gen. due to the circulating current.

* Equaliser bar conductor
Equaliser ~~bearing~~ ring → Minimises circulating current.

in case of motor.

Current sharing → $E_1 < E_2$, $E_1 \neq E_2$

Imp: Why we can't run parallel op. of 2 series generator (without eq. bar)?

Method of improvement ~~remedy~~ of the commutation:-

1) By use of high resistance brush (material of the resistance should be of high ~~[illegible]~~ resistivity)

2) By shifting of the brush
In this method, brush are shifted to the new magnectic position MNA, so that no emf will be induced in the coil undergoing commutation, thus sparking of the brush is eliminated.

3) By use of interpole/commutating pole/compole.

→ In this method, narrow pole are placed in between the main pole of the D.C machine, which re-energised to search & extend, that neutralise the field produced by the armature under load condⁿ.

→ No emf is induced in the coil undergoing commutation.

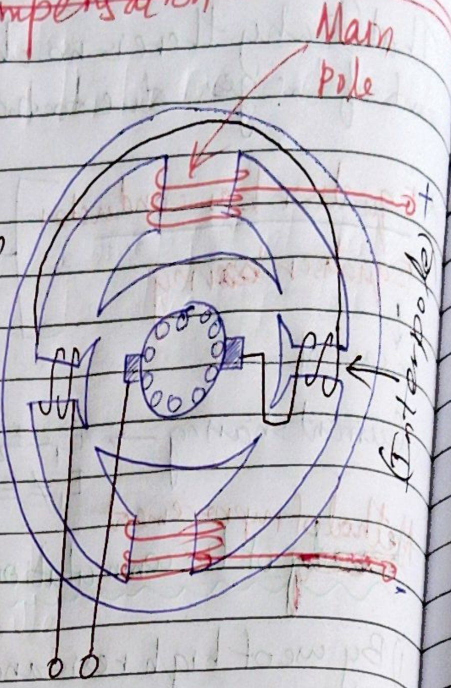
4) Compensating winding:-

In this method, a no. of conductor/coil are embedded in the slot, provided at the pole shoe ~~and~~ or pole face and carry current of such a magnitude and direction at the field produced by them neutralise the armature field and input commutation.

* Therefore there are mainly 3 methods of spark-less commutation.

1) Resistance commutation (High resistance brush).
2) Voltage commutation (interpole).
~~3) Compensating winding compensation~~

Interpoles and its necessity -



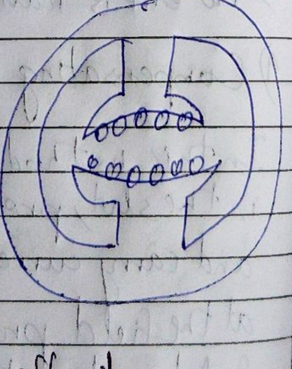
* Interpole are provided in between the main pole of the DC machine and the interpole windings are connected in series with the armature winding.

→ When the current delivered by the gen. to the load, the arm. current will increasing in nature.
Since the interpole wdg connected in series with the armature, the current in the interpole will also increase.

* The interpole wdg are energised to such an extend that they should be neutralise armature field prod. by the arm. wdg when the machine is in loaded condⁿ.

→ The commutation of the machine will be improved by this phenomenon (interpole of the machine).

Compensating winding :-



* The demag. effect of the armature rxn. is compensated by incorporating a few extra turn to the main field winding just like tapping,
whereas to neutralise the cross-mag. effect, a compensating wdg is used.

· In this case a no. of conductor/coil are embedded in the pole face/pole shoe and connected in series with the arm. wdg. In such a way the current flowing through this cond./coil setup a mag. field which neutralise the cross-mag. effect of the arm. field, This wdg is called as compensating wdg.

→ When current flow through this wdg, it setup a mag. field which is equal & opposing to the cross-mag. effect of the arm. and neutralise it, thus no emf is induced in the coil passing through under commutation and hence sparking of the brush is eliminated.

* Thus, a sparkless good conductor is obtained.

(Syllabus for End-Term):-

1) construction part of DC machine.
Draw all parts of the DC m/c, exp. each & every funct. of the parts.

2) Armature wdg design.
* No need to solve design of the wdg (wave/lap) or any dummy for wave

3) Characteristics ~~of~~ O.C and cond^n
↳ (condition, critical speed, residual mag.)

4) series generator O.CC ✗ why not possible 1 mark?

5) Load characteristics
Draw all the external characteristics of all the excitation of generator and explain in a graph paper

6) Arm. rxn of the generator, commutation of the generator.
effect, explain construction.

7) Parallel operation of Generator

8) Motor (imp. of back emf, (motor connected to a supply & reverse load (torque & emf eqn, diff. type of characteristics and exp. deviation in graph paper.

Method of speed Control, arm. rxn, why constant power,
Advantage and Disadvantage of

Starter→
Q) Write the op. principle of the starter.
Starter/ rheostat which one is better for DC generator,
(4marks).

Drawback of the 3-pt starter overcome by 4-pt starter.
Diff. of 3-pt. & 4-pt. starter, How to solve (4 pt starter,

Loss & Test → Hawkins' Test.

Numerical :- Generator (formula based)
Motor : Basic resistance in series, parallel.
Diff. types of efficiencies.