MACHINES-2

NOTES

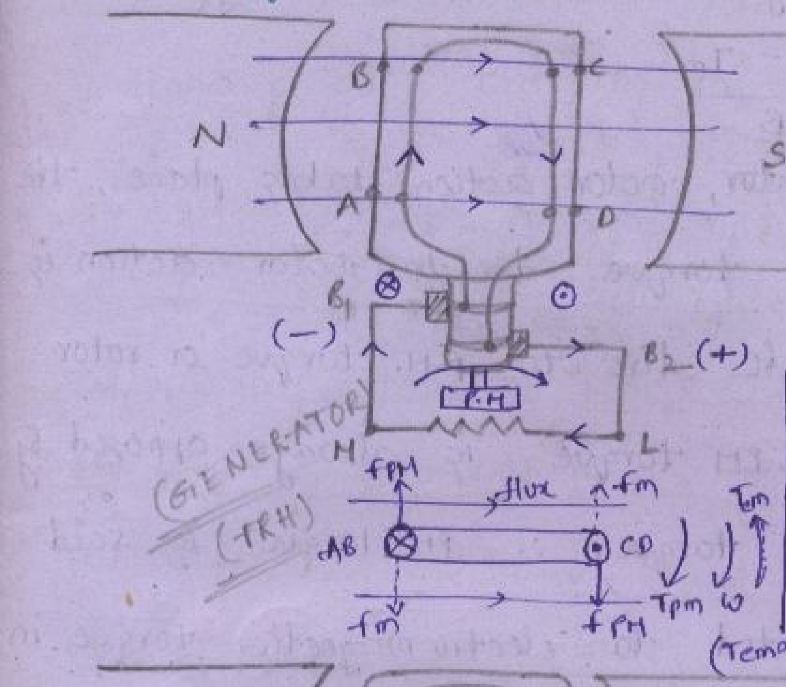
(Modified)

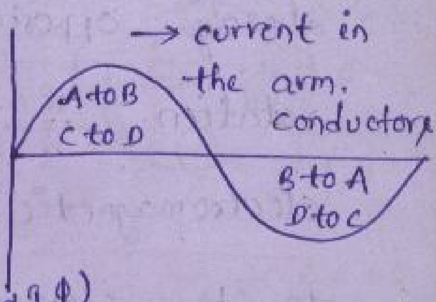
GATE 2009

JANARDHANARAO

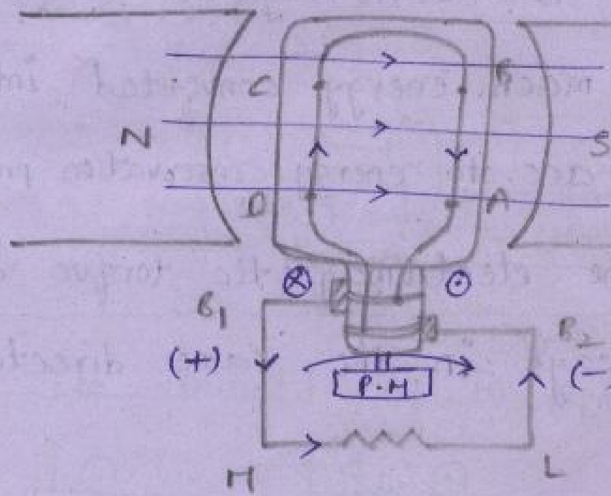
Working Model of Generator: 25/07/08

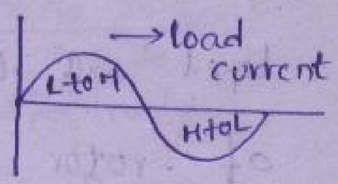
Current direction
A to B
C to D
L to H





current direction
B to A
D to C
M to L





The induced emf in 2 sides of the coil will be in aiding polarity, ie they are said to be in phase.

* Fleming's Left Hand Rule ⟶ Motor
* Fleming's Right Hand Rule ⟶ Generator

* $P_{mech} = T_{PM} \cdot \omega$

  $P_{ele} = T_m \cdot \omega$

* $T_{pm} = J\frac{d\omega}{dt} + B.\omega + T_{em}$

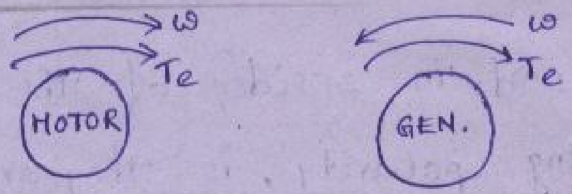
  ($J\frac{d\omega}{dt}$: Inertia torque; $B.\omega$: frictional torque)

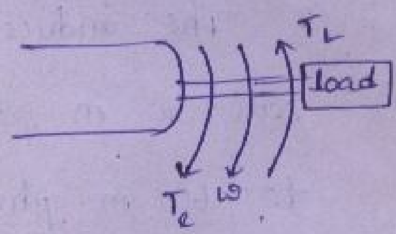
Under steady state condition, $J.\frac{d\omega}{dt} = 0$.

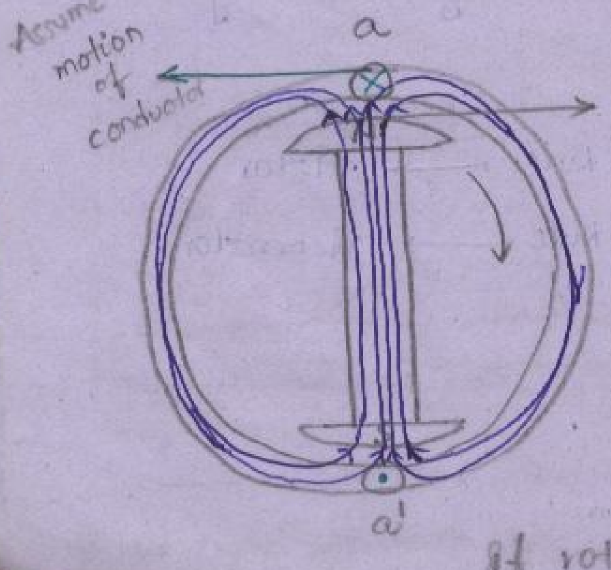
$$\therefore \quad \omega = \frac{T_{pm} - T_m}{B}$$

In generator, motor action takes place, the electromagnetic torque due to motor action is always opposite dirc. to P.M. torque or rotor rotation. ∴ PM torque is always opposed by electromagnetic torque. ∴ PM torque is said to be converted to electromagnetic torque. In other words the mech. energy converted into electrical energy acc. to energy conservation principle.

In motor the electromagnetic torque developed will be always in the same direction of rotor dirc.







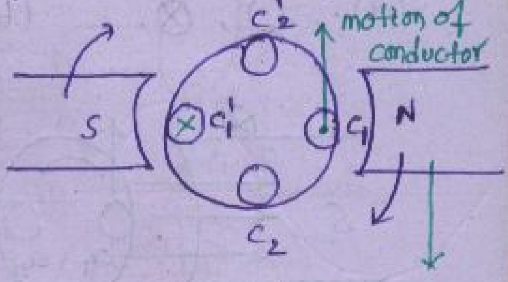
$$T_e = J\frac{d\omega}{dt} + B\omega + T_L$$

⇒ To findout induced emf use F.R.H RULE.

↓

(first findout the motion of conductor & then apply. If rotor dirc. is given, then the —

Q. Two magnetic poles revolving around stationary arm. carrying the two coils c_1, c_1' and c_2, c_2'. Identify the correct statement regarding to polarity of induced emf.

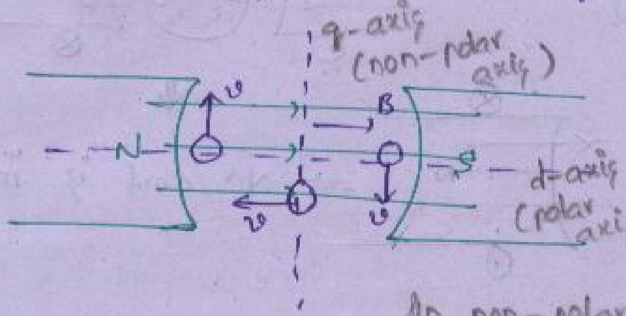


(a). ⊙ in c_1, no emf in c_2 ✓

(b). ⊗ in c_1, no emf in c_2

(c). ⊙ in c_2, no emf in c_1

(d) ⊗ in c_2, no emf in c_1



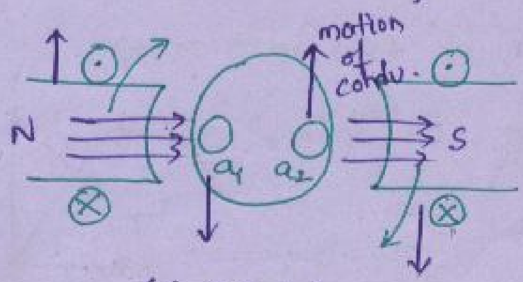
$e = Blv \sin\theta$

$\theta \to$ angle b/w B & v

* In polar axis situation, $\theta = 90°$ so $e = Blv$

In non-polar region $\theta = 0°$ so $e = 0$.

Q. The induced emf in a_1 & a_2' respectively,



(a). ⊙, ⊗ ✓

(b). ⊗, ⊙

(c). no emf

(d). data insufficient

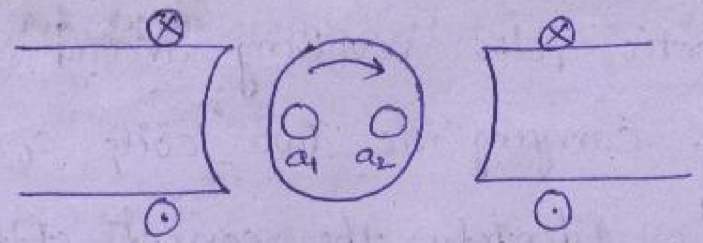
Right hand thumb rule: (in case of coil)

If wrapped fingers represent dire. of current, then thumb represents dire. of flux.

(conductor dire. is opposite to the dire of rotation of the rotor.)

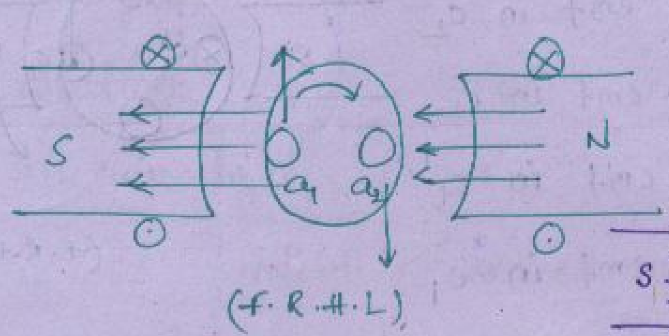
* Into the paper ⇒ ⊗ ; out from the paper ⇒ ⊙

Q.

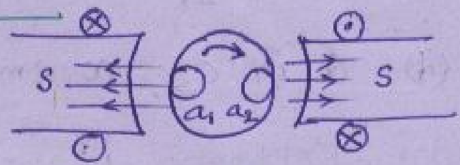


The induced emf's in a_1, a_2 respectively

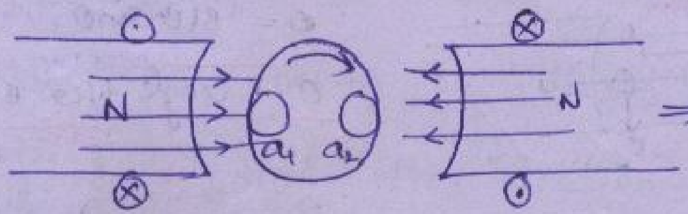
(a). ⊙, ⊗ ✓ (b). ⊗, ⊙ (c). No emf



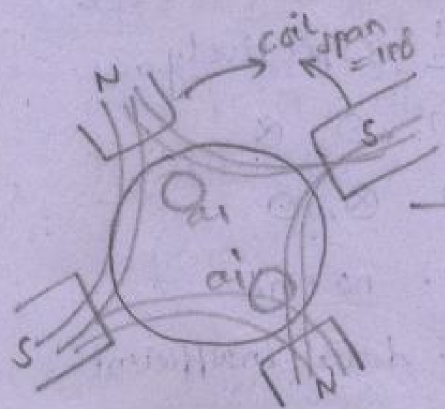
To findout flux direction → Thumb Rule



Q.



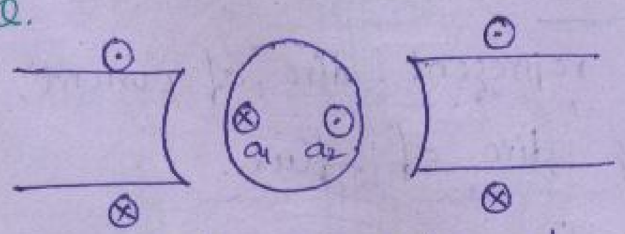
→ No emf is induced



Never be coil span > 180

→ Here coil span = 360

Q.



The direction of Torque in the above fig-?

(a) CW ✓(b) CCW (c). No torque.

Induced emf ⇒ FRH rule

Torque ⇒ FLH rule

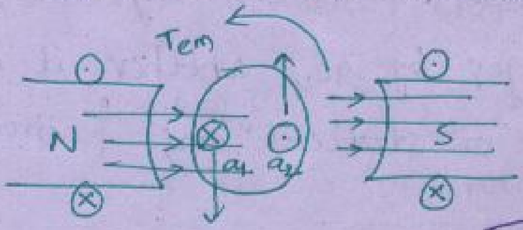
flux α current ⇒ Thumb rule

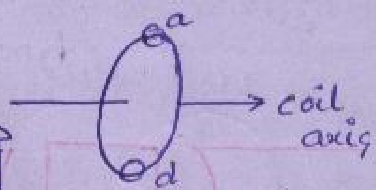
Thumb Rule

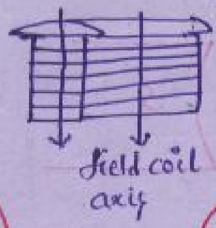
In case of st. conductor:

Thumb → current

wrapped fingers → flux

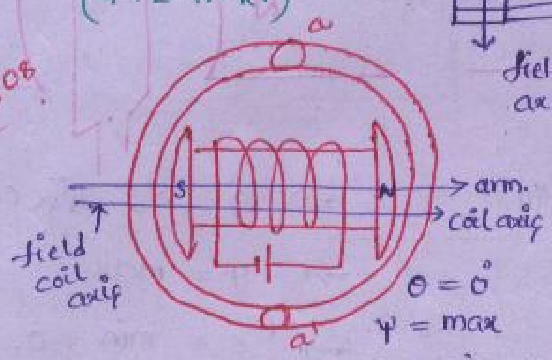






(F.L.H.R.)

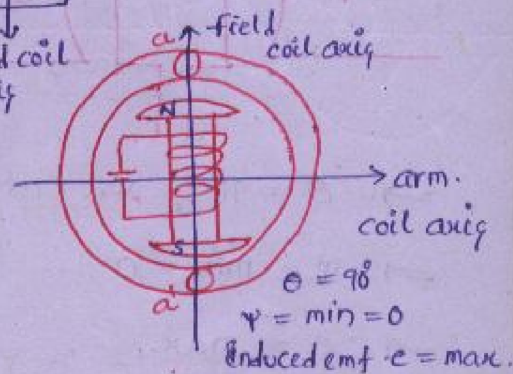
MON. 04/08/08



$\theta = 0^\circ$

ψ = max

e = min = 0



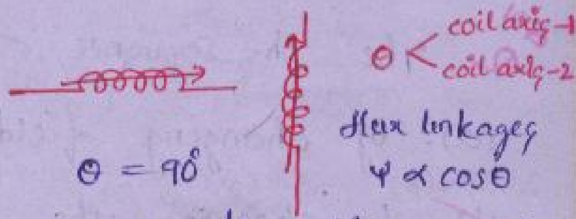
$\theta = 90^\circ$

ψ = min = 0

Induced emf e = max.

In this $\theta = 0^\circ$

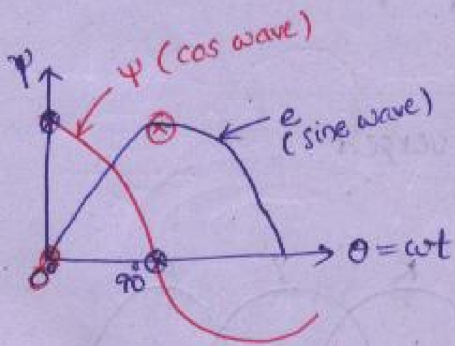
so flux linkages max.



flux linkages $\psi \propto \cos\theta$

$\theta = 90^\circ$

so the flux linkages min



$\psi \propto \cos\theta \Rightarrow \psi = \phi\cos\theta$

$= \phi\cos\omega t$ — (1)

$e = -T\cdot\frac{d\psi}{dt}$

$= -T\cdot\frac{d}{dt}(\phi\cos\omega t)$

$= T\phi\omega\sin\omega t$

$= 2\pi f\phi T\sin\omega t$

$= E_{max}\cdot\sin\omega t$ —— (2)

$= E_{max}\cdot\cos(\omega t - 90)$ —— (3)

$E_{max} = 2\pi f\phi T$

$\Rightarrow E_{rms} = \frac{E_{max}}{\sqrt{2}}$

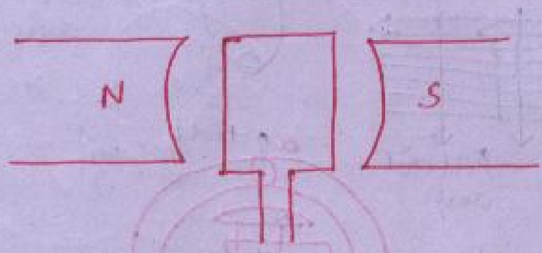
$= \sqrt{2}\pi f\phi T$

$= 4.44\phi f T$

$\Rightarrow E = 4.44\phi f T$ → emf eq. of an alternator for a full pitch, concentrated wdg.

$E = 4.44\, k_p k_d \phi f T \Rightarrow$ emf eq. of an alternator for short pitch, distributed wdg.

The induced emf lags the flux linkages by 90°, whether it is dynamically or statical induced emf. [∵ from ① & ③]



$\Rightarrow \theta = 90^\circ, \; \psi \propto \cos 90^\circ$

$\Rightarrow \psi = \min = 0$

$\Rightarrow e = \max$

$\Rightarrow \theta = 0^\circ, \; \psi \propto \cos 0$

$\Rightarrow \psi = \max$

$\Rightarrow e = \min = 0.$

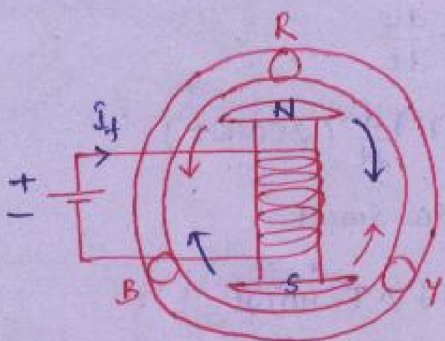
GO! Q. The ph. sequence of 3-ϕ Alt. can be reversed

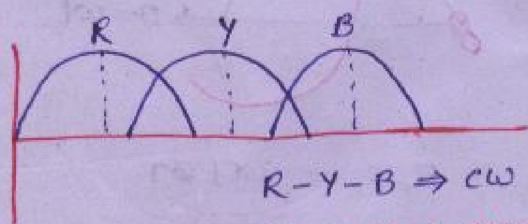
(a). by changing field polarities

(b). by changing the dire. of field rotation.

(c). both (a) & (b)

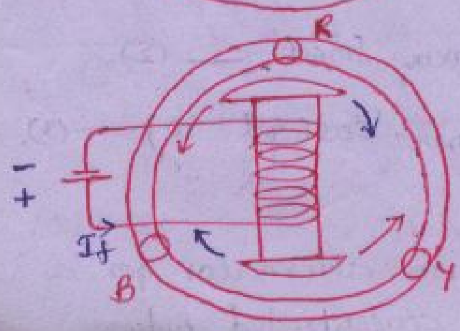
(d). ph. sequence can't be reversed.





R − Y − B ⇒ CW

⇒ R − B − Y ⇒ CCW



⇒ B − [R − Y − B] ⇒ R − Y − B ⇒ CW

⇒ Y − [R − B − Y] ⇒ R − B − Y ⇒ CCW

* ph. sequence (or) ph. order :

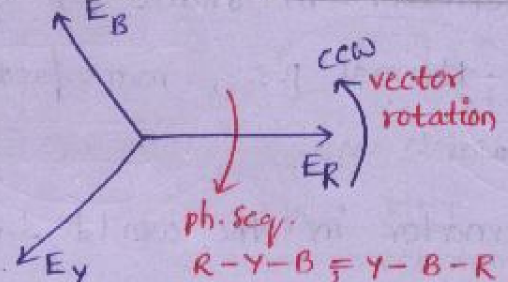
It is the order at which the max. value of induced emf (or) current obtained.

* The ph. sequence of 3-ϕ Alt. can be reversed by changing the rotor rotation [either field may be rotating or arm. may be rotating]. The ph. seq. does not depend upon field polarities.

$E_R \angle 0^\circ$

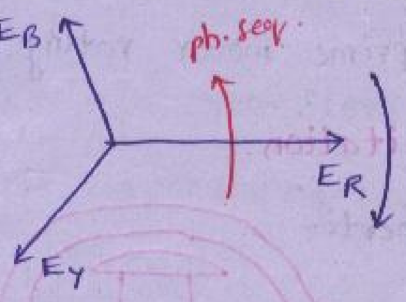
$E_Y \angle -120^\circ$

$E_B \angle -240^\circ$



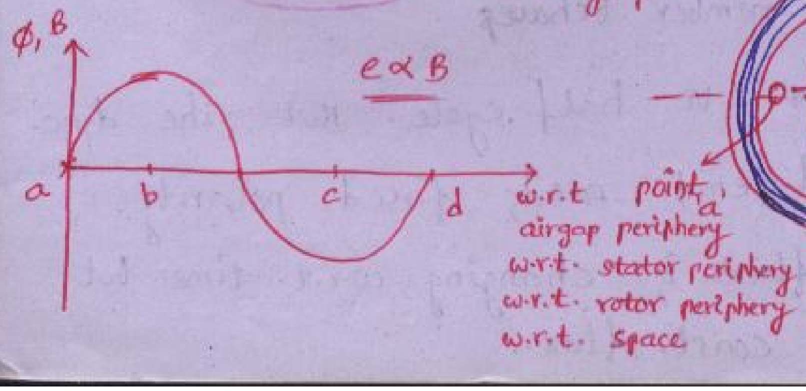
Q. The ph. seq. of the following 3-ϕ System is

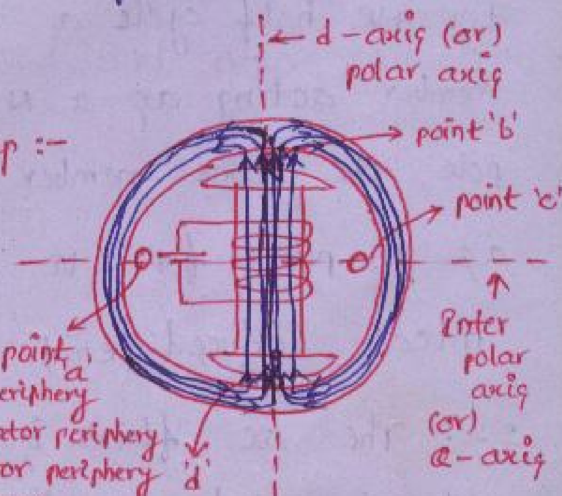
(a). R-Y-B (b). R-B-Y (c). zero seq. (d). None



* ph. seq. can be always verified in the opp. dire of vector rotation.

Flux Distribution in Air gap :-





* flux distribution in air gap is assumed to be sinusoidal and always m/c's are designed to obtained the sinusoidal flux dist. If flux distr is sinusoidal then the induced emf also sinusoidal.

∴ The main reason for the production of harmonics is non-sinusoidal flux distr. in the air gap.

* Largest alternator in India → 500 MW used in super thermal p.s., manufactured by BHEL, Haridwar.

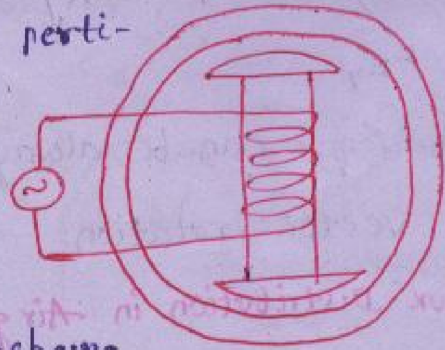
* Largest alternator in the world → 1700 MW West germany

* The rating of an alt. represented by KVA, pf or KW such that active power must be known for the selection of prime mover rating.

TUE. 05/08/08

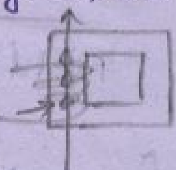
Effect of AC Excitation:

1. The polarity of a perticular pole is not fixed. for +ve half cycle a member acting as a N pole the same member behaves as S-pole for -ve half cycle. But the dynamical induced emf needs fixed polarity.



2. The ac flux is changing w.r.t. time but DI emf needs const. flux.

→ The avg. torque in the m/c is zero, so no generated voltage.

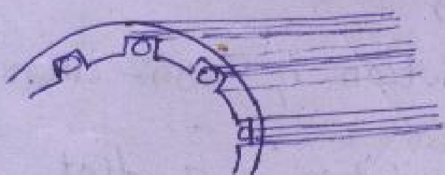


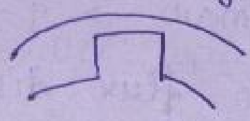
* **Construction of Alternator:-**

1. Stator
2. Rotor — Salient pole / Non-salient (or) Round (or) Cylindrical.

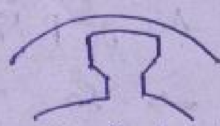
Stator ⇓

Cold Rolled Non-oriented steel (← due to the circular construction) with 3% Silicon (ie Si steel) (← To introduce some resistance to reduce eddy currents.) and laminated to reduce eddy current losses.

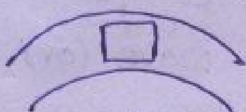




open slot



Semi closed slots



closed slot

$\downarrow \phi_L = \frac{MMF}{reluctance \uparrow}$

$\rightarrow \downarrow L = \frac{N\phi\downarrow}{i}$, $X_L \downarrow$

$Stability \propto \frac{1}{X_s} \rightarrow (X_s = X_L + X_a)$

$\rightarrow \uparrow Stability \propto \frac{1}{X_L \downarrow}$

* **Adv-s of open slots:**

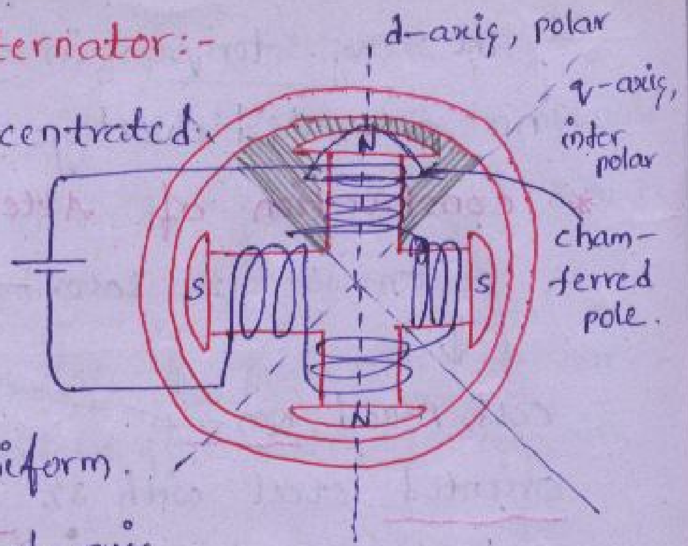
→ The access of wdg is easy. (placement & replacement)

→ leakage flux is reduced ie $L\downarrow \Rightarrow X_L\downarrow$

∴ Stability is improved and also regulation is improved.

$X_L \downarrow \Rightarrow$ reg. is better.

⇒ Salient pole Alternator:-



→ field wdg is concentrated.

↺ → ccw → N-pole

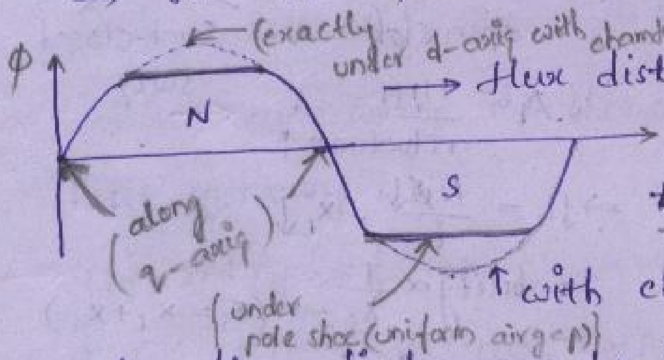
S → cw → S-pole

→ Air gap is non-uniform.

Air gap is min → d-axis

Air gap is max → q-axis

→ So the flux distribution is non-sinusoidal

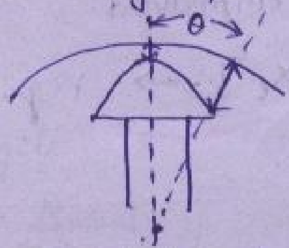


→ flux distribution is a flat topped wave (or) trapezoidal wave.

↑ with chamferred poles.

The flux distr: can be improved by reshaping the salient poles such that having min air gap along pole centre and increases along pole ends, this poles are said to be chamferred poles.

* The air gap length under the pole shoe $\propto \frac{1}{\cos\theta}$ where θ is in electrical degrees measured from pole centres.



→ Due to projecting nature & concentrated wdg, these rotor is not mechanically balanced well. & these

$\theta = 0 \Rightarrow A.G. \propto \frac{1}{\cos\theta} = 1mm$

$\theta = 60 \Rightarrow A.G. \propto \frac{1}{\cos\theta} = 2mm$

rotors driven with high speeds, centrifugal forces are developed, so speeds are restricted.

→ speed ranges : 50 – 1000 rpm
Low speed alternator.

→ No. of poles : 120 – 6

→ power ∝ volume of the rotor
⇒ $P \propto D^2 L$, D – Diameter of rotor
L – Rotor axial length.

→ Larger diameter, smaller axial length.

⇒ If the rotor diameter increases, stator dia. also increased, so more no. of slots, more no. of arm. conductors can be accomodated, so they need not to be lengthy. (axial length).

→ Prime movers are : Hydro turbines & Diesel Engines so salient pole alternators are used in hydro P.S. & Diesel P.S.

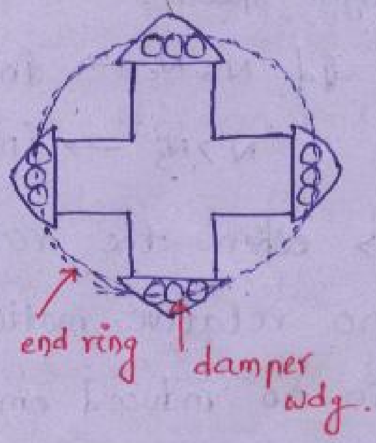
→ Hydro Alternators (Since used in hydro P.S.)

Damper winding:

for Alternator:

→ To eliminate Hunting

→ To supress the –ve sequence field



for Syn. motor:

→ To eliminate Hunting

→ for starting purpose.

{ Hunting occurs only in Syn. m/c's }

→ Causes for Hunting :-

1. Sudden change in load.
2. Sudden change in supply system.
3. Sudden change in excitation system.
4. Load containing harmonic torques.

→ To reduce Hunting : (To eliminate)

1. By using flywheel.
2. By designing the m/c such that having suitable synchronizing power coe.
3. By using damper wdg.

WED. 13/08/08

→ Damper wdg is short circuited by the end rings.

→ Damper wdg is made with low resistance Cu, Al, brass.

→ w.r.t. damper wdg, rotor behaves as squirrel cage rotor of IM ∴ Induction m/c action comes into picture, when the speed is other than syn. speed.

⇒ If $N < N_s$ → Induction motor action → T_d (I.M.)

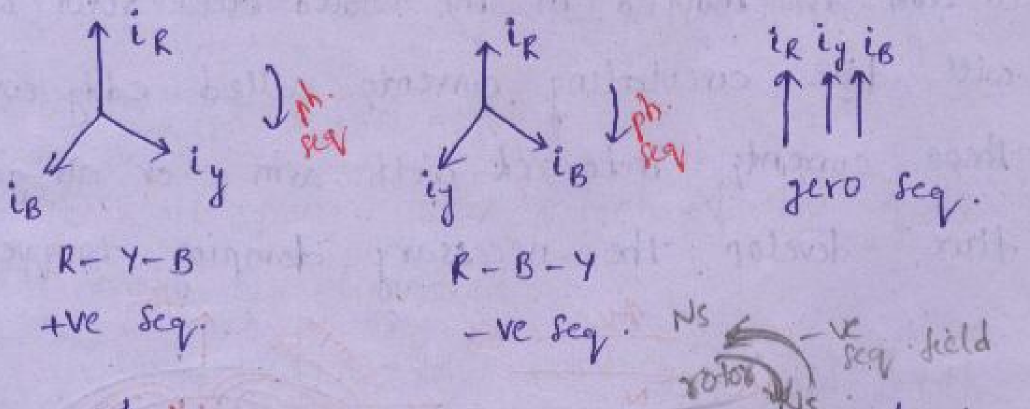
$N > N_s$ → Induction generator action → T_d (I.G.)

→ when the rotor rotating with N_s, there is no relative motion b/w arm flux & damper wdg. So no induced emf & no current and hence no damping torque. So the m/c is running at steady state condi.

→ If $N < N_s$, induction motor torque in the same dirc. of rotor rotation will develop due to which rotor accelerates and finally reaches to N_s.

→ When the rotor speed is more than N_s, induction generator torque in the opp. dirc. to rotor will develop due to which rotor decelerates and finally reaches to N_s.

→ The fun. of the damper wdg. is transient in nature, when the disturbance occurs the damping torque comes into picture to maintain synchronism. Once the disturbance clear, T_d reduces to zero.

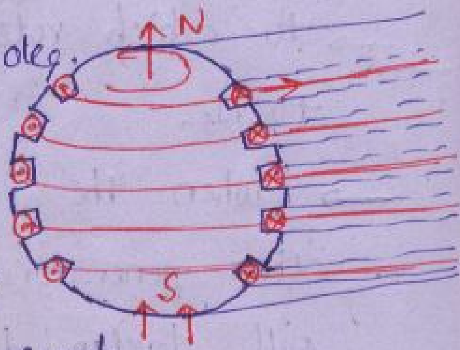


→ The relative motion b/w -ve seq. field & damper wdg = $2N_s$. Due to this an emf is induced, currents hence damping flux is produced in such a dirc. to suppress the -ve seq field acc. to Lenz's law ie always the effect opposes the cause producing it. ∴ -ve seq field is opposed by the damping flux

such that -ve seq. field is suppressed.

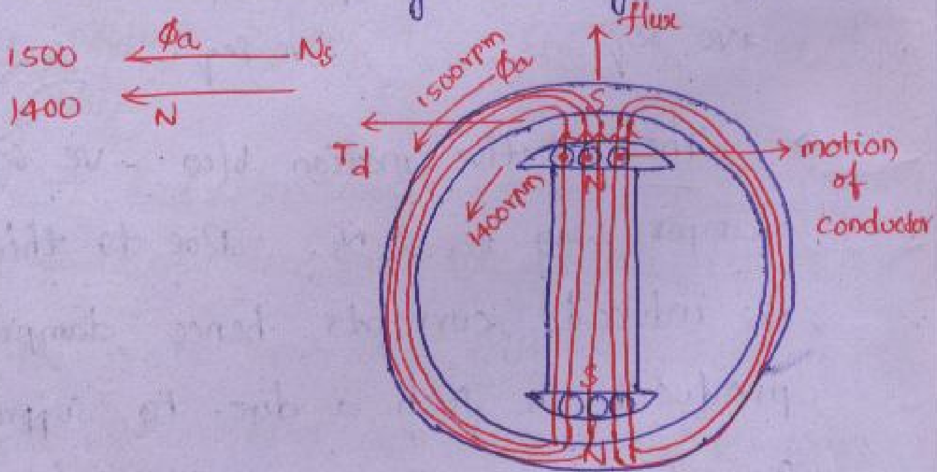
⇒ **Cylindrical rotor Alternator:-**

→ unslotted area forms the poles.

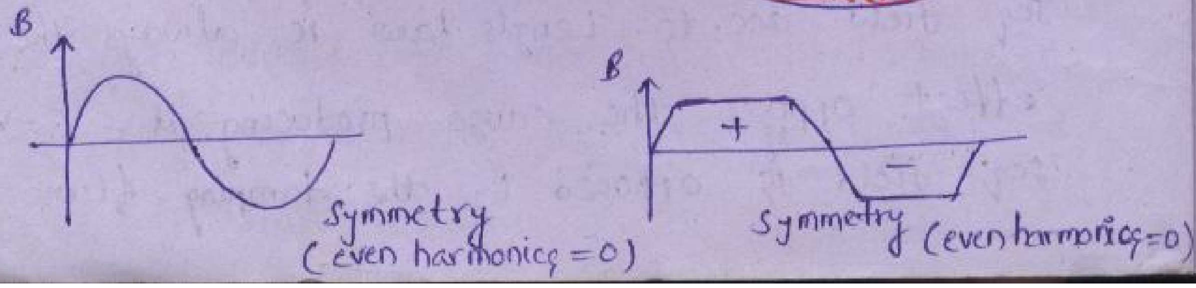


→ The rotor is mech. strong and field wdg also more rigid so these type of rotors can allow to rotate at high speeds such that it can withstand for high centrifugal forces developed.

→ No damper wdgs, b'coz hunting is less pronounce though we can elemenated with eddy current damping. when rotor speed is other than N_s, an emf is induced in the solid steel rotor which will drive circulating currents called eddy currents, these currents interact with arm φ or air gap flux, develop the necessary damping torque.



F.L.H.R



SAT. 16/08/08

Q. The coil span to eliminate 7th harmonic is —?

(a). $\frac{5}{6}\times$ pole pitch (b). $\frac{6}{5}\times$ pole pitch

✓(c). $\frac{6}{7}\times$ pole pitch (d). $\frac{7}{6}\times$ pole pitch

$$\beta = 180\left(\frac{n-1}{n}\right)$$

$$= 180\left(\frac{7-1}{7}\right)$$

$$= \frac{6}{7}\times 180^\circ = \frac{6}{7}\times \text{pole pitch}$$

Q. To eliminate both 5th & 7th harmonics, the coil span is —?

(a). $\frac{4}{5}\times$ pole pitch ✓(b). $\frac{5}{6}\times$ pole pitch

(c). $\frac{6}{7}\times$ pole pitch (d). $\frac{7}{6}\times$ pole pitch

$$\frac{5}{6}\times 180 = 150^\circ = \beta.$$

Q. The coil span = 160°, which of the following harmonic is eliminated.

(a). 3rd (b). 5th (c). 7th (d). 9th.

$$\beta = 160^\circ \Rightarrow \alpha = 180-\beta = 20^\circ$$

$$\alpha = \frac{180}{n} \Rightarrow n = \frac{180}{20} = 9\text{th}.$$

Q. A 3-ϕ, 2-pole, 18 slot alternator, the coil span is 6 slots. the pitch factor is —

(a). 0.5 ✓(b). 0.866 (c). 0.707 (d). 1.05

$$S/P = \frac{18}{2} = 9 \text{ slots}$$

For full pitch wdg coil span = S/P = 9 slots.

but coil span is 6 slots. ∴ short pitched by 3 slots.

∴ α = 3 slots.

slot angle $r = \frac{180 \times P}{S}$

$= \frac{180 \times 2}{18} = 20^\circ$

∴ $\alpha = 3 \times 20 = 60^\circ$.

∴ $k_p = \cos\frac{\alpha}{2} = \cos 30 = 0.866$

Q. In a 3-ϕ m/c slots/pole/ph. = 5. the coil span = 12 slots then the pitch factor is —.

(a). 0.866 (b). 0.707 ✓(c). 0.951 (d). 1.05

$S/P = 5 \times 3 = 15$..

$r = \frac{180 \times P}{S} = \frac{180}{S/P}$

$= \frac{180}{15} = 12^\circ$.

for full pitch wdg coil span = 15 slots
but given β = 12 slots
ie short pitched by 3 slots.

∴ $\alpha = 3 \times 12 = 36^\circ$ ∴ α = 3 slots.

∴ $k_p = \cos\frac{36}{2} = 0.951$.

Q. In a 3-ϕ m/c the pole pitch = 18 slots. the wdg is short pitched by 60°. then the coil span is —?

(a). 10 slots ✓(b). 12 slots (c). 8 slots
(d). 6 slots.

(S/P = 18 slots) $r = \frac{180}{18} = 10^\circ$

pole pitch = 18 slots = 180°

⇒ for each slot $r = \frac{180}{18} = 10^\circ$.

The wdg is short pitched by 6 slots.

ie $6 \times 10 = 60^\circ$.

$\therefore$ coil span $= 18 - 6 = 12$ slots.

Q. A 3-ϕ, 2-pole, 12 slots alternator, coil span = 1 – 5. The pitch factor is —?

(a). 0.5 (b). 0.866 (c). 0.95 (d). 1

$S/P = \frac{12}{2} = 6$ slots.

$\Rightarrow$ for full pitch wdg the coil span is 1 – 7.

but given coil span is 1 – 5. ie short pitched by 2 slots.

slot angle $\gamma = \frac{180 \times P}{S} = \frac{180 \times 2}{12} = 30^\circ$.

$\therefore \alpha = 2 \times 30^\circ = 60^\circ$.

$\therefore k_p = \cos\frac{\alpha}{2} = 0.866$.

Q. The coil span $= 150^\circ$. the 3rd harmonic pitch factor is —?

(a). $\cos 45^\circ$ (b). $\sin 45^\circ$ (c). $\cos 22.5^\circ$

(d). $\sin 22.5^\circ$.

$\beta = 150$

$\Rightarrow \alpha = 180 - \beta = 30^\circ$.

$\therefore k_{p_3} = \cos\frac{3\alpha}{2} = \cos 45^\circ$.

$\Rightarrow$ The pitch factor for full pitch wdg $k_p = 1$.

$k_{p1} = k_{p3} = k_{p5} = k_{p7} \cdots = 1$.

$\Rightarrow$ for the short pitch wdg

$k_{p1} > k_{p3} > k_{p5} > k_{p7} \cdots$

→ $KVA_{(3-\phi)} = 3\, E_{ph}(3-\phi) \cdot I_{ph}(3-\phi)$

$KVA\,(2-\phi) = 2 \cdot E_{ph}(2-\phi) \cdot I_{ph}(2-\phi)$

$$\frac{KVA\,(3-\phi)}{KVA\,(2-\phi)} = \frac{3 \cdot E_{ph}(3-\phi) \cdot \cancel{I_{ph}(3-\phi)}}{2 \cdot E_{ph}(2-\phi)\,\cancel{I_{ph}(2-\phi)}}$$

$$= \frac{3\, E_{ph}(3-\phi)}{2\, E_{ph}(2-\phi)}$$

$$\frac{KVA_{60}(3-\phi)}{KVA_{90}(2-\phi)} = \frac{3 \cdot K_{d60} \cdot T_{ph}(3-\phi)}{2 \cdot K_{d90} \cdot T_{ph}(2-\phi)}$$

$$= \frac{3 \cdot K_{d60} \times 1/3}{2 \cdot K_{d90} \times 1/2} = \frac{K_{d60}}{K_{d90}}$$

Q. In a 3-ϕ AC m/c ph. emf is E_1 and o/p is P_1 for a ph. spread of 60°. where as emf is E_2 and o/p is P_2 for the ph. spread of 120°. The terms E_1, E_2 & P_1, P_2 relates as under,

(a). $E_1 = E_2$, $P_1 = 1.15 P_2$ ✓(b). $E_1 = 1.15 E_2$, $P_1 = 1.15 P_2$

(c). $E_1 = 1.15 E_2$, $P_2 = 1.15 P_1$ (d). $E_2 = 1.15 E_1$, $P_2 = 1.15 P_1$

* 120° ⟶ 100V, 100 kVA (But) ⟶ Triplen harmonics are eliminated in phase voltages.

60° ⟶ 115V, 115 KVA. ⟶ Triplens are existed in phases.

for 3-ϕ m/c, 60° ph. spread (narrow ps) is prefer over 120° ph. spread (wide ps) b'coz with 60° ps, the induced emf & kVA ratings are 15% extra compared with 120° ps.
(due to triplens)

Q. The distribution factor for a $3-\phi$ uniformly distribution wdg is —?

(a) $\frac{2}{\pi}$ (b) $3/\pi$ (c) $\frac{4}{\pi}$ (d) $5/\pi$

Sol. For $3-\phi$, ph. spread $m\gamma = 60°$.

$$\therefore K_{du} = \frac{\sin\frac{m\gamma}{2}}{\frac{m\gamma}{2}\cdot\frac{\pi}{180}} = \frac{\sin 60/_2}{60/_2 \cdot \pi/180} = \frac{3}{\pi}.$$

Q. The distribution factor for $1-\phi$ uniformly distr. wdg — ?

(a) $\frac{2}{\pi}$ (b) $\frac{3}{\pi}$ (c) 1, (d) π

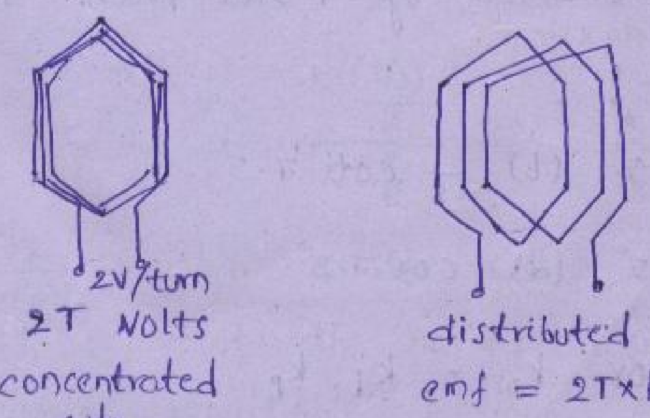
Sol. $$K_{du} = \frac{\sin\frac{180}{2}}{\frac{180}{2}\cdot\frac{\pi}{180}} = \frac{2}{\pi}.$$

For $1-\phi$ ph. spread $m\gamma = 180°$

G'98 Q. The arm. of a $1-\phi$ Alt. is completely wound with 'T' single turns coils, distributed uniformly. The induced volt. in each turn = 2V. The emf of whole wdg is —

(a). 2T volts (b). 1.11T volts (c). 1.414 T volts (d). 1.273 T volts.

Sol.



emf $= 2T \times k_d$

$= 2T \times \frac{2}{\pi} = \frac{4}{\pi} T$

$= 1.273T$ volts

$$E_{ph} = \text{emf/turn} \times T_{ph} \times k_d \quad = 2 \times T \times \frac{2}{\pi}.$$

Q. The arm. of a Y connected alt. is uniformly wound with 'T' coils. Each coil having 'n' full pitched turns, the generated emf/conductor is 2V rms. The per phase emf is –

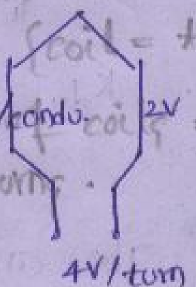
(a). $\frac{3}{\pi}$ NT volts (b). $\frac{4}{\pi}$ NT volts

(c). $\frac{6}{\pi}$ NT volts (d). $\frac{2}{\pi}$ NT volts.

Sol. 'T' coils, each coil having 'n' turns.

Total turns = nT.

[if there are 1 turn in a coil then [coil = turn] simply no. of coils = no. of turns.]



$$\Rightarrow T_{ph} = \frac{nT}{3}.$$

$$k_d = \frac{\sin 60/2}{60/2 \cdot \pi/180} = \frac{3}{\pi}$$

$$E_{ph} = \text{emf/turn} \times T_{ph} \times k_d$$

$$= 4 \times \frac{nT}{3} \times \frac{3}{\pi} =$$

{one coil may have any no. of turns.}

1-turn = 2 conductors

Q. A 3-Ø, 4-pole, Alternator has 48 stator slots carrying the 3-Ø distributed wdg. Each coil of wdg chorded by 1 slot pitch. The wdg factor is — ?

(a). $\frac{1}{16}\cos 7.5°$ (b). $\frac{1}{8}\cot 7.5°$

(c). $\frac{1}{16}\sin 7.5°$ (d). $\cos 7.5°$

Sol. wdg factor $k_\omega = k_d \cdot k_p$

$$\text{spp} = m = \frac{48}{4 \times 3} = 4, \quad \text{slot angle } \gamma = \frac{180 \times 4}{48} = 15°$$

$$K_d = \frac{\sin\frac{4\times15}{2}}{4\sin 15/2} = \frac{1/2}{4\sin 7.5^\circ} = \frac{1}{8\cdot\sin 7.5^\circ}$$

$\alpha = 1\text{ slot} = 15^\circ$

$$\Rightarrow k_p = \cos\frac{\alpha}{2} = \cos\frac{15}{2} = \cos 7.5^\circ$$

$$\therefore k_\omega = k_p \cdot k_d = \frac{1}{8}\cdot\cot 7.5^\circ$$

Fractional slot wdg :-

→ Integral slot wdg : If the spp is an integer.

Eg: A 3-ø, 2-pole, 18-slot Alternator, spp = 3

Here spp = 3 → Integer.

Fractional slot wdg: If the spp is not an integer ie it is a fraction.

Eg: A 3-ø, 10-pole, 42 slots Alternator.

$$spp = \frac{42}{10\times3} = 1.4 \rightarrow \text{fraction.}$$

For balanced fractional wdg, the no. of slots must be divisable with no. of phases ie slots/phase must be an integer.

$$\frac{42}{3} = 14 \rightarrow \text{An integer.}$$

slots/pole/phase, $spp = \frac{slots}{pole\times ph} = \frac{slots/ph}{poles}$

$$= \frac{S/3}{P} = \frac{\frac{K(S/3)}{K}}{K\cdot\frac{P}{K}} = \frac{K\cdot S_K}{K\cdot P_K} = \frac{S_K}{P_K}$$

* $\frac{S_K}{P_K}$ ⇒ characteristic Ratio, K → highest factor which represent the no. of possible parallel paths & no. of repeatable sections.

Eg: A 3-ϕ, 10-pole, 42-slots Alternator.

$$SPP = \frac{42}{10\times3} = \frac{42/3}{10} = \frac{14}{10} = \frac{2\times7}{2\times5}$$

$$= \frac{7}{5} = \frac{S_K}{P_K}.$$

char. ratio $\frac{S_K}{P_K} = \frac{7}{5}$.

$K=2$, ie no. of possible paths $=2$.
no. of repeatable sections $=2$.

* The denominator of char. ratio represents, out of 10 poles, the wdg arrangement considered only for 5 poles, it will just repeat for other 5 poles.
* The numerator of char. ratio represents, out of 42 slots, the wdg arrangement considered only for 21 (7×3) slots, the wdg arrangement repeat for other 21 slots.
* Distribution factor for fractional slot wdg

$$K_{d_{f.s}} = \frac{\sin\frac{m\gamma}{2}}{S_K \cdot \sin\frac{m\gamma}{2S_K}}$$, where S_K, numerator of char. ratio.

WED. 20/08/08

Adv.s of Fractional slot wdg:-

(1). Effect of higher order harmonics perticularly slot harmonics

(2). Any existing arm. core can be utilized no special slots are required.

(3). More flexible for the selection of coil span.

Dis.advs :-

→ It is possible only with double layer wdg.

→ The no. of $\parallel^{el}$ paths are restricted.

⇒ No. of possible $\parallel^{el}$ paths for integral slot wdg $= P/2$.

Q. A 6 pole, 3-φ, 50 Hz Y-connected narrow ph. spread alt. has 42 slots with double layer wdg. flux/pole = 0.012 wb and each full pitch coil has 8 turns.

$m\gamma = 60°$

(i). K_d is —? (a). 0.964 (b). 0.956 (c). 1 (d). 0.985.

(ii). The induced emf line to line is close to

(a). 265 V (b) 990 V (c). 494 V (d). 510 V

(iii). The L-L emf if the wdg is connected for 2-φ operation

(a). 285 V (b). 494 V (c). 403 V (d) 571 V

Sol.

No. of coils = no. of slots (∵ double layer wdg).
= 42.

$T = 42 \times 8 = 336$

$m\gamma = \frac{7}{3} \times \frac{180}{7} = 60$

3-φ: $SPP = \frac{42}{6 \times 3} = 2.33$

$SPP = \frac{s/ph}{poles} = \frac{42/3}{6} = \frac{14}{6} = \frac{2 \times 7}{2 \times 3} = \frac{7}{3} = \frac{S_K}{P_K}$

slot angle $\gamma = \frac{180 \times P}{S} = \frac{180 \times 6}{42} = 25.71°$

$K_d = \frac{\sin m\gamma/2}{S_K \cdot \sin \frac{m\gamma}{2S_K}} = \frac{\sin 60/2}{7 \cdot \sin \frac{60}{2 \times 7}} = 0.956$

$T_{ph} = \frac{336}{3} = 112$.

$k_p = 1$ (∵ full pitch wdg)

$E_{ph} = 4.44\, k_p \cdot k_d\, \phi f T_{ph}$

$= 4.44 \times 1 \times 0.956 \times 0.012 \times 50 \times 112$

$= 285.23V$

$E_L = \sqrt{3} \times 285.23 = 494V$.

2-ϕ :

$T_{ph} = \frac{336}{2} = 168, \; k_p = 1$.

$SPP = \frac{S/ph}{pole} = \frac{42/2}{6} = \frac{21}{6} = \frac{3\times7}{3\times2} = \frac{7}{2} = \frac{S_K}{P_K}$

$m = SPP = \frac{42}{2\times6} = 3.5$

$\gamma = \frac{180\times6}{42} = 25.71$

$k_d = \frac{\sin\frac{90}{2}}{7 \cdot \sin\frac{90}{2\times7}} = 0.902$

$E_{ph} = 4.44\, k_p k_d \phi f T_{ph}$

$= 4.44 \times 1 \times 0.902 \times 0.012 \times 50 \times 168$

$= 403.67V$

$E_L = \sqrt{2} \times 403.67 = 571V$.

(or).

$\frac{E_{ph}(3-\phi)}{E_{ph}(2-\phi)} = 0.707$

$E_{ph}(2-\phi) = \frac{285.23}{0.707} = 403V$

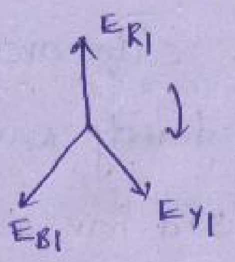
$E_L = \sqrt{2} \times 403 = 571V$

Advantages of Y-connected stator:

$$E_L = E_{RY} = E_R - E_Y$$

$$= (E_{R_1} + E_{R_3} + E_{R_5} + \dots) - (E_{Y_1} + E_{Y_3} + E_{Y_5} + \dots)$$

$$= (E_{R_1} - E_{Y_1}) + (E_{R_3} - E_{Y_3}) + (E_{R_5} - E_{Y_5}) + \dots$$



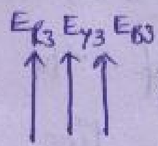
$E_{R_1}\angle 0$; $E_{Y_1}\angle -120$; $E_{B_1}\angle -240$.

$R_1 - Y_1 - B_1 \rightarrow$ ph. seq. (+ve)

$E_{R_3}\angle 0\times 3 = E_{R_3}\angle 0°$

$E_{Y_3}\angle -120\times 3 = E_{Y_3}\angle -360° = E_{Y_3}\angle 0°$

$E_{B_3}\angle -240\times 3 = E_{B_3}\angle -720 = E_{B_3}\angle 0°$

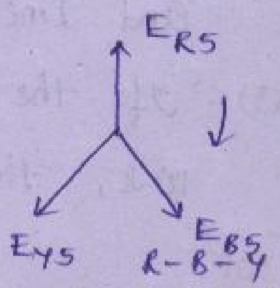


zero sequence co-phasal.

$E_{R_5}\angle 0\times 5 = E_{R_5}\angle 0°$

$E_{Y_5}\angle -120\times 5 = E_{Y_5}\angle -600 = E_{Y_5}\angle -240°$

$E_{B_5}\angle -240\times 5 = E_{B_5}\angle -1200 = E_{B_5}\angle -120$



R-B-Y (-ve seq.)

$6k-1$, $k = 1, 2, 3, \dots$

$= 5, 11, 17, 23 \dots \rightarrow$ -ve seq.

$6k+1$, $k = 1, 2, 3, \dots$

$= 7, 13, 19, 25 \dots \rightarrow$ +ve seq.

for 120° ph. spread: In Y-

* $E_{ph} = \sqrt{E_{ph_1}^2 + E_{ph_5}^2 + E_{ph_7}^2 + E_{ph_{11}}^2 + \dots}$

$E_L = \sqrt{3}\cdot\sqrt{E_{ph_1}^2 + E_{ph_5}^2 + E_{ph_7}^2 + E_{ph_{11}}^2 + \dots}$

* Circulating currents are zero, when the m/c connected for 120° ph. spread.

Q. A 3-ϕ, 6-pole, 1000 rpm Alt. has air gap dia. of 28 cm and core length 23 cm, a two layer narrow ph. spread wdg is employed and the wdg is accomodated in 4 slots per pole per ph with 8 condu. per slots. Coils are sh. pitched by 1 slot. In the flux density wave the fundamental is found as 0.87 T, 3rd har. 0.24 T and 5th har. 0.14 T.

(1). If the m/c is Y-connected, the ph. volt – ? and line volt – ?

(2). If the m/c is Δ-connected, the ph. volt – ? and Line volt – ?

(3). If the per ph. reactance of Alt. at 50 Hz is 10 Ω, the circulating current in Δ will be – ?

Sol.

3-ϕ, 6-pole, 1000 rpm, $D = 28\text{ cm} = 0.28\text{ m}$

$L = 23\text{ cm} = 0.23\text{ m}$, narrow ph. spread.

$spp = 4$, 8 condu/slot, $\alpha = 1$ slot

$B_1 = 0.87\text{ T}$, $B_3 = 0.24\text{ T}$, $B_5 = 0.14\text{ T}$

$$\boxed{\frac{E_{phn}}{E_{ph1}} = \frac{K_{wn}}{K_{w1}} \times \frac{B_n}{B_1}}$$

Max. value of fundamental, flux density $B_1 = \frac{2DL}{P} B_1$

Max. value of nth har. flux density $\phi_n = \frac{2DL}{nP} B_n$

$$f = \frac{PN}{120} = \frac{6 \times 1000}{120} = 50\text{ Hz}$$

$$\phi_1 = \frac{2DL}{P} B_1 \Rightarrow 0.87 \times \frac{2\times 0.28\times 0.23}{6} = \phi_1$$

$$\Rightarrow \phi_1 = 0.018 \text{ wb}$$

$$\text{Slots} = 4\times 6\times 3 = 72$$

$$T = \frac{72\times 8}{2} \Rightarrow T_{ph} = \frac{72\times 8}{2\times 3} = 96$$

$$\text{SPP} = m = 4, \quad \gamma = \frac{180\times P}{S} = \frac{180\times 6}{72} = 15^\circ$$

$$k_{d1} = \frac{\sin\frac{4\times 15}{2}}{4.\sin\frac{15}{2}} = 0.957$$

$$k_{d3} = \frac{\sin\frac{4\times 3\times 15}{2}}{4.\sin\frac{3\times 15}{2}} = 0.653$$

$$k_{d5} = \frac{\sin\frac{4\times 5\times 15}{2}}{4.\sin\frac{5\times 15}{2}} = 0.205$$

$$\alpha = 1 \text{ slot} = 15^\circ$$

$$\Rightarrow k_{p1} = \cos\frac{15}{2} = 0.991$$

$$k_{p3} = \cos\frac{3\times 15}{2} = 0.923$$

$$k_{p5} = \cos\frac{5\times 15}{2} = 0.793.$$

$$\Rightarrow k_{\omega 1} = k_{d1}.k_{p1} = 0.948$$

$$k_{\omega 3} = k_{d3}.k_{p3} = 0.602$$

$$k_{\omega 5} = k_{d5}.k_{p5} = 0.167$$

$$E_{ph1} = 4.44\, k_{\omega 1}\, \phi_1\, f\, T_{ph}$$

$$= 4.44\times 0.948\times 0.018\times 50\times 96 = 377.32\text{V}$$

$$E_{ph3} = E_{ph1}\times\frac{k_{\omega 3}}{k_{\omega 1}}\times\frac{B_n}{B_1}$$

$$= 377.32\times\frac{0.602}{0.948}\times\frac{0.24}{0.87} = 66.09\text{ V}$$

$E_{ph5} = 377.32 \times \frac{0.167}{0.948} \times \frac{0.14}{0.87} = 10.96\ V.$

* SUN : AUG . 24 . 2008 *

→ Slot Harmonics

→ Space Harmonics → $(6K \pm 1)$

* The speed of space harmonics of order $(6k-1)$ ie $(5, 11, 17, 23, \ldots) = (\frac{1}{5}, \frac{1}{11}, \frac{1}{17}, \ldots) N_s$

⇒ rotate in reverse (or) opposite dire. that of fundamental, since −ve seq. harmonics.

* The speed of space harmonics of order $(6k+1)$ ie $(7, 13, 19, \ldots) = (\frac{1}{7}, \frac{1}{13}, \frac{1}{19}, \ldots) N_s$, rotate in the same dire. that of fundamental, since +ve seq. harmonics.

Q. The 83rd harmonic will rotate in –

(a). In the same dire. of funda.

✓(b). In reverse dire. of funda.

(c). NO rotation.

83rd → −ve seq. harmonic

Q. The 81st harmonic will rotate in – ?

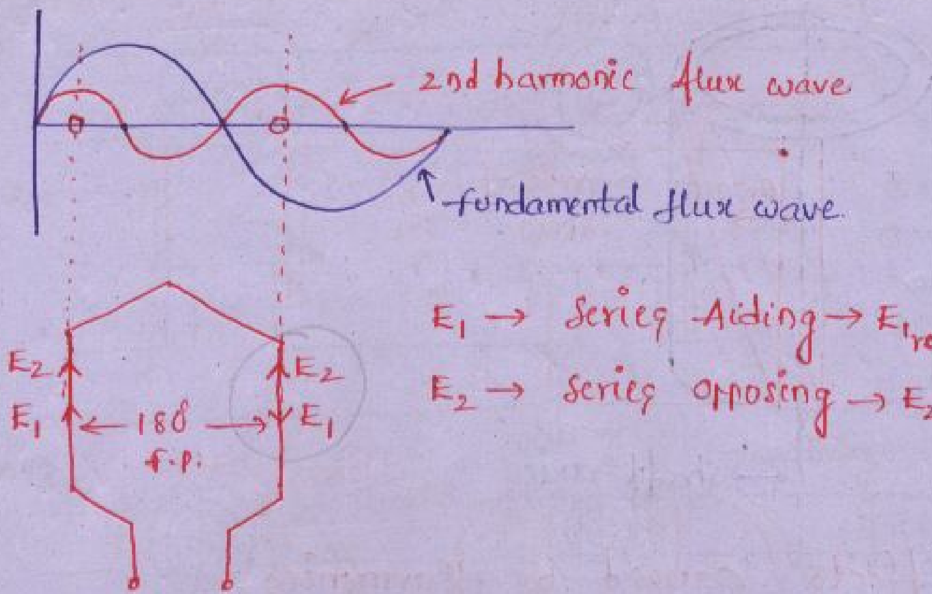
(a). Same dire. that of funda.

(b). Reverse dire. " "

(c). NO rotation.

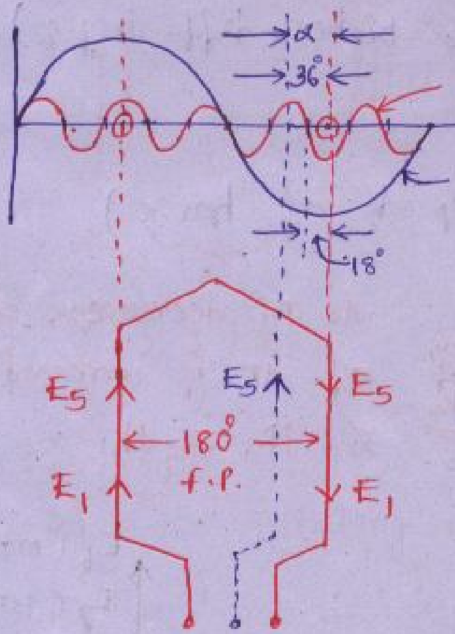
Ans: 81 → Triplen harmonic

zero seq. harmonics → no rotation.



$E_1 \rightarrow$ Series Aiding $\rightarrow E_{1res} = 2E_1$

$E_2 \rightarrow$ Series opposing $\rightarrow E_{2res} = 0$.



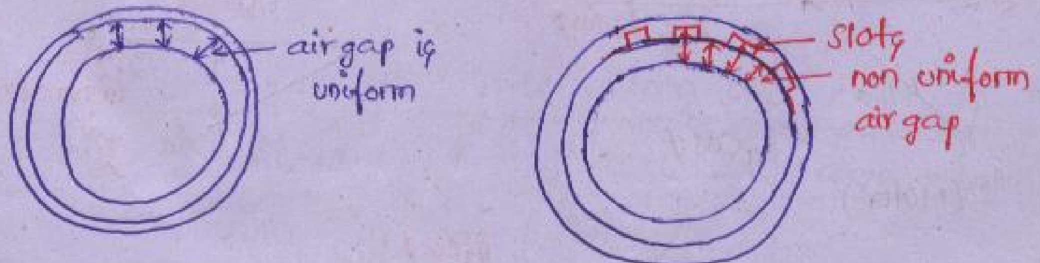
$E_1 \rightarrow$ Series Aiding $\rightarrow E_{1res} = 2E_1$

E_5 with f.p $\rightarrow$ Series Aiding $\rightarrow 2E_5$

E_5 with s.p $\rightarrow$ Series opposing $\rightarrow 0$

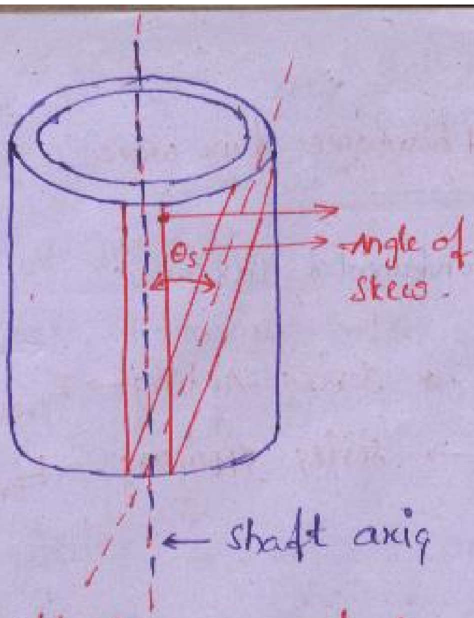
SLOT Harmonics :-

Due to variable reluctance caused by slotting the stator or rotor or both.



→ SLOT Harmonics are higher order Harmonics.

⇒ SLOT Harmonics can be eliminated by skewing the armature slots.



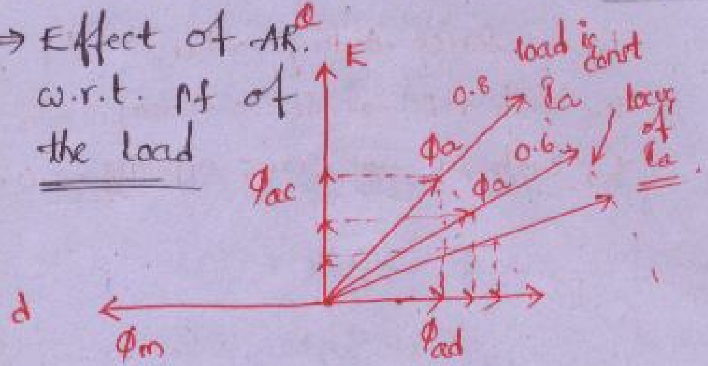
→ Effects caused by Harmonics :-

↳ Iron losses. (∵ due to higher & diff freq's)

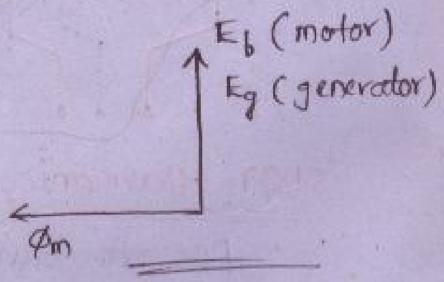
↳ Reduced η

↳ vibrations (∵ diff speeds of har.s)

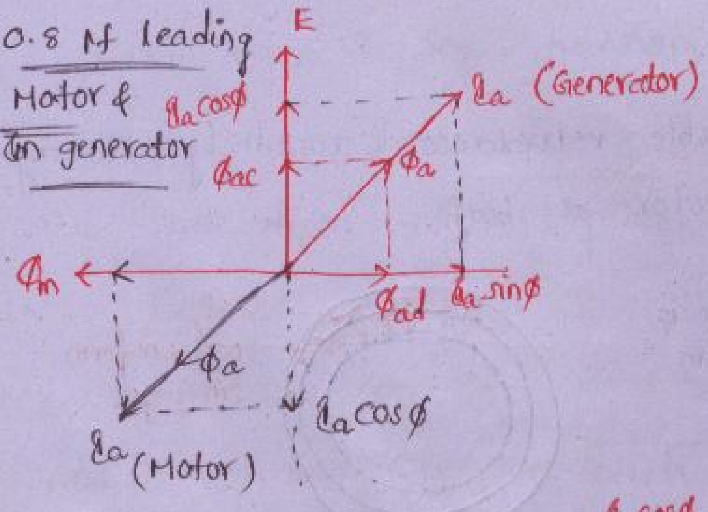
⇒ Effect of AR w.r.t. pf of the load

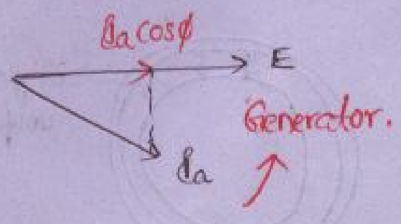


As pf decreases, effect of AR is increased. ie ϕ_{ad} ↑↑, ϕ_{ac} ↓↓

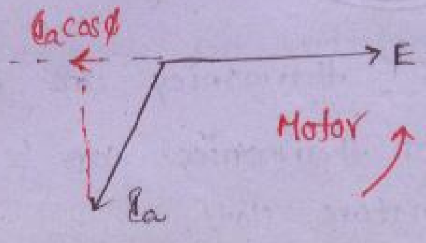


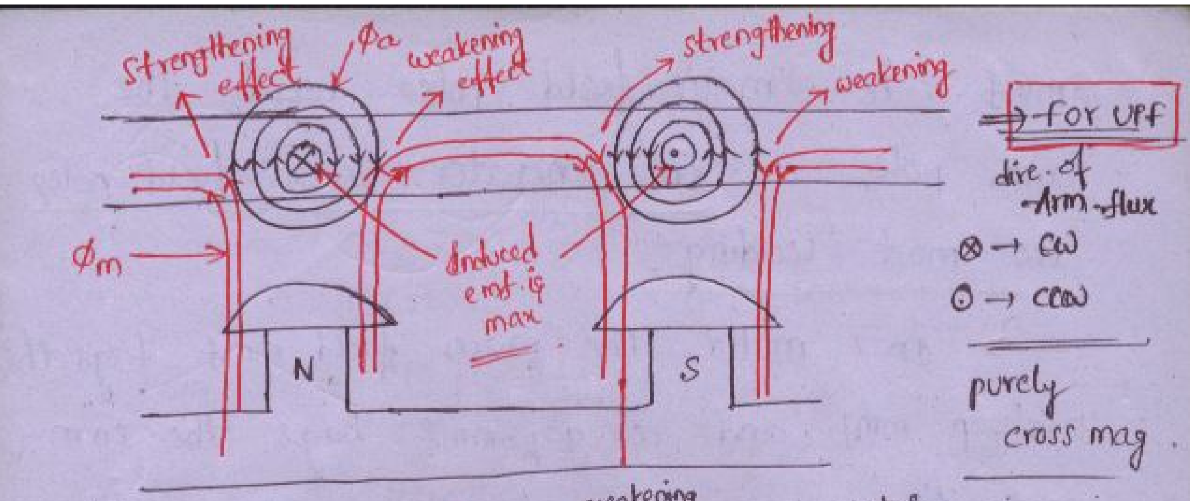
⇒ 0.8 pf leading in Motor & in generator

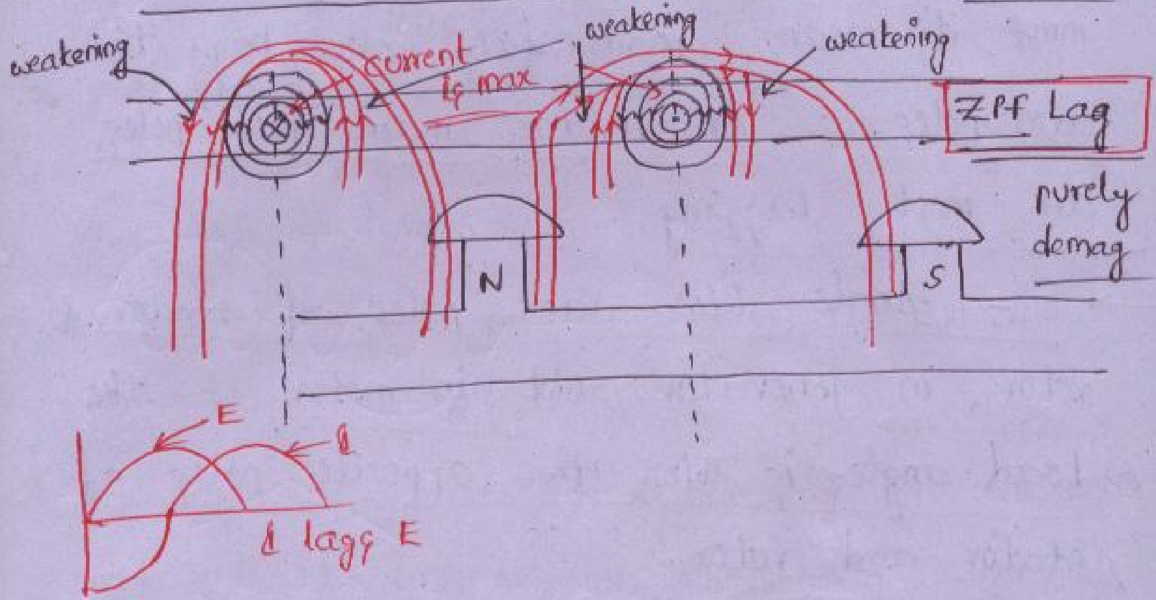




If Angle is more than 90, → motor.







⟹ Synchronous Speed :-

If the rotating mag. field or poles are rotated at equal angle in the space for the given time angle of current.

→ The magnitude of ϕ_R = 1.5 times of max. value due to any phase.

⟹ Torque :

Torque is the interaction b/w 2 fields or 2 poles. It may be attraction in case of motor, and repulsion in case of generator.

→ In generator main field mmf leads the airgap mmf & airgap mmf leads the arm

mmf. ie main field poles leads the arm. poles ∴ In generator main field poles are most leading.

→ In motor the main field mmf lags the air gap mmf and air gap mmf lags the arm. mmf, it means main field poles lags the arm poles. ∴ In motor main field poles are most lagging.

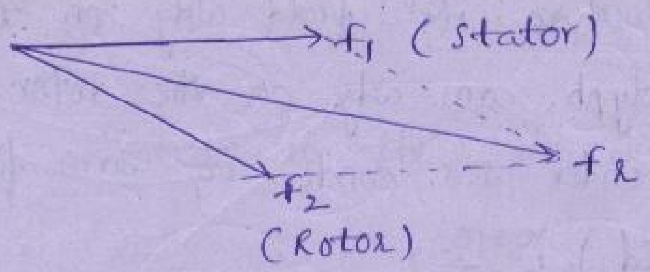
→ δ – Angle b/w same poles of stator & rotor in generator. but in motor δ – the load angle is b/w two opposite poles of stator and rotor.

→ In generator the electromagnetic torque will be in opposite dirc. to rotor of T_{pm}.

→ In motor T_{em} developed will be in the same dirc. of rotor rotation.

→ for the production of uni dirc. torque, the 2 fields must be stationary w.r.t. each other and they should have equal no. of poles. It means the relative speed b/w stator & rotor field must be zero.

→ The no. of stator poles = no. of rotor poles



$$T_{em} = -\frac{P}{2}\mu_0 \frac{\pi r l}{g} f_1 f_2 \sin\delta$$

P – no. of poles
r – radius of rotor core.
l – length of " "
g – Airgap length

–ve sign is because of always the two fields will try to allign themselves.

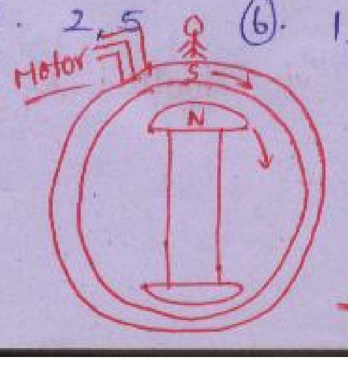
Q. A syn. m/c have its field wdg on the rotor and poly ph. arm wdg on the stator, when running under steady condi-s its arm field (air gap field) is

1. stationary w.r.t stator
2. Rotating at syn. speed N_s w.r.t. stator
3. Rotating at double N_s w.r.t. rotor.
4. stationary w.r.t rotor
5. Rotating at N_s in the dire. of rotor rotation.

from these correct Ans. is

ⓐ. 2, 5 ⓑ. 1, 4, 5 ⓒ. 2, 3, 4 ⓓ. 2, 4, 5.

Ans:



⟹ Arm. mmf will rotate at N_s w.r.t. stator.

⟹ Am mmf or poles are stationary w.r.t. rotor. (∵ relative speed = 0).

⟶ Arm. mmf will rotate in the same dire. that of rotor.

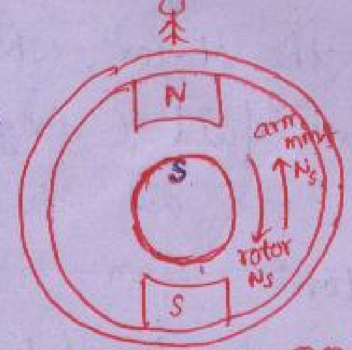
Q. A Syn. m/c has its field wdg on the stator and polyph. arm. wdg. on the rotor. When running under s.s. condi. its arm field (air gap field) is —?

1. Stationary w.r.t stator.
2. Rotating at syn. speed w.r.t stator.
3. Rotating at N_s in the dire. of rotor
4. Rotating at doubled N_s w.r.t rotor
5. Rotating at N_s w.r.t rotor.
6. Rotating in a dire. opposite to rotor rotation

from these correct answer is —?

(a) 2, 5 (b) 1, 4, 6 (c). 2, 4, 6 (d). 1, 3, 5.

Ans: motor Attraction



⇒ Main field mmf is stationary w.r.t stator.

⇒ Arm. mmf must be stationary w.r.t stator ∴ the arm mmf must be stationary w.r.t stator mmf.

⇒ when rotor rotates in cw with N_s, then S- pole (arm. mmf will try to rotate in ccw with the same speed N_s.

→ arm. mmf will rotate in opposite dire. that of rotor rotation.

→ The arm. mmf will rotate at doubled N_s w.r.t rotor.

Q. In DC generator (or motor) the arm. mmf will.

a). rotate in the same dire. of rotor

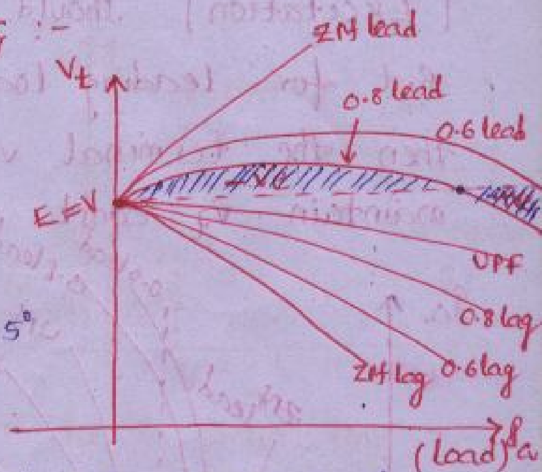
b). " " opposite dire. that of rotor

c). stationary w.r.t. stator

✓ d). both b & c.

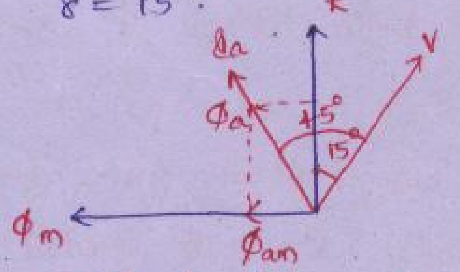
5. external characteristics :-

V_t V_f I_a | I_f = const, pf = const, N = const



Let pf = 0.707 lead, $\phi = 45°$

$\delta = 15°$.

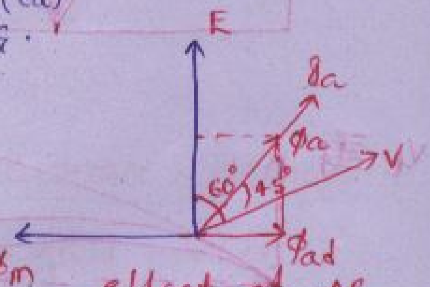


effect of AR is magnetisation,

∴ reg → −ve.

Let pf = 0.707 lead,

$\phi = 45°$, $\delta = 60°$. Since as load (I_a) increases, δ also increases.



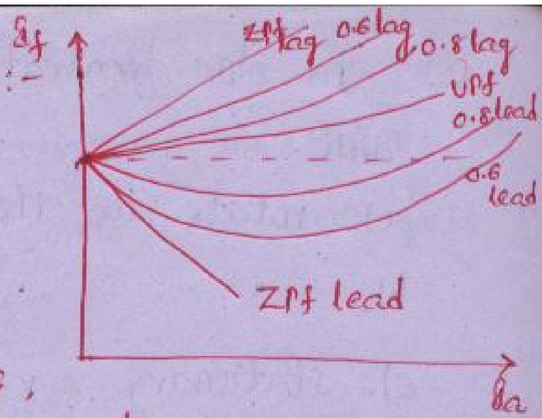
effect of AR is demagnetisation

reg → +ve

* As the load increases, for UPf (resistive loads) and for inductive loads, the terminal voltage will be decreased and so the reg. is +ve.

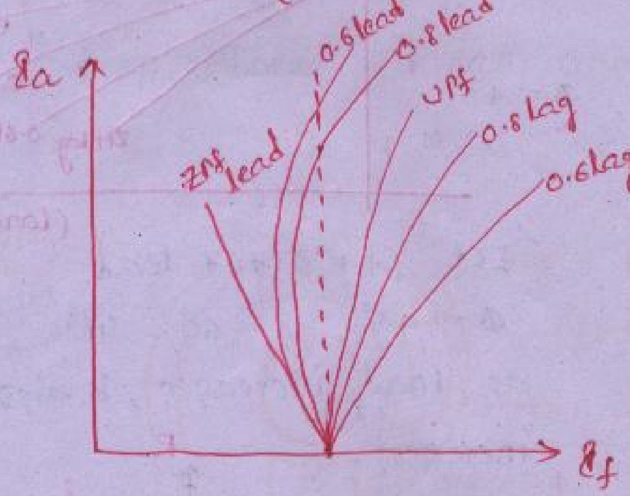
6. Compounding char.s :-

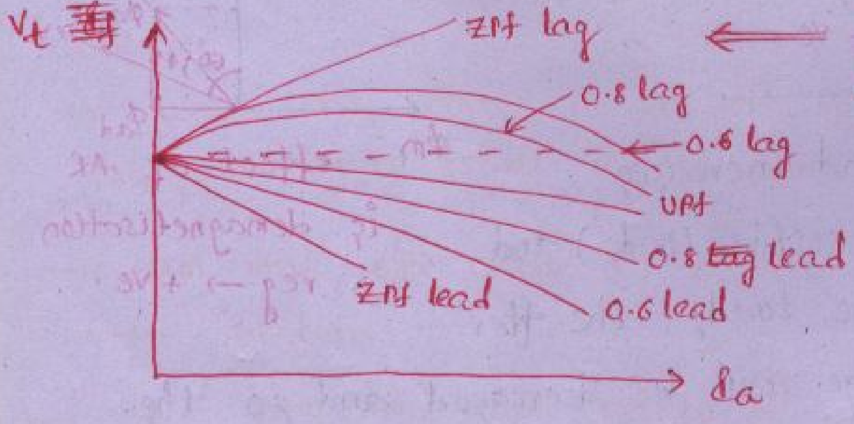
I_f vs I_a | V_t = const, pf = const, N = const.



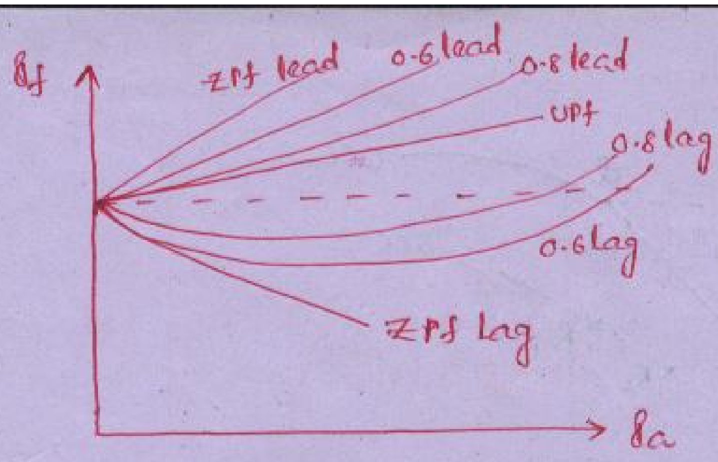
As the load [I_a] increases, the terminal voltage decreases for upf & inductive load, so to maintain V_t const, field current [Excitation] should be increased.

But for leading loads as load ~~the~~ increases, then the terminal volt. increases so in order to maintain V_t const. excitation should be decreased.



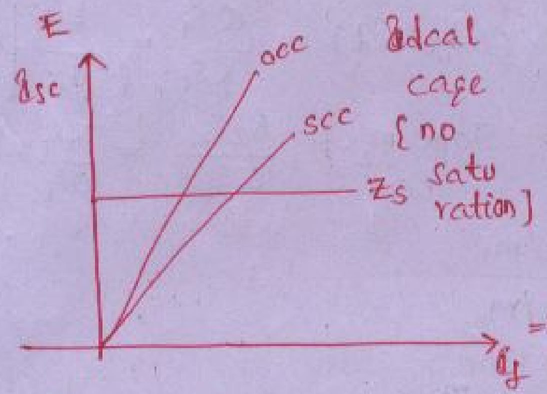


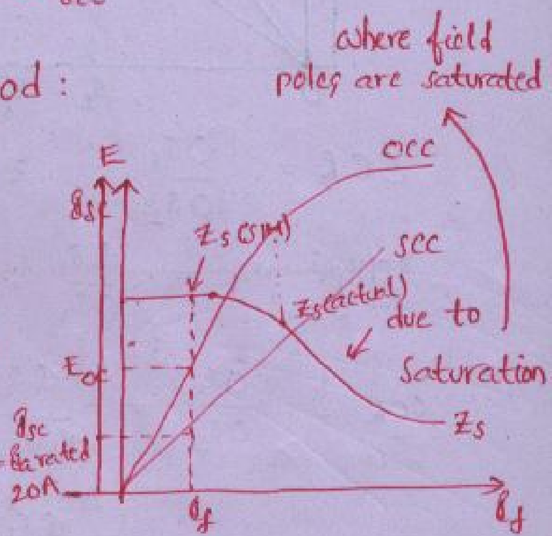
⟸ External char.s for Syn. motors



← compounding char-s for syn. motors.

Synchronous Impedance Method:





Z_s is varied w.r.t excitation due to saturation.

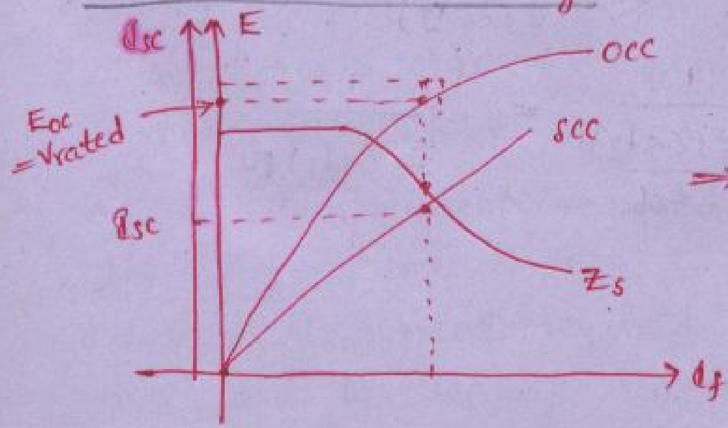
Z_s (unsat) > Z_s (sat)

→ In this method Z_s is measured corr. to field current belongs to rated short circuit current.

reg (SIM) > reg (actual)

Saturated Syn. Impedance (or reactance) Method:-

→ In this Z_s is measured, the field current corr. to rated o/c voltage.

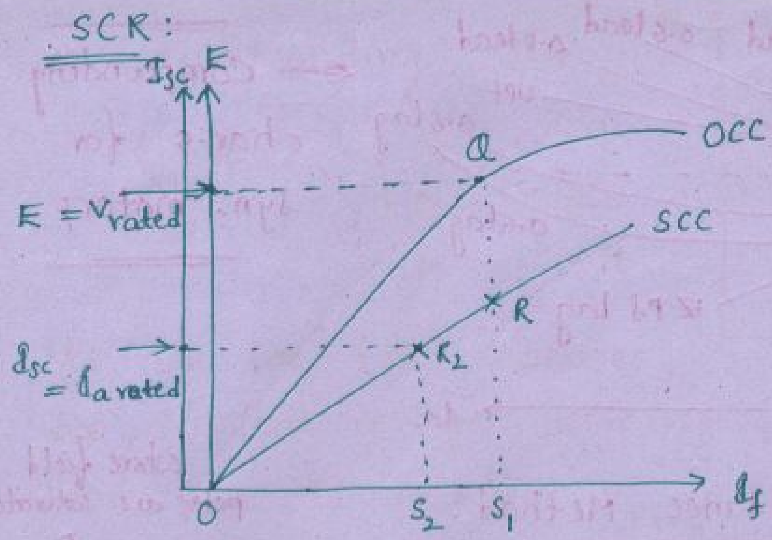


$$Z_s(\text{sat or adjusted}) = \left.\frac{E_{oc}}{I_{sc}}\right|_{I_f \text{ is}}$$

at $E_{oc} = V_{rated}$.

⇒ reg (EMF or Syn. imp. method) > reg (Sat. Syn. imp. method).

SCR:



$SCR = \dfrac{OS_1}{OS_2}$; $Z_s(\text{adjusted}) = \dfrac{QS_1}{RS_1} = \dfrac{E_{oc}}{I_{sc}}\Big|$ I_f is at $E_{oc} = V_{rated}$

Slope $m_1 = \dfrac{QS_1}{OS_1}$ (OCC) ; Slope $m_2 = \dfrac{R_2S_2}{OS_2} = \dfrac{RS_1}{OS_1}$ (SCC)

$$SCR = \frac{OS_1}{OS_2} = \frac{QS_1/m_1}{R_2S_2/m_2}$$

$$= \frac{QS_1}{R_2S_2} \times \frac{m_2}{m_1}$$

$$= \frac{QS_1}{R_2S_2} \times \frac{RS_1}{QS_1}$$

$$= \frac{QS_1}{R_2S_2} \times \frac{1}{\left(\frac{QS_1}{RS_1}\right)}$$

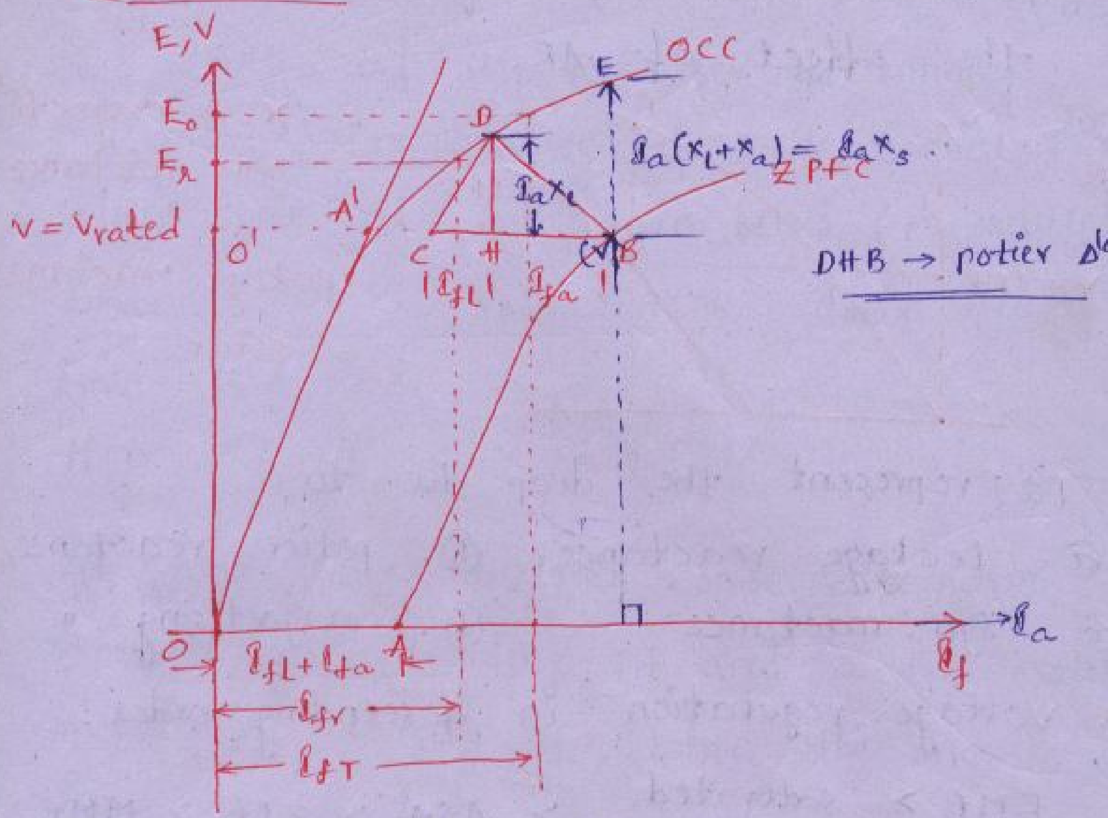
$$= \frac{V_{rated}}{I_{rated}} \times \frac{1}{Z_s(\text{adj})}$$

Base impedance

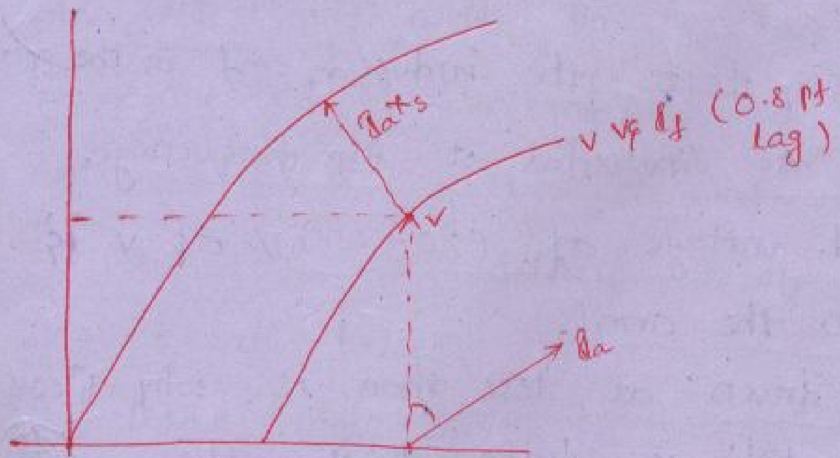
$$= Z_{sb} \times \frac{1}{Z_s(\text{adj})}$$

$$\therefore SCR = \frac{1}{\frac{Z_s(\text{adj})}{Z_{sb}}} = \frac{1}{Z_s(\text{adj})\,pu}$$

ZPf Method:



If ZPFC is not considered,



The total field current O'B can be divided as follows:

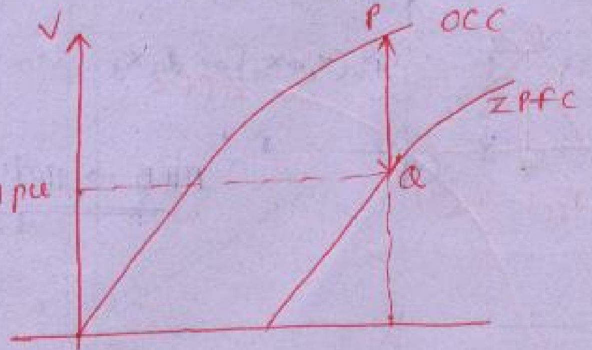
O'A' : field current required to generate rated volt under o/c condi.

A'C : field current required to overcome the saturation.

CH : field current required to overcome the drop due to leakage reactance.

HB : field current required to overcome the effect of AR.

G'03. Q.



x_a = magnetising reactance

leakage reactance = potier "

PQ represent the drop due to,

(a). leakage reactance (b). potier reactance

✓(c). syn. reactance (d). magnetising "

* voltage regulation in descending order:

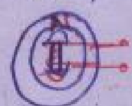
EMF > saturated syn. reactance > ASA > ZPF > MMF

SLIP TEST :-

* During slip test, the induced emf in the open field wdg which is AC sinusoidal at slip frequency.

* A reduced voltage of (20-25) % of V is applied to the arm.

* field is driven at less than N_s, why b'coz, when the field is driven at N_s, the flux linkages are max, so I_a min. always. So we wont get max values of I_a ie field is in locking with the stator poles.



Q. During slip test the induced emf in the open field wdg is — ?

✓(a) zero for X_d (b). zero for X_q

(c). max, +ve for x_q (d). max, +ve for x_d.

Q. The results of slip test for determining x_d and x_q reactances of a Y connected salient pole alt. are given below (ph. values)

V_{max} = 108 V, V_{min} = 96 V, I_{max} = 12 A

I_{min} = 10 A.

then x_d = ? & x_q = ?

* At max. power developed condi. alternator operate at leading pf and a syn. motor operate at lagging pf, when the m/c is operating on infinite bus bar.

Q. An alternator with syn. reactance of 0.8 pu is connected to an infinite bus at rated volt. with its excitation emf adjusted to 1.3 pu. The Alt. delivers an o/p of 0.5 pu neglect all losses.

(1). Load angle — ?

(a). 31° (b). 17.92° (c). 9.6° (d) 21°.

(2). The arm. current is — ?

(a). 0.581 pu (b). 0.375 pu (c) 1 pu (d). 0.8 pu

(3). The pf — ?

Sol: (a). x_s = 0.8 pu P = 0.5 pu

V = rated volt = 1 pu

E = 1.3 pu

$P = \frac{EV}{X_s} \cdot \sin\delta$

If rated KVA is given then $V = 1pu$; $I_a = 1pu$

$\Rightarrow 0.5 = \frac{1.3 \times 1}{0.8} \sin\delta$

$\Rightarrow \delta = 17.9°$.

$I_a = \frac{E\angle\delta - V\angle 0}{Z_s \angle\theta}$

$= \frac{1.3\angle 17.9 - 1\angle 0}{0.8\angle 90} = 0.581\angle -30.63°$

$\Rightarrow I_a = 0.581$ pu ; pf $= \cos(30.63)$

$= 0.86$ lag

Q. A Syn. Gen. is connected to an infinite bus bar at 1pu volt. and draws 0.6 pu current at UPF. Its syn. reactance is 1pu and resistance is negligible. The excitation volt. E & load angle δ will be res.

(a) 0.8 pu, 36.86° lag (b). 0.8 pu, 36.86° leading

(c). 1.17 pu, 30.96° leading (d). 1.17 pu, 30.96° lag

Sol:- $V = 1$ pu , $I_a = 0.6$ pu , UPF.

$X_s = 1.0$ pu.

$E = V\angle 0 + I_a\angle \pm\phi \cdot Z_s\angle\theta$

$= 1\angle 0 + 0.6\angle 0 \times 1\angle 90°$

$= 1.17\angle 30.96$

$\Rightarrow 1.17, 30.96°$ leading.

Q. A 3,300 V, Y connected syn. Gen. has syn impedance of $(0.4 + j5)\ \Omega/ph$. per an excitation emf of 4,000 V, and power o/p of 1000 kw at rated volt. The line current is —? and pf is —?

sol:-

$V = 3{,}300\ V$, Y- connected

$Z_s = (0.4 + j5)\ \Omega/ph$

$E = 4000\ V$

$P = 1000\ kw$

$$V_{ph} = \frac{3300}{\sqrt{3}} = 1905\ V$$

$$E_{ph} = \frac{4000}{\sqrt{3}} = 2309\ V$$

$$Z_s = 0.4 + j5 = 5.01 \angle 85.14 \leftarrow \theta$$

$$P = \frac{EV}{Z_s}\cos(\theta - \delta) - \frac{V^2}{Z_s}\cos\theta$$

$$\rightarrow \frac{1000 \times 10^3}{3} = \frac{2309 \times 1905}{5.01}\cos(85.14 - \delta) - \frac{(1905)^2}{5.01}\cos(85.14)$$

$$\Rightarrow \delta = 21.8^\circ$$

$$I_a = \frac{E\angle\delta - V\angle 0}{Z_s \angle\theta} = \frac{2309\angle 21.8 - 1905\angle 0}{5.01\angle 85.14}$$

$=$

Q. The freq. of the existing system is 50 Hz. An alt. with the freq 50.2 Hz is connected ||el to the existing system through dark lamp method. The flickering of bulbs per min is — ?

(a) 2 (b) 10 ✓(c) 12 (d) 0.2

flickering rate $= f - f' = 50 - 50.2 = 0.2$ Hz

$= 0.2$ flicker/sec

$= 0.2 \times 60$ flickering/min

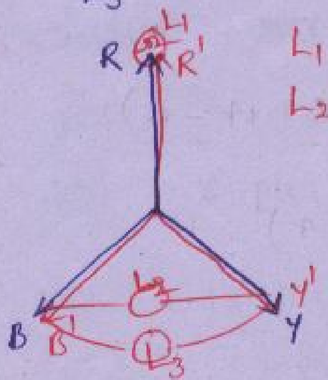
→ one dark, two lamps equally bright :-

→ two lamps are connected as cross connected

$L_1 \rightarrow R - R'$

$L_2 \rightarrow Y - B'$ } cross connected.

$L_3 \rightarrow B - Y'$



L_1 — dark

L_2, L_3 — equally bright.

→ In the 3 lamps simul. dark & bright method, if the volt. across the lamps falls to 1/3 of rated volt, the lamps won't glow, if the switch is closed at this position, results circulating currents, but this dis. adv. can be overcome in one dark, 2 equally bright. At the position of synchronization if 2 are equally bright, it will be confirm

other lamp will be completely dark, when the switch is closed at this position min circulating currents.

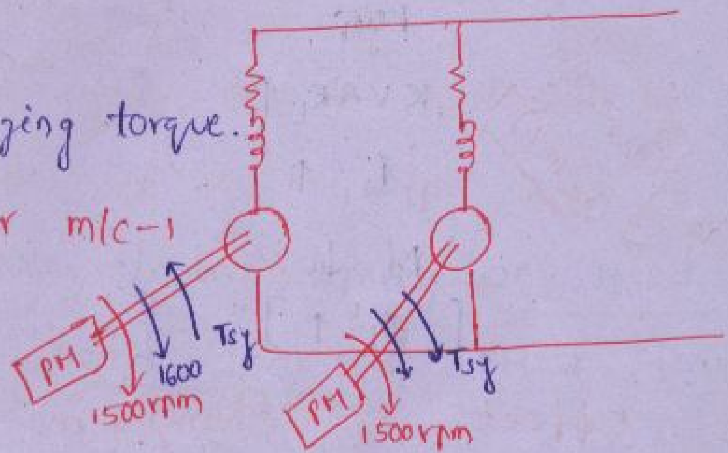
Effect of change in excitation :-
Syn. power is reactive power

when excitation of one m/c increased, syn. power is reactive power, which will produces flux to magnetize other m/c and demag.s the m/c whose exci. is increased.
During ||el operation, an over excited m/c will always demag.s and under excited m/c will always magnetise to maintain the terminal voltage.

→ Active power will create torque
→ Reactive power will create flux.

Effect of change in steam i/p (or Mech. power i/p) :-

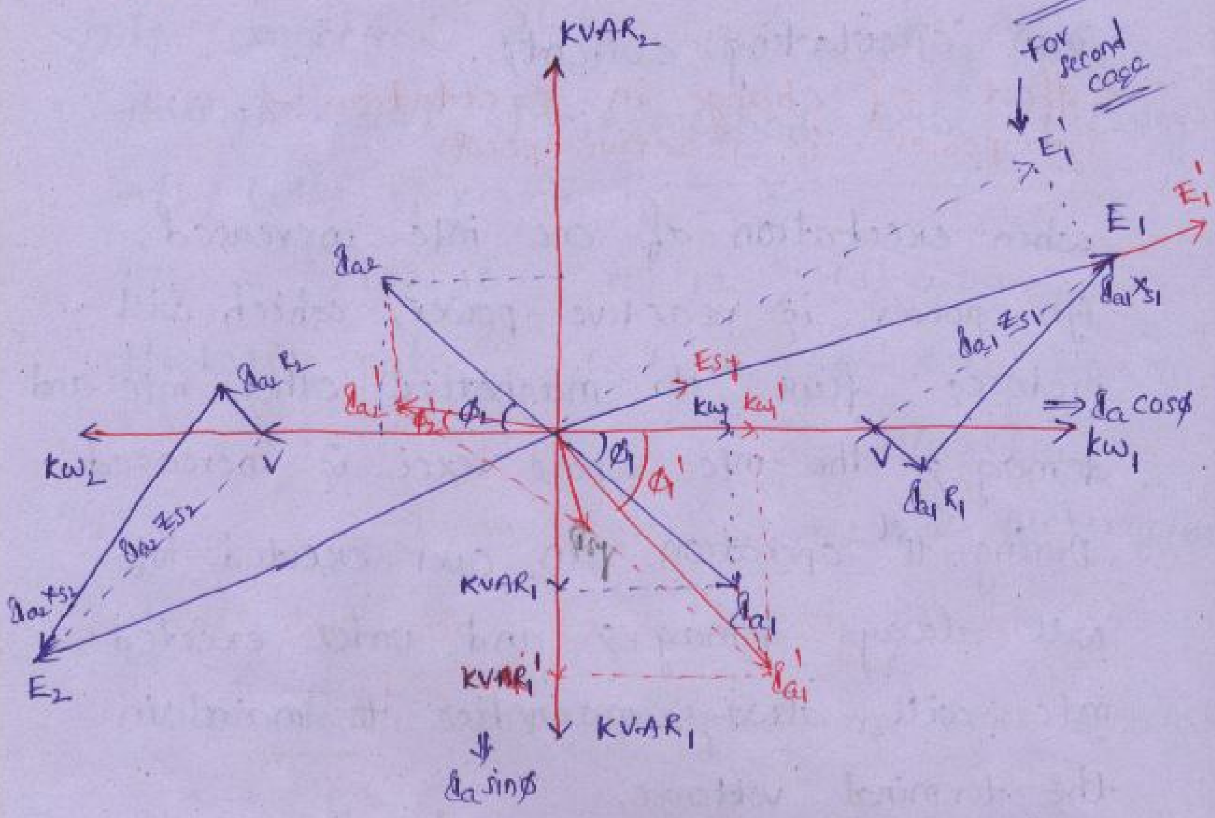
T_{sy} - Synchronizing torque.



w.r.t Syn. power m/c-1 acts as Gen & m/c-2 acts as motor.

∴ P_{sy}, decelerates 1st m/c & accelerate the II m/c such that set freq. equalize.

Effect of change in excitation :-
[steam i/p kept const.]



If excitation of m/c$_1$ is increased,
ie $E_1 \uparrow$ to E_1'.

m/c – 1		m/c – 2
KW_1	=	KW_2
$KVAR_1 \uparrow$		$KVAR_2 \downarrow$
$I_{a1} \uparrow$		$I_{a2} \downarrow$
pf $\downarrow$		pf $\uparrow$
[$\phi_1' \uparrow$]		[$\phi_2' \downarrow$]

$I_a = \sqrt{(I_a \cos\phi)^2 + (I_a \sin\phi)^2} \uparrow$

Effect of change in steam i/p :-
[excitation is kept constant] :-

If the steam i/p of m/c-1 is increased

m/c – 1		m/c – 2
$KVAR_1$	=	$KVAR_2$
kW_1 ↑		kW_2 ↓
I_{a1} ↑		I_{a2} ↓
pf ↑		pf ↓

$I_a = \sqrt{(I_a \cos\phi)^2 + (I_a \sin\phi)^2}$

$pf \propto \frac{kW}{KVAR}$

→ change in pf will be more when the change in excitation [I case].

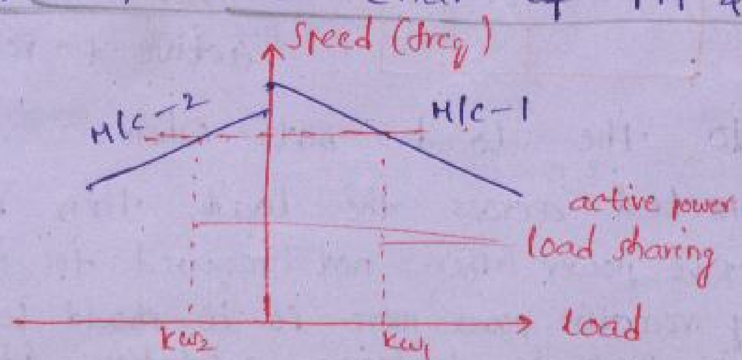
→ The effect of change in excitation causes change in reactive power but no change in active power.

→ The effect of change in steam i/p causes change in its active power but no change in its reactive power.

→ ∴ The reactive power is controlled by varying the excitation thereby pf can be controlled.

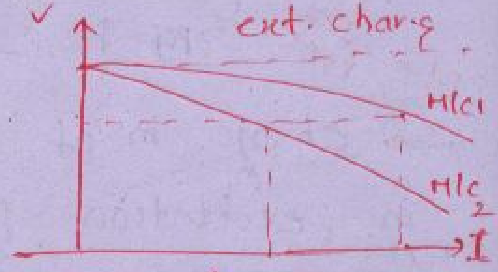
→ The active power can be controlled by controlling steam i/p or PM i/p.

→ Active power sharing depends on speed (or freq) vs load char. of PM & steam i/p.



For proper sharing of load PM should have drooping charᵍ. ie as load ↑, speed ↓

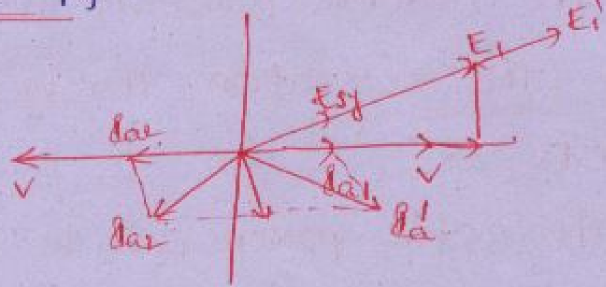
⟹ Reactive power sharing depends upon the amount of excitation & external char [V vs I] of the Alternator



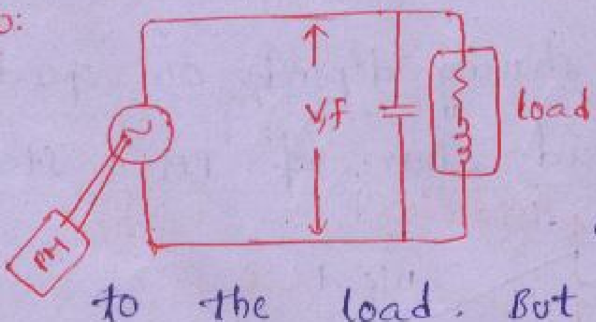
Q. Two alt-s m_1 & m_2 have been properly syn.ed and connected .... [see in objectives - 5 & q.no. 5].

Ans: M/c - 1 magnetizes & M/c - 2 demagnetizes so M/c - 1 operates with leading pf & m/c-2 with lagging pf.

Q6:



Q10:



If the load is inductive then the Alt delivers both active & reactive powers to the load. But when a capacitor connected across the load, then it will supply reactive power then not required for the alt. to supply reactive power more so it should be decreased its reactive power by decreasing excitation. If excitation is

not decreased then the terminal volt increases. so to maintain terminal volt. excitation should be decreased.

Q.15: Two 3-ϕ, Y- connected . . . . . .

Ans: $E_{L_1} = 3300\,V$, $E_{L_2} = 3200\,V$

$X_{S1} = X_{S2} = 1.7\,\Omega$ { X_{S1} & X_{S2} are per ph. values }

$$I_{sy} = I_c = \frac{E_1 - E_2}{X_{S1} + X_{S2}} = \frac{\frac{3300}{\sqrt{3}} - \frac{3200}{\sqrt{3}}}{1.7 + 1.7} = 16.98\,A \leftarrow \text{ph. current.}$$

Q.17 :- 500 MW, 3-ϕ, Y- connected.

$V_L = 21.5\,kV$, 0.85 pf.

$I_L = ?$ at FL.

$\sqrt{3}\, V_L I_L \cos\phi = P$

$$\rightarrow I_L = \frac{P}{\sqrt{3}\, V_L \cos\phi} = \frac{500 \times 10^6}{\sqrt{3} \times 21.5 \times 10^3 \times 0.85} = 15.97\,kA$$

Q. 16 : 400V, 50 kVA, 0.8 pf lead, Δ- connected 50Hz, $X_s = 2\,\Omega$, $R_a = 0$, friction & windage loss = 2 kW, core loss = 0.8 kW

shaft supplying 9 kW at 0.8 pf lead.

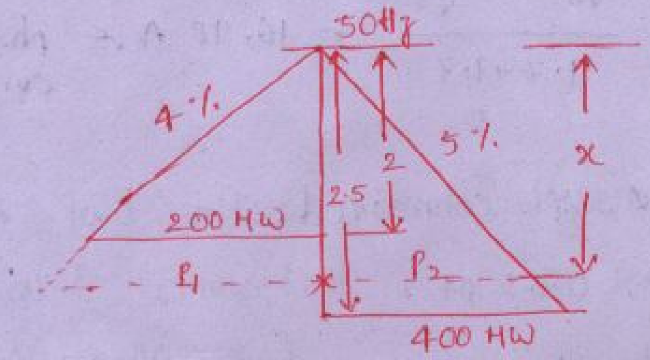
$\therefore P_{input} = P_{o/p} + \text{losses}$

$= 9 + 2 + 0.8 = 11.8\,kW$

$$P_{i/p} = \sqrt{3}\, V_L I_L \cos\phi \longrightarrow I_L = \frac{11.8 \times 10^3}{\sqrt{3} \times 400 \times 0.8}$$

$= 21.29\,A$

Q.9: Two alt-s rated 200 MW & 400 MW are operating in ||el. The governer drooping char-s are 4 % & 5 % res. from NL to FL. At NL the system freq. is 50 Hz when supplying a load of 600 MW, the system freq. will be – ?



$50 \times 0.05 = 2.5$ Hz

47.5 Hz

$50 \times 0.04 = 2$ Hz

$\frac{P_1}{200} = \frac{x}{2} \Rightarrow P_1 = 100x$

$\frac{P_2}{400} = \frac{x}{2.5} \Rightarrow P_2 = 160x$

$P_1 + P_2 = 600$

$100x + 160x = 600$

$\Rightarrow x = 2.3$

$\Rightarrow f = 50 - 2.3 = 47.3$ Hz.

Alternator in parallel with Infinite Bus Bar:-

$\phi \propto \frac{V}{f} = \text{const}.$

$\phi_r = \phi_m \pm \phi_a = \text{const}.$

$+ \rightarrow$ mag

$- \rightarrow$ demag

$\phi_r = \phi_m \pm \phi_a = \text{const}$
$= 10$ mwb

→ Normal Exci., 10 mwb = 10 mwb + 0

→ under Exci, 5 mwb + 5 mwb = 10 mwb.

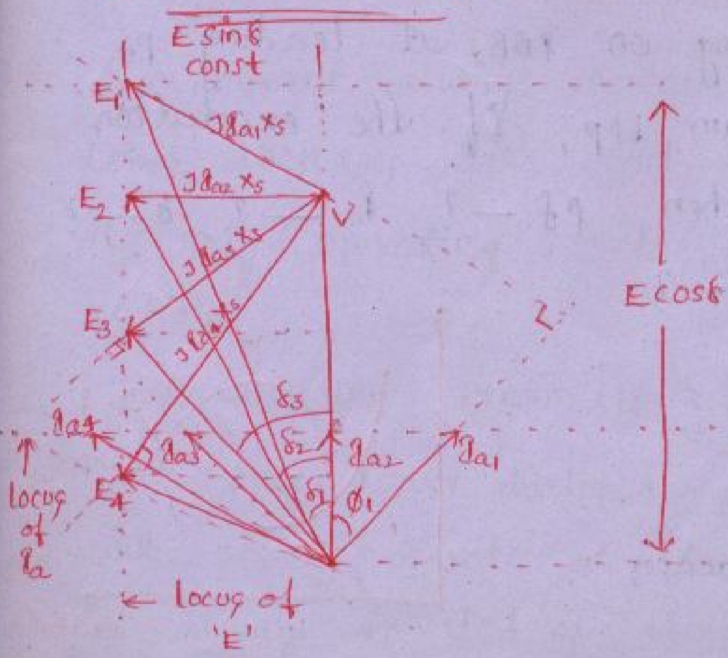
→ over Exci, 15 mwb − 5 mwb = 10 mwb

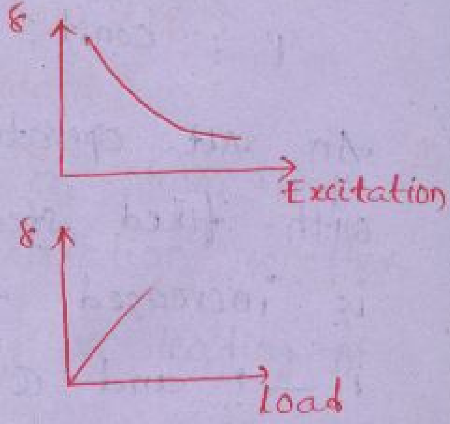
→ The role of the reactive power is to maintain the const. airgap flux, The m/c is under exci.d then it absorb the reactive power, flux aids to the main field flux ∴ combinely maintain the air gap flux const.

→ when the m/c is O.E'd ie field exci. is given more than the m/c required then m/c deliver the reactive power, produces flux which will demag.s main field flux, and hence ϕ_R maintains const.

→ for N.E.n the dc exci.n is just sufficient to create working flux ∴ no need of reactive power ie neither deliver nor absorb.

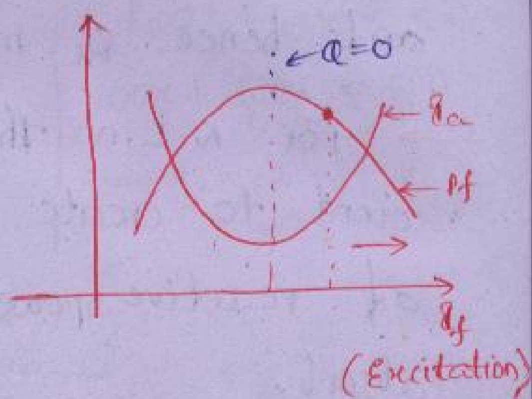
ON load condi :-





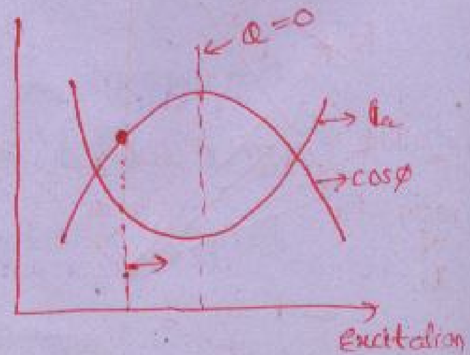
⇒ when alt-s operate on IBB, for generally over excited b'coz most of the loads are inductive nature, they will absorb reactive power which is supposed to deliver by over excited alternators, with over excitation stability will improve and stable parallel operation. ('V' & 'Λ' curves).

Q. An alt. operating on IBB at lagging pf with fixed steam i/p, if excitation is increased then pf —? , I_a —?, δ —? and P —?, Q — ?



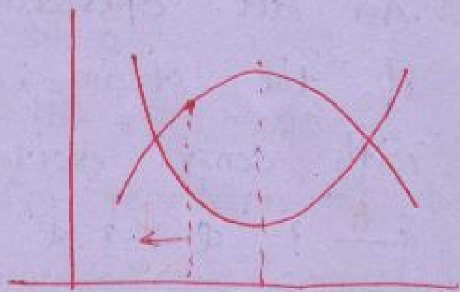
Ans:
pf : decreases
I_a : increases
δ : decreases
Q : DELIVER, increases
P : const.

Q. An Alt. operating on IBB at leading pf with fixed steam i/p, if the excitation is increased then pf —?, I_a —?, δ —?, P —? and Q —?



Ans: pf : increases
I_a : decreases
δ : decreases
Q : ABSORB, decreases
P : const.

Q. In the above question, if the excitation is decreased then?



Ans :

Pf : decreases

I_a : increases

δ : increases

Q : ABSORB, increases

P : const.

Q. An Alt. operating on IBB at upf. with fixed steam i/p, excitation increases then m/c will

(a). absorb Q, operating at lagging pf

(b) " , operated at leading pf

✓(c). deliver Q, operated at lagging pf

(d). " , operated at leading pf

Effect of change in steam i/p :- [excitation is kept constant] :-

⇒ Arm. current always increases as steam i/p or load increases with const. excitation, whether it may operating at lagging or leading pf region.

* current ∝ steam i/p ∝ load

⇒ At max. power developed condi. an alternator will always operate at leading pf, a syn motor is always operated at lagging pf when the

m/c is operating on IBB.

Q. An alt. operating on IBB at lagging pf, if the steam i/p or load is increased with const. excitation then pf ⇑?, I_a ⇑?, δ ⇑?, Q_{DEL} ⇓? & P ⇑?

P ∝ sin δ
δ ⇑ ⇒ sin δ ⇑
⇒ P ⇑.

Q. An alt. operating on IBB, at leading pf, if the steam i/p or load increased with const. excitation then pf ⇓?, I_a ⇑?, δ ⇑? Q_{ABS} ⇑? & P ⇑?

Q. An alt. operating on IBB at upf, if the load is reduces to 50% (half) then the m/c will operated —?

(a). lagging pf (b). leading pf (c). upf
(d). depends on m/c parameters.

Q. An alt. operating on IBB at lagging pf. If the steam i/p (or load) is decreased with const. excitation then pf ⇓?, I_a ⇓? δ ⇓?, Q_{DEL} ⇑? & P ⇓?

Q. An alt. operating on IBB with a load angle of 30°. if the load is doubled then its load angle —?

(a). 30° (b) 60° (c). 45° (d). 90°.

$P \propto \sin\delta$

$\frac{P_2}{P_1} = \frac{\sin\delta_2}{\sin\delta_1} \Rightarrow \frac{2}{1} = \frac{\sin\delta_2}{\sin 30}$

$\Rightarrow \sin\delta_2 = 1 \Rightarrow \delta_2 = 90^\circ$.

Q. A 3-ϕ turbo alt. with syn. reactance of 10Ω per ph. and negligible arm resistance is connected to 11 kV const. volt, const freq bus bar and supplies 100 A at upf to the system. with the turbine power kept const and excitation of alt. is increased by 25%.

(a). The new load angle will be —?

(1). 8.94° (2) 7.14° (3). 58.4° (4). 4.12°

(b). The new current is —?

(1). 190.6 A (2). 100 A (3). 125 A (4). 330.2 A

(c). The pf is —?

(1). 0.524 lag (2). 0.524 lead (3). upf (4). 0.86 lead

Sol: 3-ϕ turbo, $X_s = 10\ \Omega/ph$, $R_a = 0$

11 kV IBB, $I_a = 100A$, upf.

steam i/p const. & Excitation $E' = 1.25 E$

Then $\delta' = ?$, $I_a' = ?$ & $pf = ?$

$V_{ph} = \frac{11\times10^3}{\sqrt{3}} = 6350\ V$

$E = V\angle 0 + I_a\angle\pm\phi \cdot Z_s\angle\theta$

$= 6350\angle 0 + 100\angle 0^\circ \times 10\angle 90^\circ$

$= 6429\angle 8.94^\circ$

$\Rightarrow E' = 1.25 E$

$= 1.25 \times 6429 = 8035\,V$

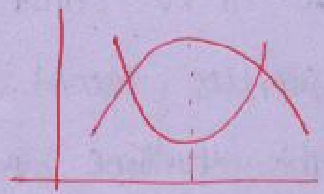
Steam i/p const. ⇒ active power const. → $E \sin\delta = \text{const}$

$\Rightarrow E' \sin\delta' = E \sin\delta$

$\rightarrow \sin\delta' = \frac{E}{E'} \sin\delta$

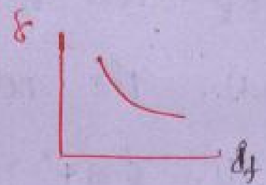
$= \frac{1}{1.25} \sin 8.94 =$

$\rightarrow \delta' = 7.14^\circ.$



$I_a' = \frac{E' \angle\delta' - V\angle 0}{Z_s \angle\theta}$

$= \frac{8035 \angle 7.14 - 6350\angle 0}{10\angle 90^\circ}$



$= 190.54 \angle -58.4^\circ$

$\therefore I_a' = 190.54\,A$

$pf = \cos(-58.4) = 0.54$ lag.

Q. A 6600 V, 1200 KVA Alt. has reactance of 25% and is delivering FL at 0.8 pf lagging. It is connected to const. freq bus bar. If the steam supply is gradually increased –

(1). The current at which pf to be unity

(a) 645 (b). 252.96 A (c) 70.25 (d) 252 A

(2). The pf at which power o/p to be max –

(a). 0.8 lead (b) 0.759 lead (c). 0.759 lag

(d). 0.8 lag.

(3). The max power o/p appr. without loosing synchronism

(a). 4.69 MW (b). 12 MW (c) 3.6 MW (d). 4 MW.

Sol:

6600 V, 1200 kVA, $I_a X_s = 0.25$, fL at 0.8 lag

$$V_{ph} = \frac{6600}{\sqrt{3}} = 3810\text{ V}$$

$$I_{L\text{-}R} = \frac{\text{kVA}}{\sqrt{3} \cdot V_L} = \frac{1200 \times 10^3}{\sqrt{3} \times 6600} = 105\text{ A} = I_{ph} = I_a$$

$$I_a X_s = 0.25\text{ V}$$

$$\rightarrow 105\, X_s = 0.25 \times 3810 \rightarrow X_s = 9.07\ \Omega$$

$$E = V\angle 0 + I_a \angle \pm\phi \cdot Z_s \angle\theta$$

$$= 3810\angle 0 + 105\angle -36.87 \times 9.07\angle 90^\circ$$

$$= 4447\angle 9.86^\circ$$

For UPf, $E\cos\delta = V$. [∵ Excitation const.] $E' = E$

steam i/p varied

$$\Rightarrow E'\cos\delta' = V$$

$$\Rightarrow 4447\cos\delta' = 3810$$

$$\Rightarrow \delta' = 31.06^\circ$$

$$I_a' = \frac{E\angle\delta' - V\angle 0}{Z_s\angle\theta}$$

$$= \frac{4447\angle 31.06 - 3810\angle 0}{9.07\angle 90}$$

$$= 252.96\angle 0.014$$

At P_{max}, $\delta = 90^\circ$.

$$I_{a\ \text{at}\ P_{max}} = \frac{E\angle 90 - V\angle 0}{Z_s\angle\theta}$$

$$= \frac{4447\angle 90 - 3810\angle 0}{9.07\angle 90} = 645.48\angle +40.5$$

pf at P_{max} = cos 40.5 = 0.76 lead

$$P_{max} = \frac{3EV}{X_s} \cdot \sin\delta$$

$$= \frac{3 \times 4447 \times 3810}{9.07} \cdot \sin 90^\circ$$

= 5.6 MW.

TUE 04/11/08.

Synchronous Motors

⇒ The speed of a syn. motor can be controlled by varying frequency, to maintain the flux at rated value voltage also controlled. ie $\frac{V}{f}$ ratio control.

Q. The direction of rotation of syn. motor can be reversed — ?

(a). by changing field polarity
✓(b). by changing the ph. seq.
(c). both a & b
(d). dire. of rotation can't be reversed.

Q. The speed of the syn. motor can be controlled by —?

(a). freq. (b). voltage ✓(c). a & b (d). none.

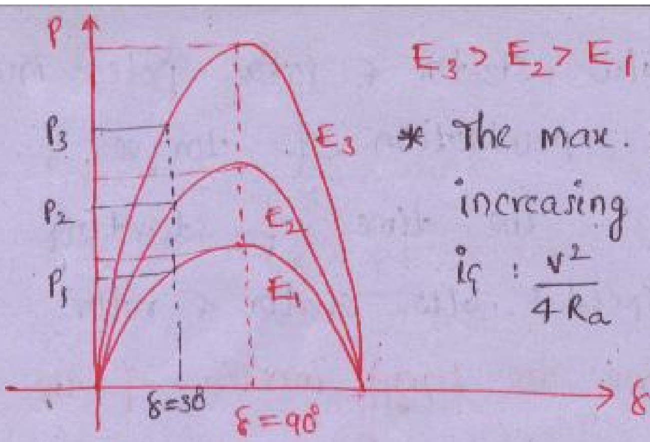
⇒ Dire. of rotation can be reversed only by changing the ph. seq but not by the field polarities.

Q. In syn motors $T_{st} = 0$.

$$\text{so } \frac{T_{st}}{T_{FL}} = 0 \;\&\; \frac{T_{FL}}{T_{st}} = \infty.$$

* Relative motion b/w stator & rotor poles must be zero for the production of torque.
In syn. motor at the time of starting relative motion (speed) b/w stator & rotor poles = N_s. (due to Large inertia of the rotor).

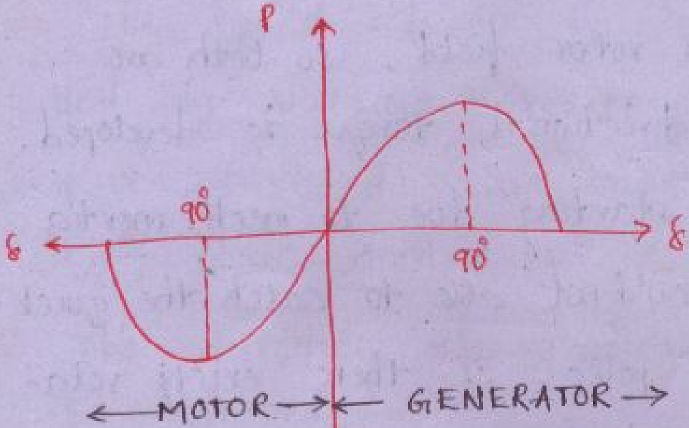
Under running condi, there is no relative motion b/w stator & rotor field, so both are stationary so unidirectional torque is developed. At the time of starting due to mech. inertia of rotor, rotor could not able to catch the quick reversals of stator poles. ∴ there exists relative motion b/w stator & rotor poles ∴ torque is zero, hence syn. motor is not self starting. It can be started by applying external force to overcome the inertia. The motor is driven near to N_s, by the time inertia is overcome and then by giving the excitation, motor will rotate at N_s due to magnetic locking.



$E_3 > E_2 > E_1$

* The max. power developed by increasing both load & excitation is : $\frac{V^2}{4R_a}$

power angle curves :

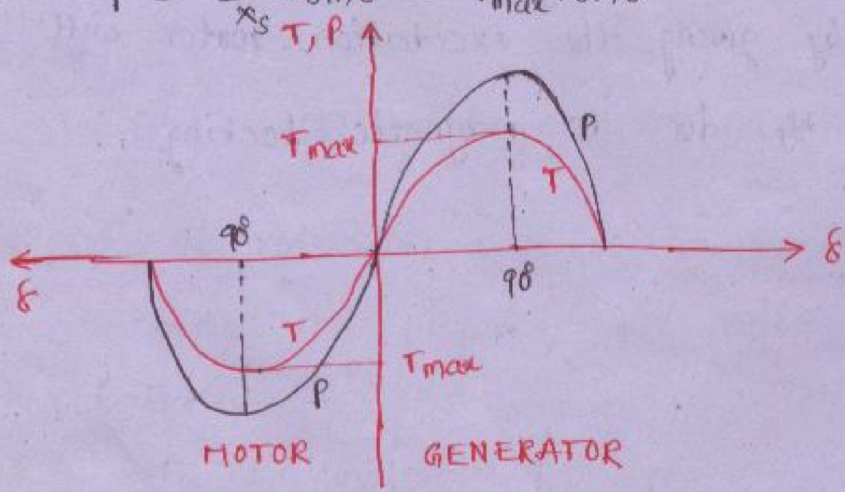


$$T = \frac{P}{\omega}$$

$$= \frac{\frac{EV}{X_s}.\sin\delta}{\omega} = \frac{EV}{X_s.\omega}.\sin\delta$$

$$\Rightarrow T = T_{max}.\sin\delta$$

$$P = \frac{EV}{X_s}.\sin\delta = P_{max}.\sin\delta$$

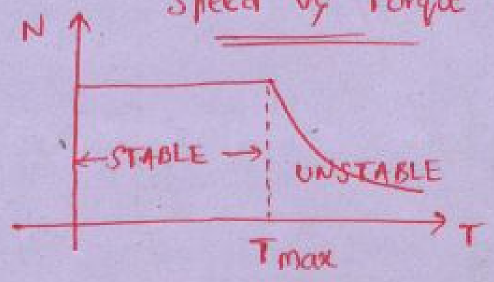


Maximum torque / breakdown torque / pull out torque / stalling torque.

· Max. torque / pull out torque:

It is the max. torque, that can be developed by a syn. motor without losing its synchronism.

Speed vs Torque char.s :-



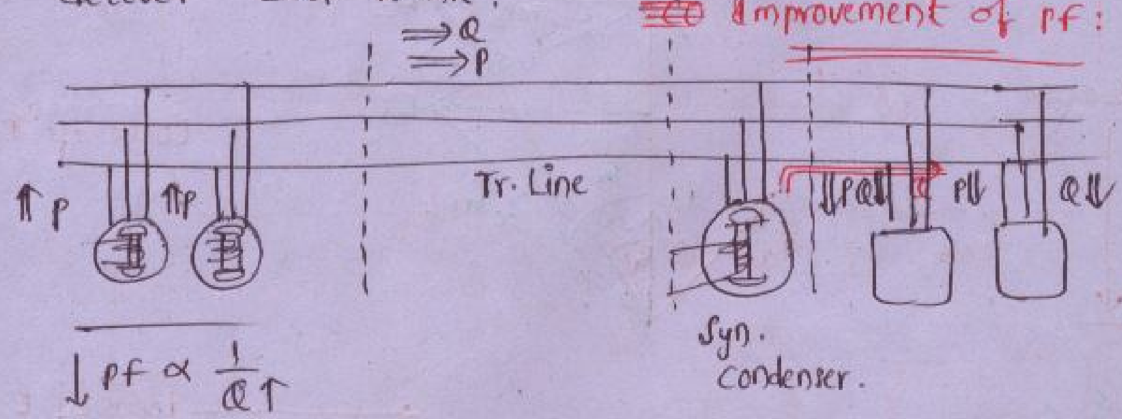
NOTE:

Floating occur for normal excitation under NL condi. only.

OVER EXCITED SYN. MOTOR UNDER NO LOAD :-

deliver LAG. KVAR.

Improvement of PF:



* over excited syn. motor under NL condi. is used as syn. condenser to improve the PF.
* An under excited syn. motor under NL condi behaves as an inductor and used to deprove the PF such that voltage profile is maintained.

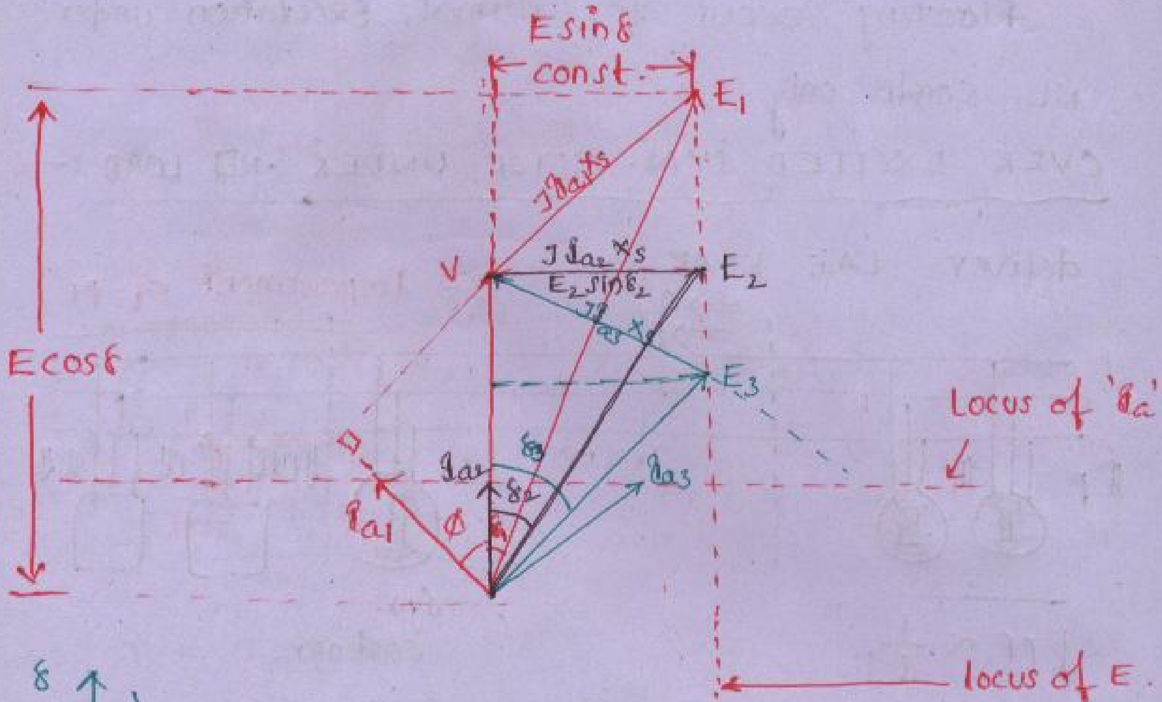
Effect of change in excitation with mech. load kept constant :-

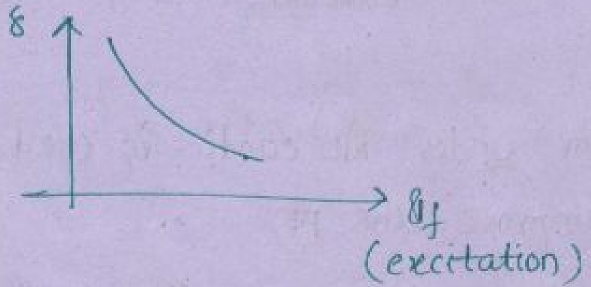
$P \propto E \sin\delta = \text{const.}$

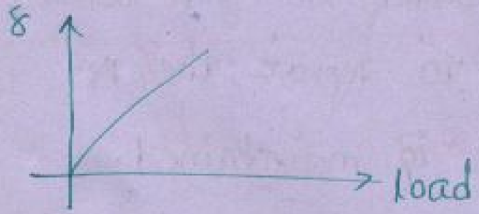
$P \propto I_a \cos\phi = \text{const.}$

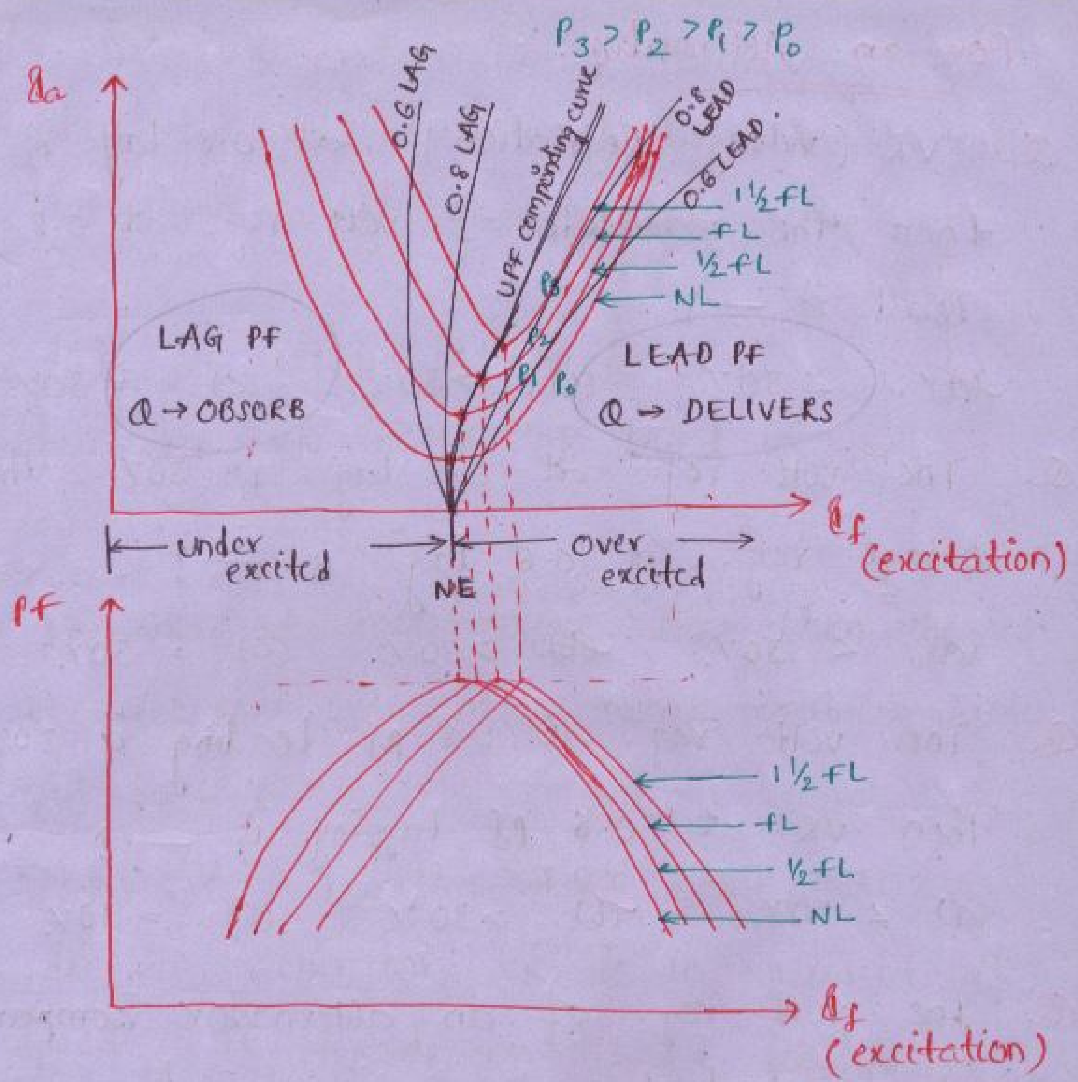
$V = E + j I_a X_s$

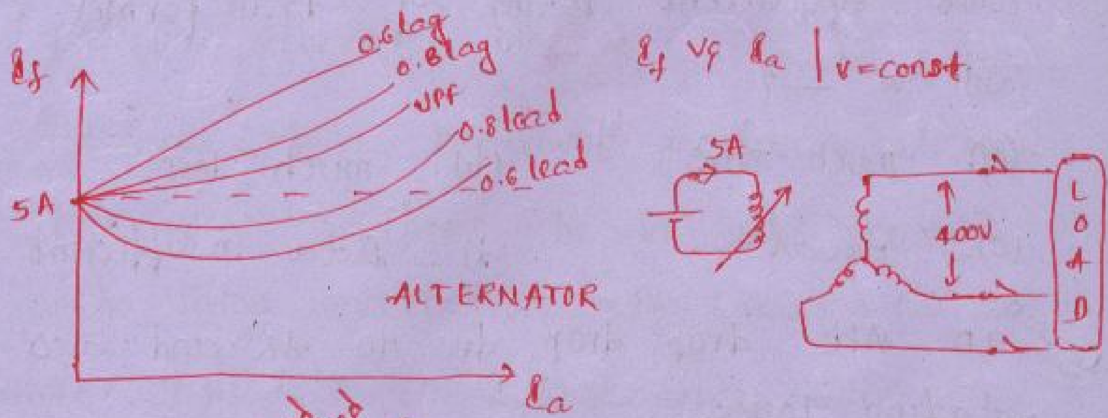
$$Q = \frac{V}{X_s}\left[V - E\cos\delta\right].$$

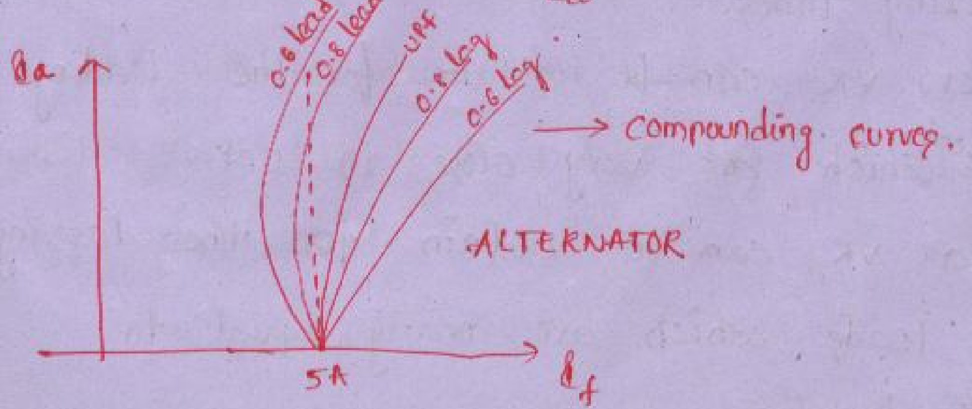







P3 > P2 > P1 > P0
Ia
0.6 LAG
0.8 LAG
UPF compounding curve
0.8 LEAD
0.6 LEAD
1½ FL
FL
½ FL
NL
LAG PF
Q → OBSORB
LEAD PF
Q → DELIVERS
P3
P2
P1
P0
If (excitation)
under excited
NE
over excited
pf
1½ FL
FL
½ FL
NL
If (excitation)


If
0.6 lag
0.8 lag
UPF
0.8 lead
0.6 lead
5A
ALTERNATOR
Ia
If vs Ia | v = const
5A
400V
LOAD


Ia
0.6 lead
0.8 lead
UPF
0.8 lag
0.6 lag
→ compounding curves.
ALTERNATOR
5A
If

For an Alternator:

Q. VR (voltage Regulation) at 0.8 lag is 30%. then the magnitude of volt. reg. at 0.8 lead is —?

(a). < 30% (b). > 30% (c). = 30%

Q. The volt. reg. at 0.8 lag is 30%, the voltage reg. at 0.6 lag is —?

(a). < 30% (b). > 30% (c) = 30%

Q. The volt reg. at 0.8 pf leading is 30%. then VR at 0.8 pf lagging is —?

(a) < 30% (b). > 30% (c). = 30%

Q. The volt. reg. of an alternator compared with equivalent rating of transformer will be —?

(a). much more (b). much less

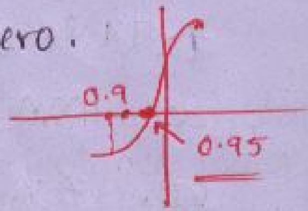
(c). equal (d). Data insufficient

Reason: In Alt. drop drop due to AR and also rotating losses.

* Zero VR can be obtain for the leading pf loads which are very close to UPF.
* Max VR can be obtain for the lagging pf loads which are nearly equal to ZPF Lagging

Q. The VR at 0.95 pf Load is zero. Then the VR at 0.9 pf load will be —?

(a). +ve ✓(b). −ve (c). zero.



Q. The VR at 0.8 pf lag is 12%. then the VR at 0.8 pf lead is —?

Refer this factor

(a).

Q. The VR at 1000 rpm is 20%. then the VR at 900 rpm with other things remaining same will be —?

(a). < 20% (b). > 20% ✓(c) = 20%

In Syn. Generator, VR is independent of Speed. It depends on load & load pf.

In DC Generator, VR ∝ Speed

Q. The VR of a DC Shunt generator at 1000 rpm is 10%. Then the VR at 1200 rpm with same excitation will be —?

(a). > 10% ✓(b). < 10% (c). = 10%

Q. The VR is max. for —?

✓(a). ZPF lag (b). 0.8 pf lag (c). 0.8 pf lead (d). ZPF lead

Q. A 1-Φ, 2000V, alternator armature resistance and reactance are 0.8 Ω & 4.94 Ω res. Then the VR of alternator at 100A and 0.8 pf lead will be —?

(a). 7 %. (b). −8.9 %. (c). 14 %. (d). 0 %.

$$E = \sqrt{(V\cos\phi + I_a R_a)^2 + (V\sin\phi - I_a X_s)^2}$$

$$= \sqrt{(2000 \times 0.8 + 100 \times 0.8)^2 + (2000 \times 0.6 - 100 \times 4.94)^2}$$

$$= 1823.86\ V$$

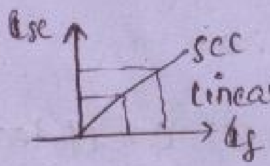
$$\therefore \%\ reg = \frac{E - V}{V} \times 100$$

$$= \frac{1823.86 - 2000}{2000} \times 100$$

$$= -8.9\%$$

Q. The s/c current at 1000 rpm at rated field current I_f = 2A, is 20A. The s/c current at 900 rpm with a field current of 3A will be —?

(a). 20A (b). > 20A (c). < 20A (d) 30A



linear relation,

2A ⟶ 20A

3A ⟶ ?

$$\longrightarrow \frac{3}{2} \times 20 = 30A$$

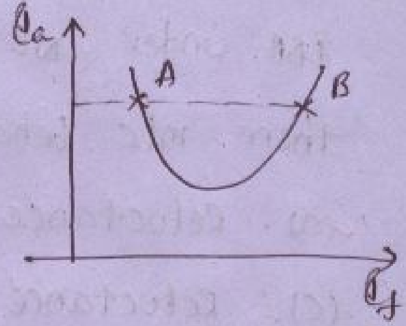
Q. A Syn. m/c operating at IBB under FL condi. If excitation fails the m/c behaves as ——?

(a). Induction Generator (b). Syn. Generator
(c). Reluctance Generator (d). Reluctance motor.

Q. In Syn m/c. the m/c is more stable at ——?

(a) A (b) B (c) None.

But η at point B is little small when compare to A. b'coz of excitation losses. [∵ I_f is more].



* Synchronizing power is active in nature when the disturbance is in sudden change of load, sudden change in PM, or in supply system.

But P_{sy} is reactive in nature when there is sudden change in Excitation.

Q. A Salient pole Syn. m/c operating on IBB. under light load condi. acting as generator. If excitation fails then m/c behaves as —?

(a). Induction generator. (b). Syn. generator.
(c). Reluctance generator (d). Reluctance motor.

Q. A salient pole syn. generator operating on IBB, if PM fails then m/c will behave as —?

(a). Syn. motor (b). Induction motor
(c). Induction generator (d). Reluctance generator.

Q. A salient pole syn. motor operating on IBB under NL condi. If excitation fails then m/c behaves as —?

(a). Reluctance motor (b). Induction motor
(c). Reluctance generator (d). Syn. motor.

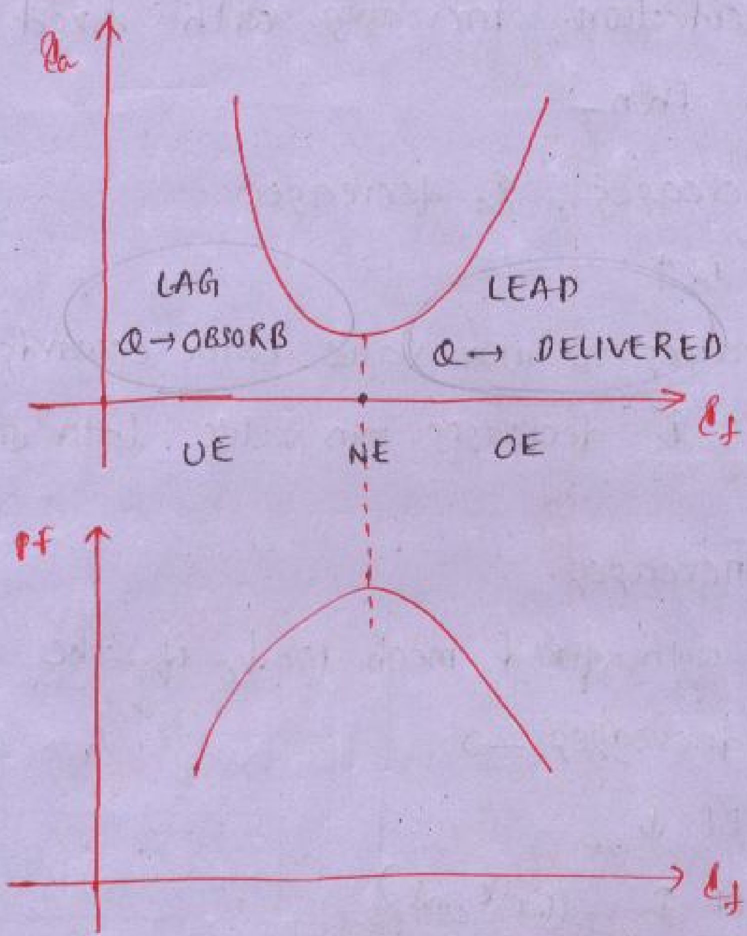
Q. A salient pole syn. motor under FL condi. operating on IBB. If excitation fails —? Then m/c will behave as —?

(a). Reluctance motor (b). Induction motor
(c). Syn. motor (d). would stop.

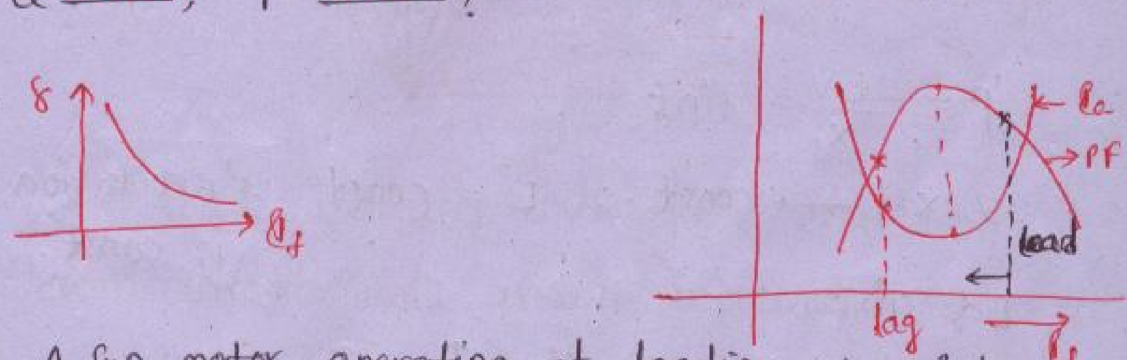
* In all cases when excitation fails then m/c will absorb reactive power from the bus bar. ∴ m/c operated at poor pf, with large arm. current.

∴ Tripping is necessary after some delay

Syn. motor:



Q. A Syn. motor operating at lagging pf with fixed mech. load, if the excitation increases then pf ⇑, Ia ⇓, δ ⇓, Q OBSORB ⇓, P const. ?



Q A Syn. motor operating at leading pf, with fixed mech. load, if excitation decreases then pf ⇑, Ia ⇓, δ ⇑, Q DELIVER ⇓ P const. ?

Q. A Syn. motor operating at lagging pf, If the excitation increases with fixed mech load then –

(a). pf increases, I_a decreases

(b). pf ↓, I_a ↑

✓(c). pf increases to max. value later onwards decreases, I_a decreases min value later onwards increases.

(d). Both increases.

Q. Syn. motor with fixed mech. load, if the excitation decreases –

(a). I_a ↑, pf ↓

(b). I_a ↓, pf ↑ (back emf)

✓(c). induced emf ↓, load angle ↑

(d). Both I_a & pf ↑.

EFFECT OF CHANGE IN MECH LOAD: [EXCITATION IS KEPT CONSTANT] :-

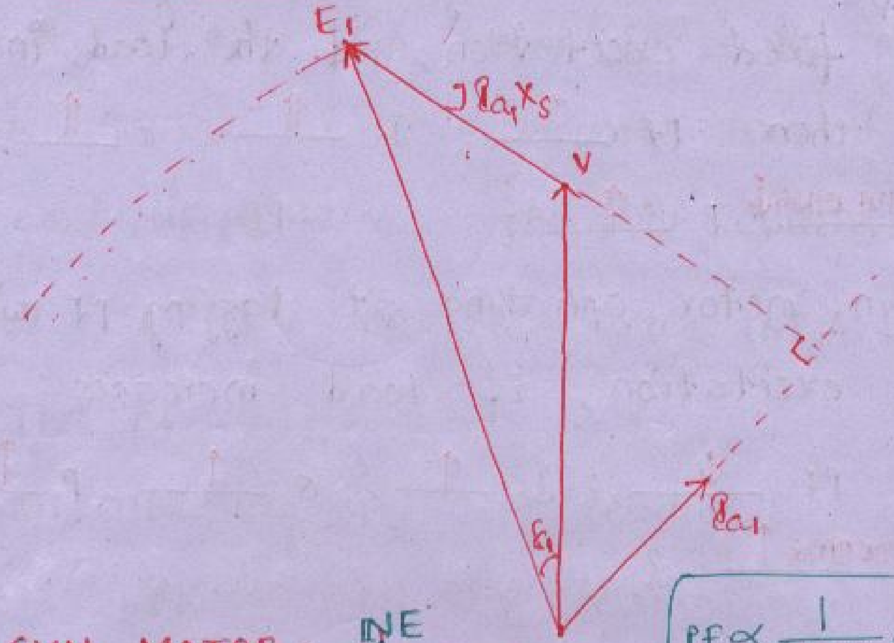
$$P = \frac{EV}{X_s} \cdot \sin\delta$$

$V, X_s \longrightarrow$ const. ; $E = $ const ∵ excitation is const.

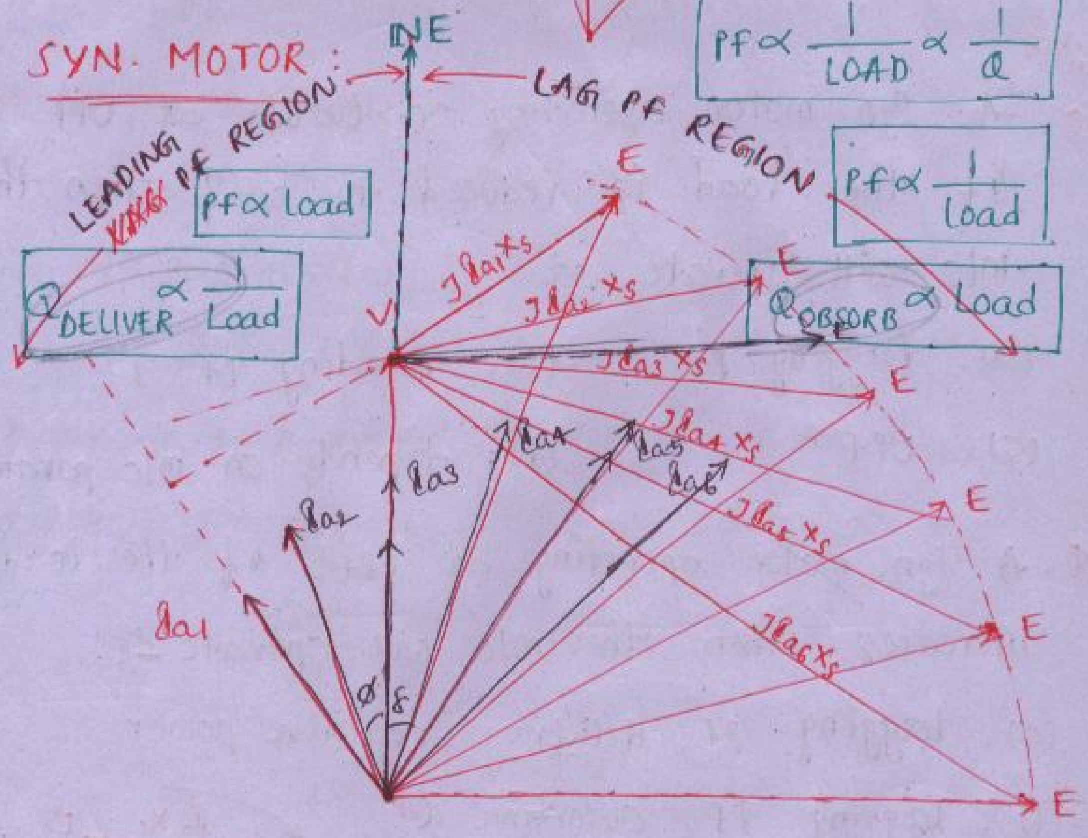
$P \propto \sin\delta$

As load ↑, P ↑, $\sin\delta$ ↑, δ ↑.

ALTERNATOR:



SYN. MOTOR:



As load increases with fixed excitation, arm current will always increases.

Q. A Syn. motor operating at leading pf with fixed excitation, if the load increases then pf ⇑, I_a ⇑, δ ⇑, Q DELIVERING↓, P ↑ ?

Q. A Syn. motor operating at lagging pf with fixed excitation, if load increases then pf ↓, I_a ↑, δ ↑, P ↑, Q OBSORBING ↑ ?

G'07.

Q. A Syn. motor operating on busbar at UPF & if the load is reduced to half then the m/c will operate at :

(a). lagging pf ✓(b). leading pf

(c). UPf (d). depends on m/c parameters

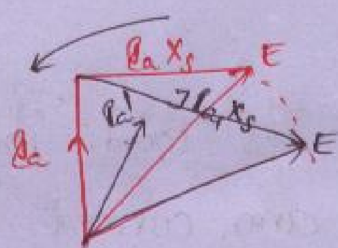
Q. A Syn. motor operating at UPf, & if the load increases then the m/c will operate –

(a). lagging pf, delivering reactive power

✓(b). lagging pf, obsorbing Q.

(c). leading pf, delivering Q

(d). leading pf, obsorbing Q



Q. The syn. reactance per ph. of a 3-ϕ Y-connected 6600 V, syn. motor is 20 Ω, The i/p is 915 kW at normal volt, induced line emf is 8942 V, the line current is —

(a). 97 A (b). 56 A (c). 168 A (d) 80 A.

(ii). The pf — ?

(a). 0.82 lag (b) 0.82 leading

(c). UPF (d). 0.7 leading

Sol: $X_s = 20\,\Omega/ph$

$V_L = 6600\,V$

$P_{in} = 915\,kW$

$E_L = 8942\,V.$

$\longrightarrow I_L = ?\ \&\ pf = ?$

$$P_{in} = \frac{EV}{X_s}\cdot \sin\delta$$

$$V_{ph} = \frac{6600}{\sqrt{3}} = 3810\,V$$

$$E_{ph} = \frac{8942}{\sqrt{3}} = 5163\,V$$

(per ph.) $$P_{in} = \frac{EV}{X_s}\cdot \sin\delta$$

$$\frac{915\times 10^3}{3} = \frac{5163\times 3810}{20}\cdot \sin\delta$$

$\longrightarrow \delta = 18^\circ.$

$$I_a = \frac{V\angle 0 - E\angle -\delta}{Z_s\angle\theta}$$

Alternator

⇓

$$I_a = \frac{E\angle\delta - V\angle 0}{Z_s\angle\theta}$$

$$I_{a_{ph}} = \frac{3810\angle 0 - 5163\angle -18}{20\angle 90}$$

$$= 97\angle 34.9^\circ = I_L$$

$$pf = \cos(34.9) = 0.82 \text{ lead.}$$

Q. A 2000V, 3-Ø, Y-connected syn. motor has an effective resistance and syn. reactance of 0.2Ω & 2.2Ω res. The i/p is 800 kW at normal volt & induced line voltage is 2500 V.

(i). The line current is (a). 254 A

(b). 440 A (c) 231 A (d). 400 A

(ii). The pf is —

(a). 0.908 lagging (b). 0.908 leading

(c). 0.7 lagging (d). 0.7 leading

Sol: $$I_a = \frac{V\angle 0 - E\angle -\delta}{Z_s\angle \theta}$$

$$\rightarrow I_a^* = \frac{V}{Z_s}\angle \theta - \frac{E}{Z_s}\angle \theta+\delta$$

$$P = \frac{V^2}{Z_s}\cdot\cos\theta - \frac{EV}{Z_s}\cos(\theta+\delta)$$

$V = 2000V$, 3-Ø, Y, $R_a = 0.2\,\Omega$

$X_s = 2.2\,\Omega$, $P_{in} = 800\,kW$, $E_L = 2500V$

$I_L = ?$ & $pf = ?$

$$V_{ph} = \frac{2000}{\sqrt{3}} = 1154\,V$$

$$E_{ph} = \frac{2500}{\sqrt{3}} = 1443\ V$$

$$Z_s = 0.2 + j2.2 = 2.2\angle 84.8^\circ = \theta$$

$$P_{in} = \frac{V^2}{Z_s}\cdot\cos\theta - \frac{EV}{Z_s}\cos(\theta+\delta)$$

$$\Rightarrow \frac{800\times10^3}{3} = \frac{1154^2}{2.2}\cos(84.8) - \frac{1443\times1154}{2.2}\cdot\cos(84.8+\delta)$$

$$\Rightarrow \delta = 21.4^\circ.$$

$$I_{a_{ph}} = \frac{V\angle0 - E\angle-\delta}{Z_s\angle\theta} = \frac{1154\angle0 - 1443\angle-21.4}{2.2\angle84.8}$$

$$= 254.3\angle24.49$$

$$= 254.3\ A = I_L$$

$$pf = \cos(24.49^\circ)$$

$$= 0.908 \text{ leading.}$$

Q. A 230V, 4 pole, 50Hz, Y-connected syn. motor has an impedance of $(0.6 + j3)\Omega/ph$. Its field current is so adjusted that motor draws 10A at upf from rated voltage source. With the field current unchanged the load on the m/c is increased till it draws 40A from the supply

(i). The operating pf ___?

(a). UPF (b). 0.954 lag (c). 0.954 lead

(d). 0.603 lag

(ii). The torque developed ——?

(a). 65.3 Nm (b). 26.5 Nm (c). 78.45 Nm

(d). 45.3 Nm.

Sol: A 230V, 4-pole, 50Hz, star,

$Z_s = (0.6 + j3)\,\Omega/ph$ motor draws 10A at upf, with field current unchanged ie same the load on the m/c is increased till $I_a = 40$ A then pf = —? T = —?

$V_{ph} = \frac{230}{\sqrt{3}} = 132V$

$Z_s = 3.054 \angle 78.6^\circ$

$I_a = 10$ A, upf, $E = V\angle 0 - I_a\angle \pm\phi \cdot Z_s\angle\theta$

$\rightarrow E = 132\angle 0 - 10\angle 0 \times 3.054\angle 78.6$

$= 130.3 \angle -13.31^\circ$

$E' = E$ ∵ Excitation const.

$E' = E$, $I_a' = 40$ A $\Rightarrow$ pf = ——

$I_a Z_s = \bar{V} - \bar{E}$

$= \sqrt{V^2 + E^2 - 2VE\cos\delta}$

$\Rightarrow 40 \times 3.054 = \sqrt{132^2 + 130.3^2 - 2 \times 132 \times 130.3 \cos\delta}$

$\Rightarrow \delta = 55.5^\circ$

$I_a' = \frac{V\angle 0 - E'\angle -\delta'}{Z_s\angle\theta}$

$= \frac{132\angle 0 - 130.3\angle -55.5}{3.054\angle 78.6} = 40\angle -17^\circ$

$pf = \cos 17° = 0.95$ lag.

$P_{in} = 3 V_{ph} \cdot I_{ph} \cdot \cos\phi$

$= 3 \times 132 \times 40 \times 0.95$

$= 15.04$ kw

$P_{out} = P_{in} -$ cu loss

$= 15.04 - 3(40)^2 \times 0.6$

$= 12.16$ kw

$$T = \frac{P_{out}}{\omega} = \frac{12.16 \times 10^3}{2\pi \times \frac{1500}{60}} = 77.41 \text{ Nm}$$

G'08

Q. A Syn. motor is connected to IBB at 1pu voltage and draws 0.6 pu current at upf. Its syn. reactance is 1pu and resistance is negligible.

(i). The excitation voltage E and load angle δ will be res.ly

(a). 0.8 pu, 36.86° lag (b). 0.8 pu, 36.86 lead

(c). 1.17 pu, 30.96° lead (d). 1.17 pu, 30.96° lag

(ii). keeping the excitation voltage same, the load on the motor increased such that the motor current increased by 20%. The operating pf become (a). 0.995 lag,

(b). 0.995 lead (c). 0.791 lag (d). 0.848 lead

Sol: $V = 1.0$ pu, $I_a = 0.6$ pu at UPF

$X_s = 1$ pu, $R_a = 0$.

(i) $E = ?$ (ii). $E' = E$; $I_a' = 1.2 I_a$, $PF = ?$

$E = V - I_a Z_s$

$= 1\angle 0 - 0.6\angle 0 \times 1\angle 90$

$= 1.17 \angle -30.96$

$= 1.17$ pu and 30.96 lag.

(ii). $E' = E, = 1.17$ pu

$I_a' = 1.2 \times 0.6 = 0.72$ pu

$I_a Z_s = \bar{V} - \bar{E}$

$= \sqrt{V^2 + E^2 - 2VE\cos\delta'}$

$\Rightarrow 0.72 \times 1 = \sqrt{1^2 + 1.17^2 - 2 \times 1 \times 1.17 \cos\delta}$

$\Rightarrow \delta' = 37.85°$

$I_a' = \dfrac{V\angle 0 - E'\angle -\delta'}{Z_s\angle\theta}$

$= \dfrac{1\angle 0 - 1.17\angle -37.85°}{1\angle 90°}$

$= 0.72 \angle -6.23°$

$\therefore pf = \cos 6.23$

$= 0.994$ lag

$E = V - I_a Z_s$

$$= \sqrt{V^2 + (I_a Z_s)^2 - 2V I_a Z_s \cdot \cos(\theta \pm \phi)}$$

Here $I_a \angle \pm\phi$, $Z_s \angle \theta$, $V \angle 0$

$\rightarrow$ $I_a \angle \pm\phi \cdot Z_s \angle \theta = I_a Z_s \angle \theta \pm \phi$.

G'06

Q. A 3-ϕ, 400V, 5 kW, Y-connected syn. motor having an internal reactance of 10Ω is operating at 50% load, UPF. Now the excitation is increased 1%. What will be the new load in %, if pf is kept same, neglect all losses and consider linear magnetic circuit.

(a). 67.9% (b). 56.9% (c). 51% (d). 50%

Sol:

A 3-ϕ, 400V, 5 kW, star

$X_s = 10\Omega$, 50% load, UPF.

Now the excitation increased by 1%

$\Rightarrow E' = 1.01E$

What will be the new load in %, for the pf is same as UPF.

$$V_{ph} = \frac{400}{\sqrt{3}} = 231V$$

$$I_{FL} = \frac{5 \times 10^3}{\sqrt{3} \times 400 \times 1} = 7.21\,A$$

(I_L)

$I_{1/2 fl} = \frac{7.21}{2} = 3.608 A$

$E = V - I_a Z_s$

$= 231 \angle 0 - 3.608 \angle 0 \times 10 \angle 90$

$= 233.8 \angle -8.87°$

$E' = 1.01 E$

$= 1.01 \times 233.8$

$= 236.1 V$

pf to be UPF, $E' \cos\delta' = V$

$\Rightarrow \cos\delta' = \frac{V}{E'}$

$= \frac{231}{236.1}$

$\Rightarrow \delta' = 11.97$

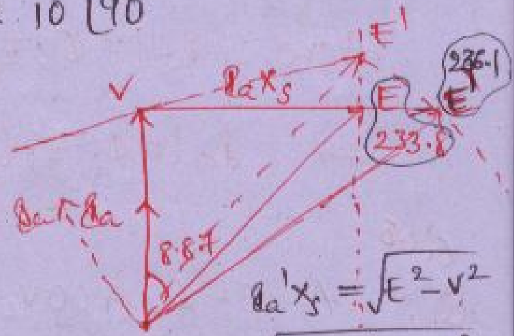
$I_a' = \frac{V \angle 0 - E' \angle -\delta'}{Z_s \angle 0}$

$= \frac{231 \angle 0 - 236.1 \angle -11.97}{10 \angle 90°}$

$= 4.89 A$

$\Rightarrow \frac{4.89}{7.21} \times 100$

$= 67.8\%$



$I_a' X_s = \sqrt{E'^2 - V^2}$

$= \sqrt{236.1^2 - 231^2}$

$= 48.8$

$I_a' = \frac{48.8}{10}$

$= 4.88 A$

Q. Two alternators of rating 200 kW, 300 kW working in ||el are driven by PM whose speed reg. curve are 3% & 5% res'ly. The governor setting gives NL speed for the two PM's a load of 190 kW will be shared by them res.ly

(a). 76 kW, 114 kW (b). 114 kW, 76. kW

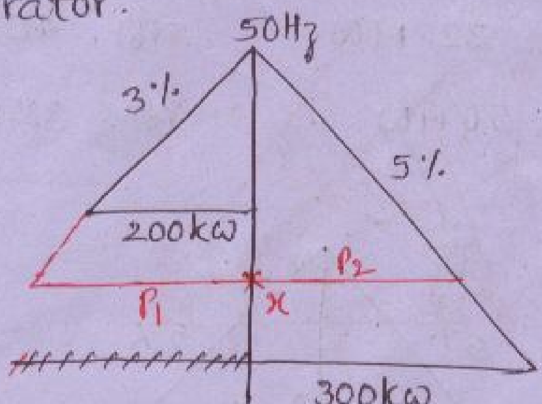
(c). 100 kW, 90 kW (d). 90 kW, 100 kW.

Sol:

→ for proper sharing of load, the turbine should have drooping char.s.

→ The active power sharing depends on mech. power i/p and turbine chars (freq vs load char.).

→ Reactive power sharing depends on the excitation and V-I chars (external char.s) of generator.



$$\frac{P_1}{200} = \frac{x}{3} \Rightarrow P_1 = 66.66\,x$$

$$\frac{P_2}{300} = \frac{x}{5} \longrightarrow P_2 = 60\,x$$

$P_1 + P_2 = 190$

$\Rightarrow 66.66x + 60x = 190$

$\Rightarrow x = 1.5$

$\therefore P_1 = 66.66 \times 1.5 = 100$ kW

$P_2 = 60 \times 1.5 = 90$ kW.

$\frac{50 \times 1.5}{100} = 0.75$ Hz

100 — 1.5

50 — ?

In 50 Hz 1.5% drop

$50 \times 0.015 = 0.75$

$\Rightarrow \frac{50}{100} \times 1.5 = 0.75$ Hz

$\Rightarrow f = 50 - 0.75 = 49.25$ Hz.

~~Two generators rated at 200MW, 400MW~~

Q. Two Alt·s working parallel and supplying total load of 80 MW.

M/C-1 : 40 MW with 5% speed reg.

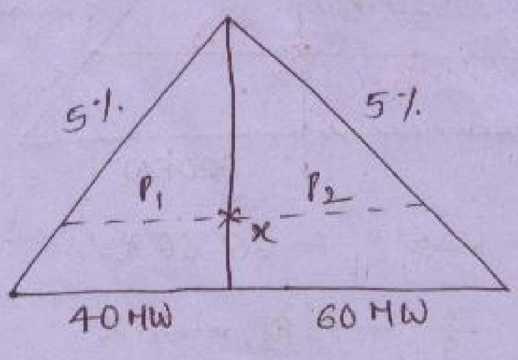
M/C-2 : 60 MW with 5% speed reg.

The total load sharing b/w m/c-1 & 2 res.ly

(a). 48 MW, 32 MW (b). 40 MW, 40 MW

(c). 30 MW, 50 MW (d). 32 MW, 48 MW

Sol:



$$\frac{P_1}{40} = \frac{x}{5} \Rightarrow P_1 = 8x$$

$$\frac{P_2}{60} = \frac{x}{5} \rightarrow P_2 = 12x$$

$$P_1 + P_2 = 8x + 12x = 80$$

$$\rightarrow x = 4.$$

$$P_1 = 8 \times 4 = 32$$

$$P_2 = 12 \times 4 = 48$$

CIRCLE DIAGRAMS:

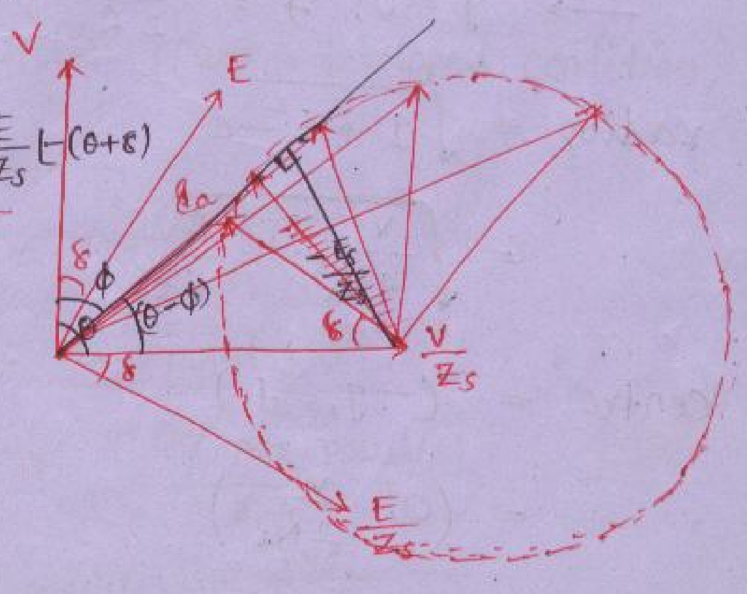
(1). Excitation circle → Locus of arm. current I_a, with fixed excitation for variable loads.

(2). power circle → Locus of arm. current I_a, with fixed load (or power) for variable excitation.

EXCITATION CIRCLE :-

$$I_a = \frac{V\angle 0 - E\angle \delta}{Z_s \angle \theta}$$

$$= \frac{V}{Z_s}\angle -\theta - \frac{E}{Z_s}\angle(\theta+\delta)$$



* Radius of the circle = $\frac{E}{Z_s}$.

$$\sin(\theta-\phi) = \frac{E/Z_s}{V/Z_s} = \frac{E}{V}.$$

$$\sin(\theta-\phi) = \frac{E}{V}$$

where ϕ is the pf angle at max. pf

ie max pf = $\cos\phi$.

POWER CIRCLE:

Mech. power developed, $P_m = P_{in} -$ arm. cu loss.

$$P_m = V I_a \cos\phi - I_a^2 R_a$$

$$I_a^2 = \frac{V}{R_a} I_a \cos\phi - \frac{P_m}{R_a}$$

$$(I_a \sin\phi)^2 + (I_a \cos\phi)^2 = \frac{V}{R_a} \cdot I_a \cos\phi - \frac{P_m}{R_a}$$

Let $x = I_a \sin\phi$

$y = I_a \cos\phi$

$$x^2 + y^2 - \frac{V}{R_a} y + \frac{P_m}{R_a} = 0 \longrightarrow \text{eq. of circle.}$$

$$x^2 + y^2 + 2gx + 2fy + c = 0$$

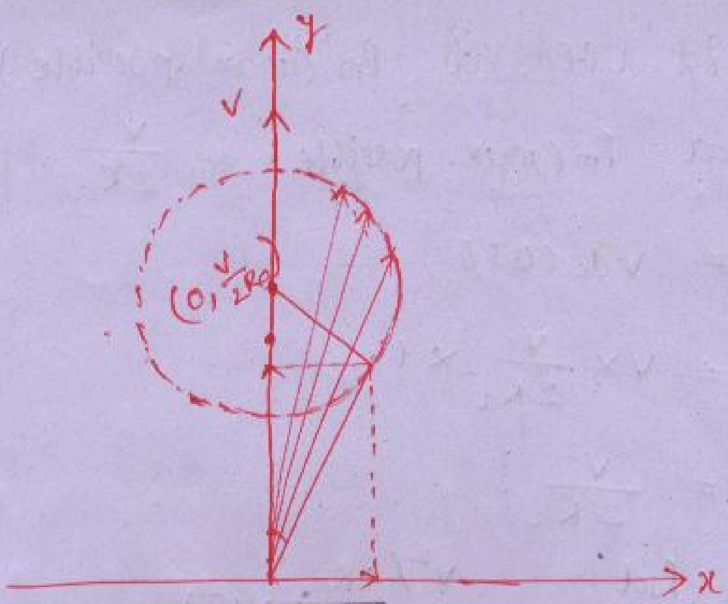
$$\longrightarrow g = 0;\ f = \frac{-V}{2R_a};\ c = \frac{P_m}{R_a}$$

$$\text{radius} = \sqrt{g^2 + f^2 - c}$$

$$= \sqrt{\frac{V^2}{4R_a^2} - \frac{P_m}{R_a}}$$

$$\text{centre} = (-g, -f)$$

$$= \left(0, \frac{V}{2R_a}\right).$$



$$\text{Radius} = \sqrt{\frac{V^2}{4R_a^2} - \frac{P_m}{R_a}}$$

As load increases, $P_m \uparrow \Rightarrow$ radius $\downarrow$

As load decreases, $P_m \downarrow \Rightarrow$ radius $\uparrow$.

At NL condi, $P_m = 0$.

$$\therefore \text{Radius} = \sqrt{\frac{V^2}{4R_a^2} - 0}$$

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

NL circle passes through origin.

At max. possible power developed condition, radius = 0.

$$r = \sqrt{\frac{V^2}{4R_a^2} - \frac{P_{m(\text{max. possible})}}{R_a}}$$

$\therefore$ circle is a point o^le.

$$\Rightarrow \frac{V^2}{4R_a^2} = \frac{P_{m(\text{max. possible})}}{R_a}$$

$$\Rightarrow P_{m(\text{max. possible})} = \frac{V^2}{4R_a}$$

pf is UPf, at P_m (max. possible).

I_a at P_m (max. possible) $= \frac{V}{2R_a}$.

$P_{in} = V I_a \cos\phi$

$= V \times \frac{V}{2R_a} \times 1$

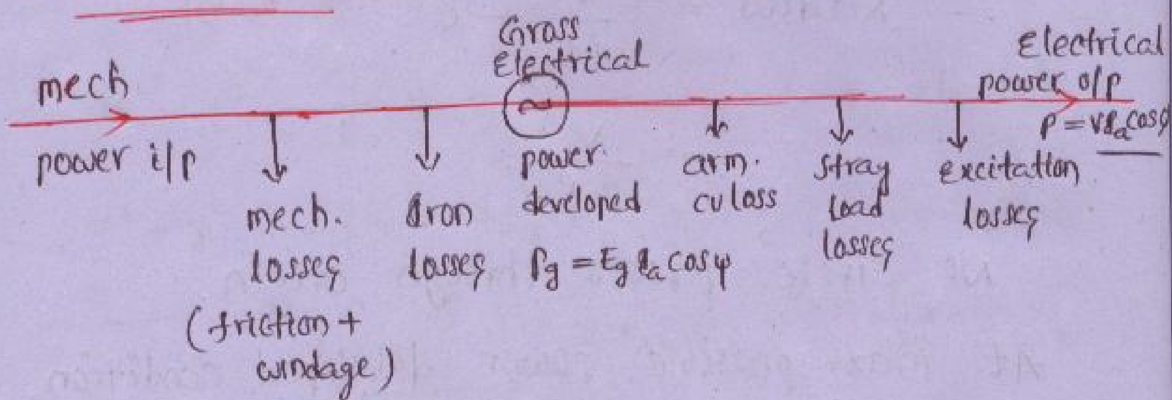
$= \frac{V^2}{2R_a}$.

$\eta = \frac{P_{out}}{P_{in}} = \frac{V^2/4R_a}{V^2/2R_a} \times 100$

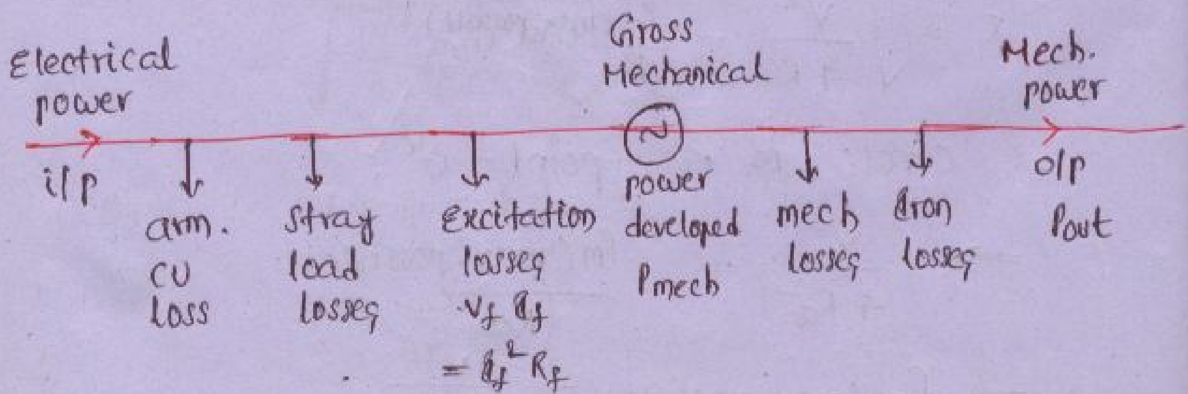
$= 50\%$ → Efficiency at P_m (max. possible).

POWER STAGES:

ALTERNATOR:



SYN. MOTOR:



→ Torque developed $= \frac{P_{mech}}{\omega} = \frac{E_b I_a \cos\phi}{\omega}$

→ Shaft torque $T_{sh} = \frac{P_{out}}{\omega}$

DC M/C's

03. $I = \frac{12 \times 1000}{240} = 50 A$

$\frac{E_L}{E_\omega} = \frac{A_\omega}{A_L}$ & $\frac{I_L}{I_\omega} = \frac{A_L}{A_\omega}$

power rating is const. [remain same]

EMF eq. of D/C M/c :-

In dc m/c brushes collect the max. value ∵ flux distr. is a flat topped wave.

$\therefore E = E_{avg} = E_{max} = \sqrt{2} \times E_{rms}$

$= \sqrt{2} \times \sqrt{2}\pi \, k_p k_d \phi f T$

$\rightarrow E = 2\pi \, k_p k_d \phi f T.$

In dc m/c the arm. wdg is a full pitch wdg. ∴ $k_p = 1$.

Arm. wdg is uniformly distributed ∴ emf polygon is a cle. $\rightarrow k_d = \frac{2}{\pi}$ [∵ $mr = \pi$].

$T_{path} = \frac{Z}{2} \times \frac{1}{A}$

$\Rightarrow E_{avg} = 2\pi \times 1 \times \frac{2}{\pi} \times \phi \times \frac{PN}{120} \times \frac{Z}{2} \times \frac{1}{A}$

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

$V = 220 V$; $R_a = 1\Omega$.

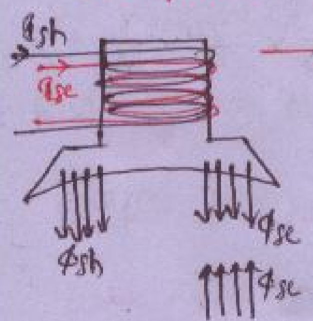
$I_a = \frac{V}{2R_a} = \frac{220}{2 \times 1} = 110 A$ ← Arm. current corr. to max. mech. power developed.

At max. power developed condi. the η is nearly 50% ∴ the m/c never be operated at max. power developed condi. b'coz due to large heating effect the insulation may spoil and dmr wdg may get damage. All the m/c's are generally designed for max. η at rated power or load condition.

Shunt & Series dc m/c's :-

* Series field wdg cross section is more. $R = \frac{\rho l}{A}$
* Shunt field wdg is made with more no. of turns with thin wire
* Series field wdg is made with less no. of turns with thick wire.
* The order of R_{sh} : 100 - 200 Ω
  R_{se} : 0.1 - 1 Ω
* The order of arm resistance is 1 or 2 Ω.
* Area CS (Series) > Area CS (arm) > Area CS (Shunt)

Compound dc m/c's :-



→ Series field is placed on the top of shunt field since cu losses are more in series field so heat dissipation is effective.

→ In long shunt, volt. reg is more when compared to short shunt with same terminal volt. b'coz series field wdg carries entire arm. current.
b'coz generated volt. is more.
series flux is more in long shunt.

→ The generated volt. for long shunt connection is little more than the short shunt.

Volt. buildup in self excited dc m/c's :-

Magnetic Materials :

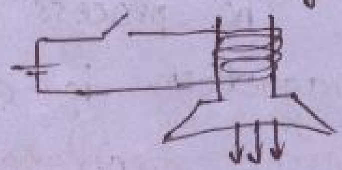
(1). Hard (2). Soft.

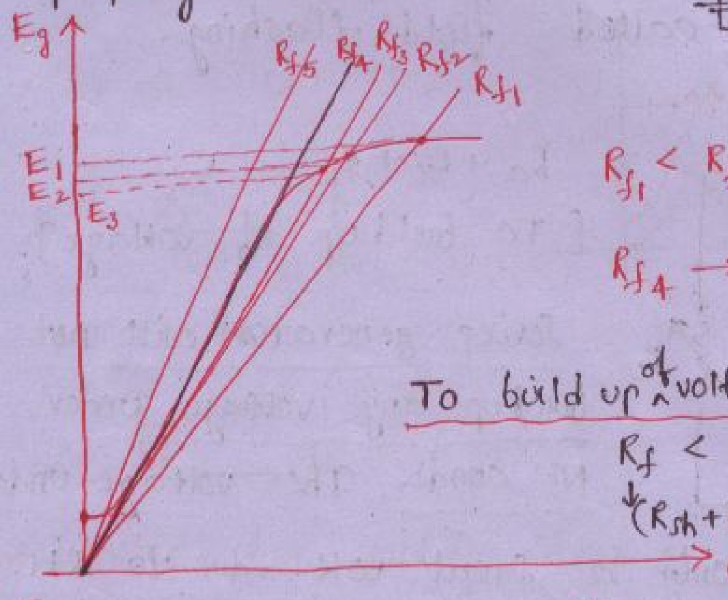
Hard → highly retentive.

Ex: Cobalt steel, cobalt varnadium

Soft → cast steel, cast iron, Silicon steel.

Even field current is, they will posses some flux [residual flux] is called retentivity property.





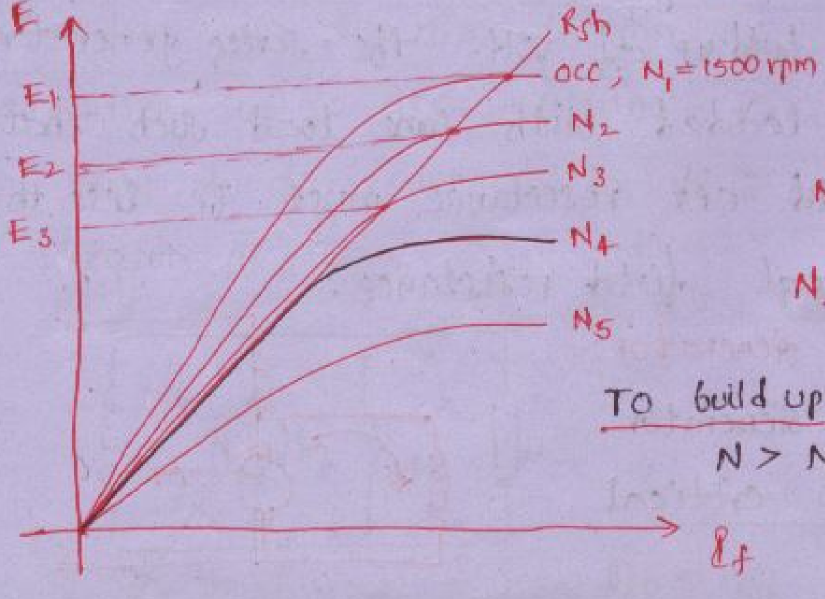
$R_{f_1} < R_{f_2} < R_{f_3} < R_{f_4} < R_{f_5}$

R_{f4} → critical field resistance (R_c)

To build up of volt.:

$R_f < R_c$

↓ $(R_{sh} + R_e)$



↓ $E \propto N$ ↓

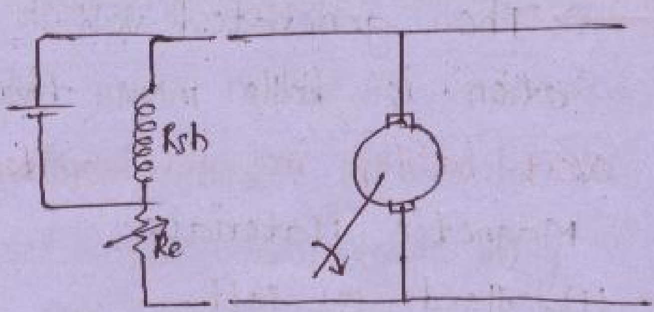
$N_1 > N_2 > N_3 > N_4 > N_5$

N_4 → critical speed (N_c)

To build up of volt. :

$N > N_c$

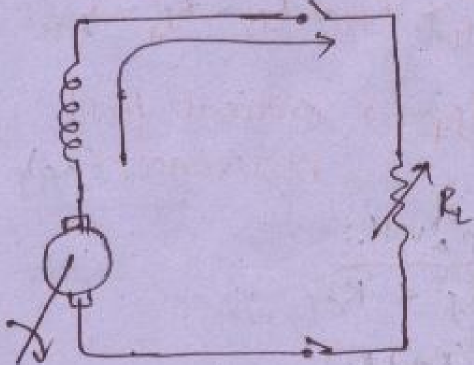
Field flashing :-



If the field terminals are not properly connected, the residual magnetism may be loss. To reestablish residual magnetism, the field wdg terminals are seperated and excited with low volt. for some time. Then due to retentivity property the field poles, holds the residual magnetism.

The process of Reestablishing the residual magnetism is called field flashing.

Series Generator:

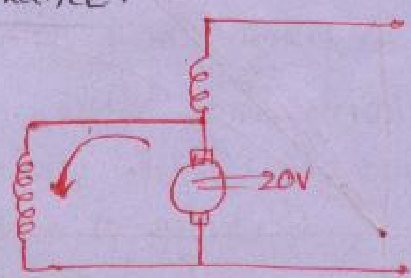


$R_a + R_{se} + R_L < R_c$

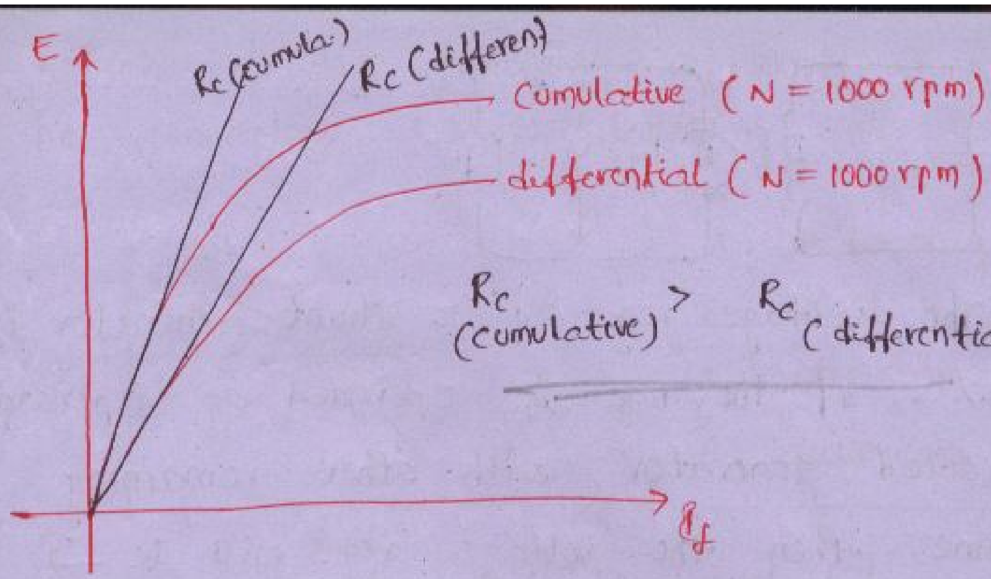
[To build up of voltage].

Series generator will not build up any voltage under NL condi. The voltage under NL condi. is only a small volt. due to RM. for the build-up of volt. the series generator must be loaded with some load such that total field ckt resistance must be less than the critical field resistance.

Compound Generator:-



Compound Generator having two critical resistances.

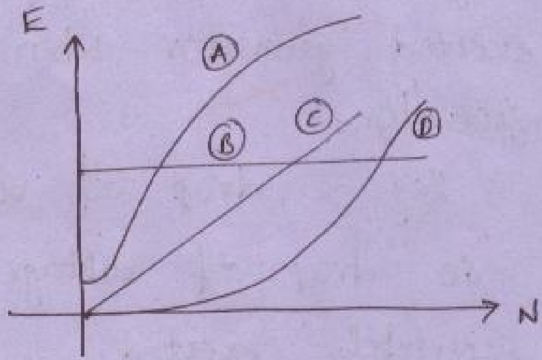


R_c (cumulative) > R_c (differential).

Q. which of the following char.s represents voltage vs speed of DC shunt m/c.

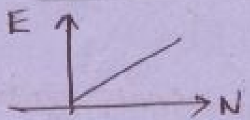
(a). A (b). B

(c). C (d). D.



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

$\Rightarrow$ $E \propto N$.

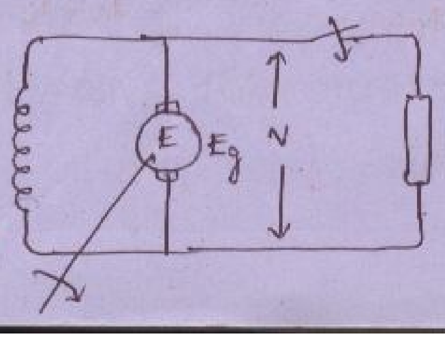


* causes for voltage drop :

(1). drop due to arm. reaction

(2). drop due to arm. resistance, $I_a R_a$ drop.

(3). drop due to reduction in field current due to reason ① & ②.

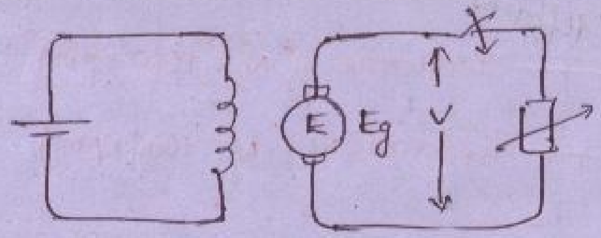


$E = V + I_a R_a +$ drop due to AR.

$= E_g +$ drop due to AR.

$\because E_g = V + I_a R_a$

$I_{sh} = \frac{V}{R_{sh}}$



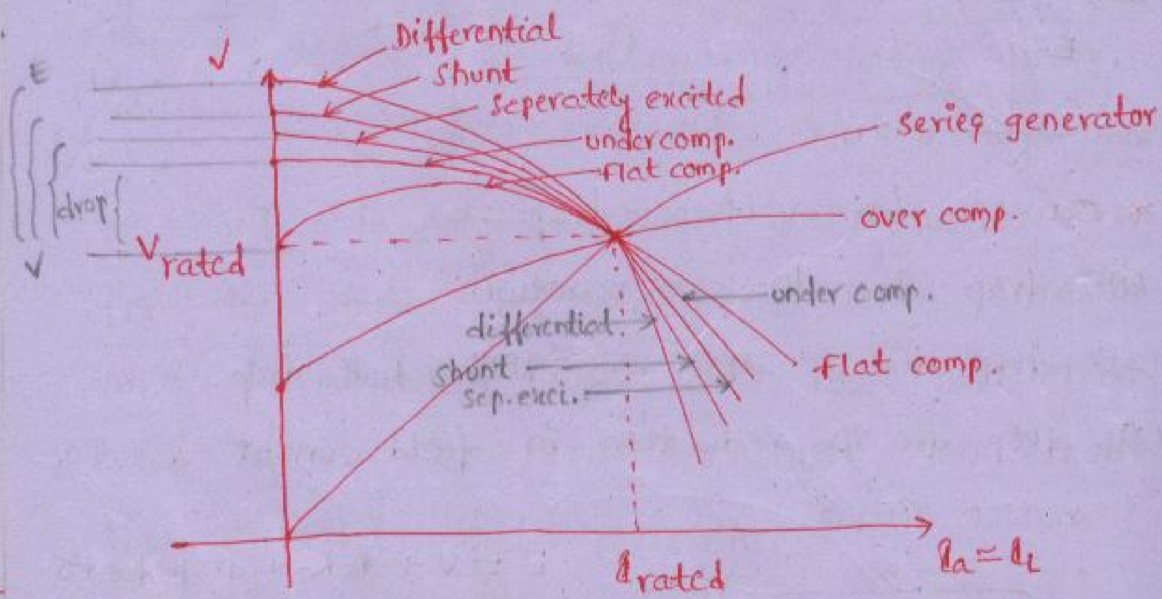
Q. The voltage reg. of a shunt generator is 10%. If the m/c is operated as seperately excited generator, with other remaining same then the voltage reg. will be —?

(a). reg. is 10% ~~(b)~~ < 10% (c). > 10%

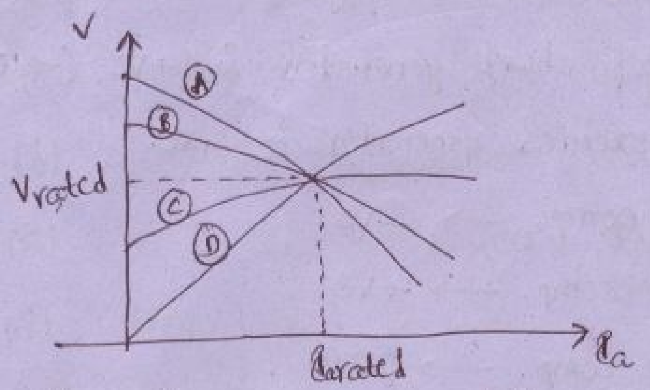
→ Regulation is better in case of seperately excited generator when compared to shunt generator.

Reg ∝ drop of voltage

so drop of voltage is less in case of seperately excited.



Q. Which of the following represents V – I char. DC generators. Match the following.



A : Differential

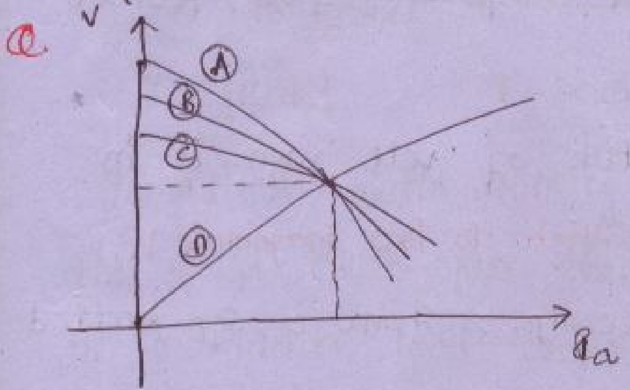
B : Shunt

C : over comp.

D : series comp.

{ series, over comp, differential, shunt }.

Q.



A : shunt

B : series

C : diff

D : cumulative

VOLTAGE REGULATION :

$$\frac{\text{NL voltage} - \text{FL voltage}}{\text{FL voltage}} = \frac{E-V}{V} \times 100$$

⟹ In DC generators volt. regn is proportional to speed.

∴ volt. regn ∝ speed.

But in syn. generator the volt. regn. is independent of speed, depends only on magnitude of load and load pf.

Q. The volt. reg. of a shunt generator at 1000 rpm is 10%. The volt. reg. at 1250 rpm will be —? (with other things remaining same).

(a) < 10% (b) = 10% (c) > 10%.

→ The volt. regn for series generator is −ve ($\simeq -100\%$) ie poorest regn. (−ve volt. regn.).

→ The volt. regn. of shunt generator is +ve ($< 10\%$)

→ The VR of sep. excited generator is +ve.

→ The VR of over comp. → −ve.

→ The VR of under comp. → +ve

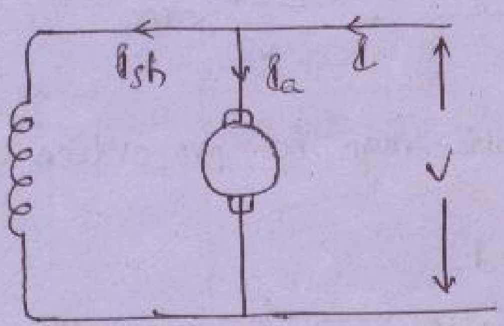
→ The VR of flat comp. → zero.

→ The VR of differential comp. → +ve, poorest +ve volt. regn.

* The order of magnitude of volt. regn. is in descending order: (High to low magnitude).

Series > Diff. > over comp. > shunt > sep. excited > under comp. > flat comp.

SHUNT MOTOR :



$T \propto \phi I_a \Rightarrow +ve$

$T \propto (-\phi)(-I_a) \Rightarrow +ve.$

→ The dire. of rotation can be reversed by reversing either field or arm terminals but not both.

→ If the supply terminals are changed then motor rotation can't be reversed.

Q. A shunt motor is running at rated speed, If the field ckt open then motor will

(a). rotate at dangerously high speed

(b). rotate at same speed

(c). " " reduced speed

(d). stops.

$\uparrow N \propto \frac{1}{\phi_{residual}} \rightarrow$ small value

$T \propto \downarrow \phi I_a \uparrow$; $E_b \propto \phi \downarrow$; $\uparrow I_a = \frac{V - E_b}{R_a}$.

If shunt motor running under FL condi. if the field ckt open then back emf reduces, to maintain load torque const. motor will draw more I_a, ∴ arm. wdg get damage and finally motor comes to stop.

Q. A shunt motor running at rated speed. If the arm ckt open then the motor will –

(a). rotate with reduced speed

(b). " " same "

(c). " " dangerously high speed

(d). stop. (motor would come to stop.).

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

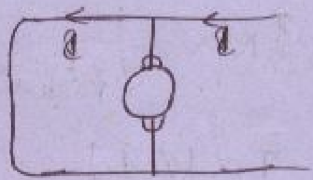
Q. A shunt motor running at rated speed. If its field wdg is s/c'ed then motor will

(a). Rotate with same speed.

(b). " " dangerously high speed

(c). " " reduced speed

(d). would come to stop.



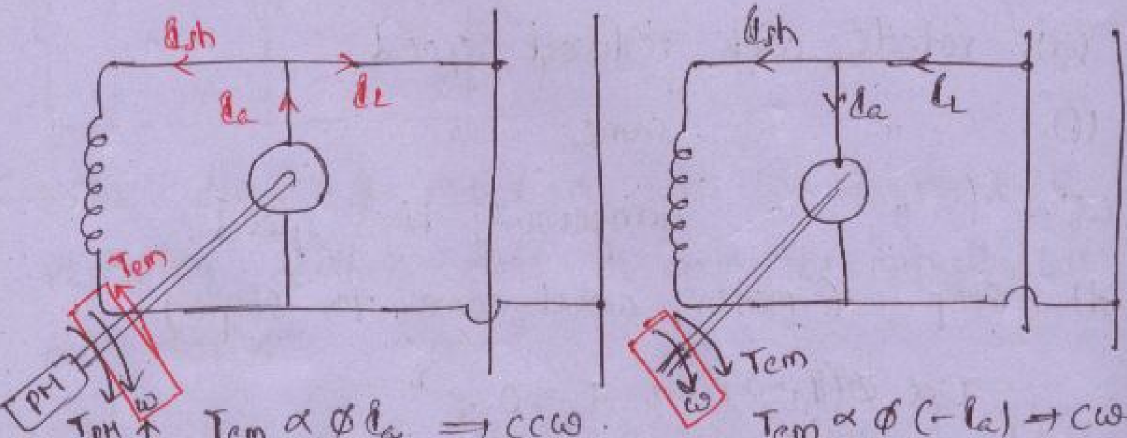
Q. A shunt generator supplying power to the dc bus bar. If the PM fails, the m/c will behaves as,

(a). shunt motor, rotate in the same dirc.

(b). " " " opp. dirc.

(c). shunt generator with reduced speed

(d). m/c would come to stop.



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

(generator)

ω

Tem

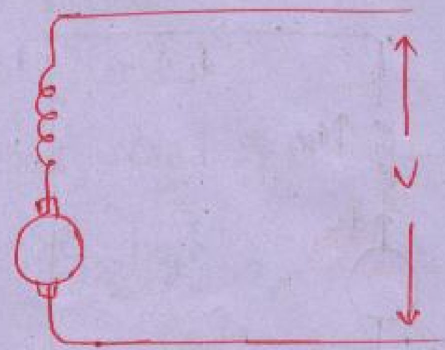
$T_{em} \propto \phi(-I_a) \rightarrow CW$.

(Motor).

ω

Tem

SERIES MOTOR :



Q. A series is running at rated speed, if field ckt opens then the motor will –

(a). Rotate with same speed

(b). " reduced speed.

(c). " " dangerously speed.

(d). would comes to stop. → arm. also open

Q. A series motor running at rated speed. if its field wdg s/c'ed then the motor will –

(a). Rotate with same speed

(b). " " reduced speed

(c). " " dangerously high

(d). comes to rest.

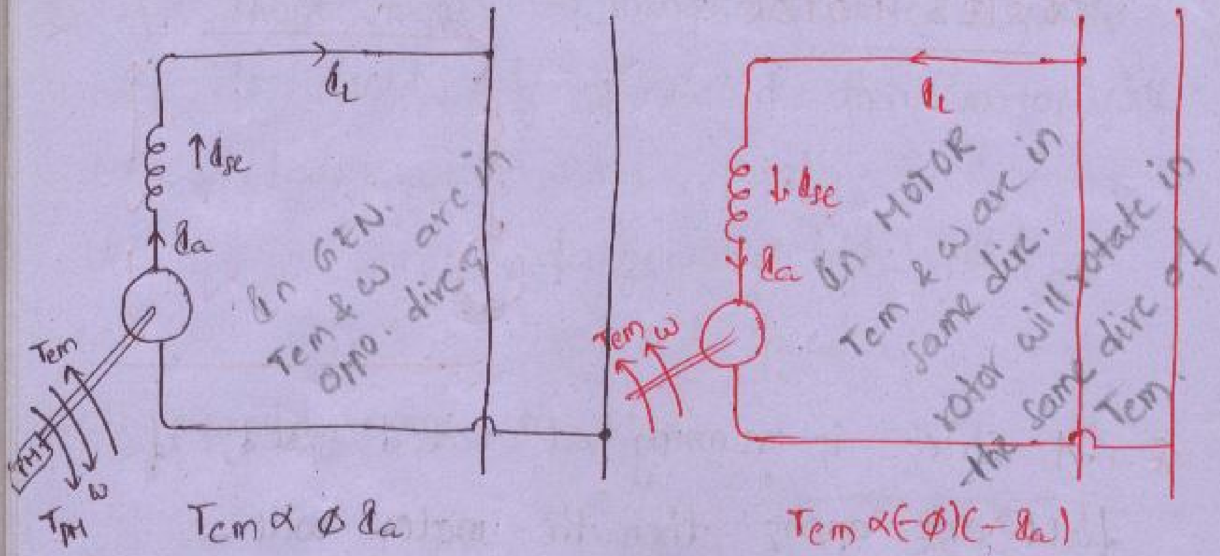
Q. A series generator supplying power to the dc bus bar. If the PM fails then the m/c will behaves as ——

(a). series motor rotate in the same dire.

(b) " " " opp. dire

(c). series generator rotate at reduced speed

(d). m/c would comes to stop.



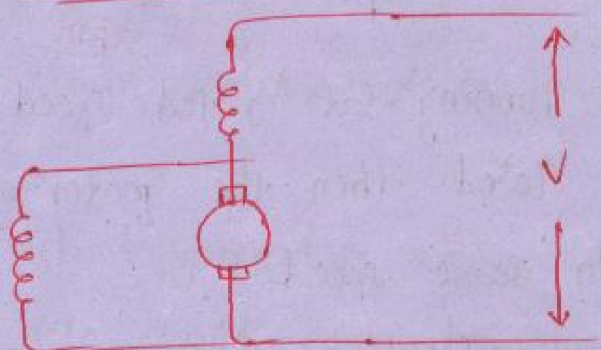
$T_{em} \propto \phi I_a$ $\qquad$ $T_{em} \propto (-\phi)(-I_a)$

$\propto I_a^2 \Rightarrow$ ccw. $\qquad$ $\propto (-I_a)^2 \rightarrow I_a^2$

$\Rightarrow$ ccw.

* If arm is s/c'ed then motor comes to rest.

COMPOUND MOTOR:



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

$+ \longrightarrow$ cumu.

$- \longrightarrow$ diff.

Q. A cumu. comp. motor running at rated speed. If the series field wdg opened then the motor would come to stop.

Q. A cumu. comp. motor running at rated speed. If the series field wdg is s/c'ed then the motor will ___

(a). Rotate with same speed

(b). " " reduced speed

(c). " " increased speed $\uparrow N \propto \frac{1}{\downarrow \phi_{sh} + \phi_{se}}$ (Net ϕ) $\phi_{se} \downarrow 0$

(d) " " dangerously high

(e). come to stop.

→ If it is differential comp. motor, if the series field wdg is s/c'ed then,

$\downarrow N \propto \frac{1}{\uparrow \phi_{sh} - \phi_{se}}$ ($\phi_{se} = 0$) ⇒ Net flux ϕ increases

motor will rotate with reduced speed.

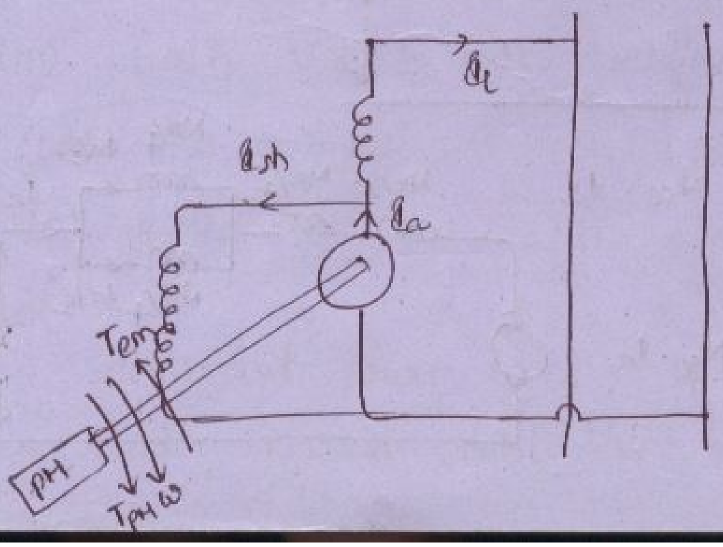
Q. A belt driven cumu. comp. generator supplying power to dc bus bar. If belt breaks then the m/c behaves as —

(a). diff comp. motor, rotate in the same dirc.

(b). " " " " the opp. dirc.

(c). cumu. " " " the same dirc.

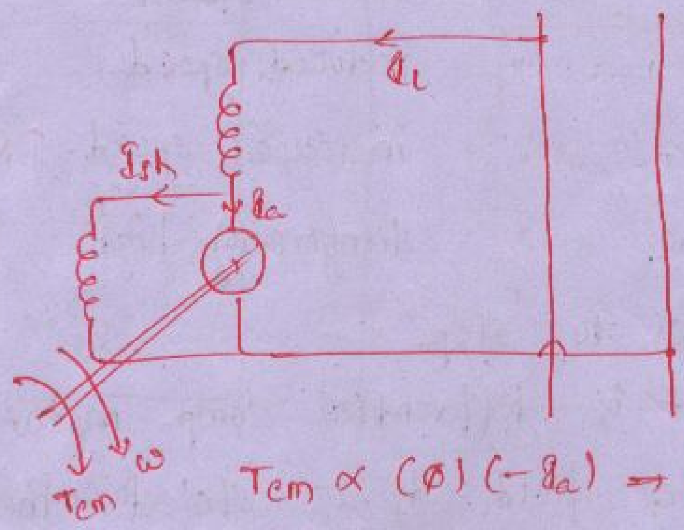
(d). " " " " the opp. dirc.



$T_{em} \propto \phi I_a \Rightarrow$ ccw.

$\phi_{sh} > \phi_{se} \rightarrow$ normally under comp. motor.

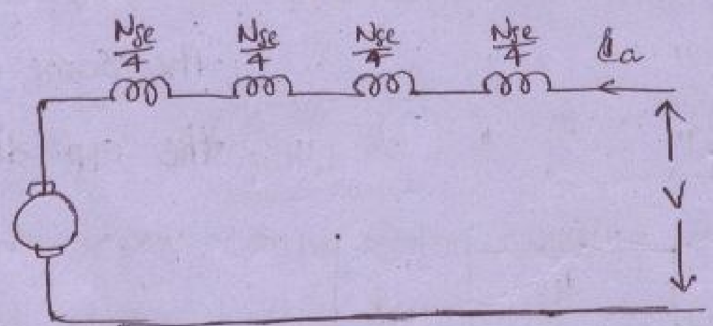
$\phi = \phi_{sh} + \phi_{se}$



$T_{em} \propto (\phi)(-I_a) \rightarrow cw$

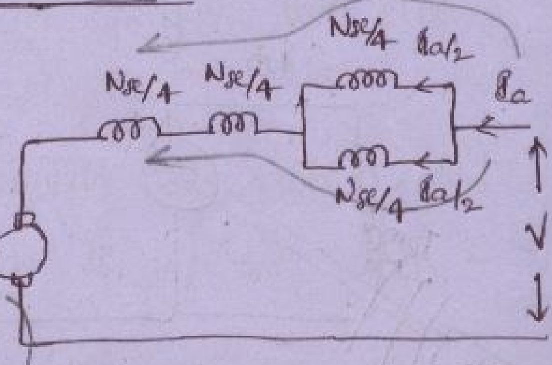
Here

Q. A series motor series field is divided into 4 Groups. If all are connected in series, the speed is 1000 rpm. Then if 2 are connected in series and another 2 are connected in $\parallel^{el}$ and those are connected in series then the speed of the motor will be ___?



$\left[\left(4 \cdot \frac{N_{se}}{4}\right) \cdot I_a\right]$

$AT_1 = N_{se} \cdot I_a$



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

$\left(\frac{3N_{se}}{4} \cdot \frac{I_a}{2} + \frac{3N_{se}}{4} \cdot \frac{I_a}{2}\right)$

$$\frac{N_2}{N_1} = \frac{E_{b2}}{E_{b1}} \times \frac{AT_1}{AT_2} \quad \because E_{b1} \simeq E_{b2} \text{ if } I_a(R_a+R_{se}) \text{ is neglected.}$$

$$= \frac{AT_1}{AT_2}$$

$$= \frac{N_{se} \cdot I_a}{3/4 \cdot N_{se} \cdot I_a}$$

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

Q. DC shunt motor driving a const. power load. Under rated condi.s motor takes rated arm i, and runs at rated N. The speed and current for the following changes.

(i). Arm. terminal volt. is halfed, field current unchanged.

(a) 2 pu, 0.5 pu (b). 0.5 pu, 2 pu.

(c) 1 pu, 1 pu (d). 1 pu, 0.5 pu

(ii). V is unchanged & I_f is halfed.

(a). 2 pu, 1 pu (b). 1 pu, 2 pu

(c). 0.5 pu, 1 pu (d). 0.5 pu, 2 pu

(iii). Both V & I_f are halfed,

(a). 1 pu, 0.5 pu (b). 1 pu, 2 pu

(c). 2 pu, 1 pu (d). 4 pu, 4 pu.

Sol:

constant power load, $P_1 = P_2$

under rated condi. $V_1 = 1$ pu, $I_{a_1} = 1$ pu

$N_1 = 1\,pu$ & $I_{f_1} = 1\,pu$.

(i). $V_2 = 0.5\,pu$ & $I_{f_2} = 1\,pu$.

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

$1 \times 1 = 0.5 \times I_{a2}$

$\Rightarrow I_{a2} = 2\,pu$.

$I_{f_1} \cdot I_{a1} \cdot N_1 = I_{f_2} \cdot I_{a_2} \cdot N_2$

$\Rightarrow 1 \times 1 \times 1 = 1 \times 2 \times N_2$

$\Rightarrow N_2 = 0.5\,pu$

$\frac{N_2}{N_1} = \frac{V_2}{V_1} \times \frac{I_{f_1}}{I_{f_2}}$

$\Rightarrow \frac{N_2}{1} = \frac{0.5}{1} \times \frac{1}{1} = 0.5\,pu$.

N_2 & $I_{a2} \Rightarrow 0.5\,pu$ & $2\,pu$.

constant power load

$P_1 = P_2$

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

$N_1 T_1 = N_2 T_2$

$\rightarrow I_{f_1} I_{a_1} \cdot N_1 = I_{f_2} I_{a_2} N_2$

$\Rightarrow \frac{N_2}{N_1} = \frac{V_2}{V_1} \times \frac{I_{f_1}}{I_{f_2}}$

(ii). $V_2 = 1\,pu$, $I_{f_2} = 0.5\,pu$

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

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

$\Rightarrow I_{a2} = 1\,pu$.

$I_{f_1} \cdot I_{a1} \cdot N_1 = I_{f_2} \cdot I_{a_2} \cdot N_2$

$\Rightarrow 1 \times 1 \times 1 = 0.5 \times 1 \times N_2$

$\Rightarrow 2\,pu$.

Q. A dc shunt motor driving a const torque load and under rated condi.s motor takes rated arm i, and runs at rated N. The speed & arm i for the following changes —

(i). V is halfed, I_f is unchanged.

(a). 1 PU, 0.5 PU (b). 0.25 PU, 2 PU

(c). 1PU, 2 PU (d). 0.5 PU, 1 PU.

(ii). V is unchanged, I_f is halfed,

(a). 2 PU, 2 PU (b). 1 PU, 1 PU

(c). 0.5 PU, 0.5 PU (d). 2 PU, 0.5 PU.

(iii). Both V & I_f are halfed

(a). 1 PU, 2 PU (b). 2 PU, 1 PU

(c). 1 PU, 0.5 PU (d). 2 PU, 4 PU.

Sol:

const. torque load ie $T_1 = T_2$

$V_1 = 1\,PU$, $I_{a1} = 1\,PU$, $I_{f1} = 1\,PU$ & $N_1 = 1\,PU$.

(i). $V_2 = 0.5\,PU$

$I_{f2} = 1\,PU$

$I_{f1} \cdot I_{a1} = I_{f2} \cdot I_{a2}$

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

$\Rightarrow I_{a2} = 1\,PU$

Constant Torque load

$T_1 = T_2$

$I_{f1} \cdot I_{a1} = I_{f2} \cdot I_{a2}$

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

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

$$\Rightarrow \frac{N_2}{1} = \frac{0.5}{1} \times \frac{1}{1} \Rightarrow N_2 = 0.5 \text{ pu.}$$

(ii). $V_2 = 1\text{ pu}$, $\phi_{f2} = 0.5\text{ pu}$.

$$\phi_{f1} \cdot I_{a1} = I_{a2} \cdot \phi_{f2}$$

$$\rightarrow 1 \times 1 = 0.5 \times I_{a2}$$

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

$$\frac{N_2}{N_1} = \frac{V_2}{V} \times \frac{\phi_{f1}}{\phi_{f2}}$$

$$\Rightarrow \frac{N_2}{1} = \frac{1}{1} \times \frac{1}{0.5} \Rightarrow N_2 = 2\text{ pu.}$$

LOSSES

- Cu losses
  - arm. cu. loss
  - shunt cu. loss
  - series field cu. loss.
- Iron losses or core losses
  - W_h, $W_h = \eta B_{max}^{1.6} f V \Rightarrow W_h \propto N$
  - W_e, $W_e = B_{max}^2 f^2 V^2 t^2 \Rightarrow W_e \propto N^2$
- Mechanical losses
  - frictional losses at brushes & bearing
  - Air frictional losses ie Air friction b/w stator & rotor.
- Stray losses
  - Stray iron losses → Due to cross mag. effect of AR, max B increases ∴ iron losses increases, which are said to be stray iron losses.
  - Stray cu losses. → Due to self flux linkages in arm. condu. an emf induced, which will drive circulating current called stray current, these current distort the current distr. the current is preferred to flow through outer surface called skin effect. ∴ Net effective CS area reduced ∴ resistance increased, due to this additional cu losses said to be stray cu losses.

NL rotational losses :

Mech. losses + Iron losses + stray load losses

= stray losses or Rotational losses.

Stray losses + shunt field cu losses = const. losses.

arm. cu. losses + series field cu losses = variable losses.

Q. A DC series motor driving an electric train faces a const. power load. It is running at rated speed and rated voltage. If the speed has brought down to 0.25 pu, the supply voltage has to be appr.ly brought down to — ?

(a). 0.75 pu (b). 0.5 pu

(c). 0.25 pu (d). 0.125 pu

Sol: const. power load.

$P_1 = P_2$

$T_1 N_1 = T_2 N_2$

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

$\Rightarrow 1^2 \times 1 = I_{a2}^2 \times 0.25$ pu

$\Rightarrow I_{a2} = 2$ pu.

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

$\Rightarrow 1 \times 1 = V_2 \times 2 \Rightarrow V_2 = 0.5$ pu.

G'00

Q. A 240 V DC series motor takes 40 A, when giving its rated o/p at 1500 rpm. Its resistance is 0.3 Ω. The value of resistance which must be added to obtain rated torque at 1000 rpm is — ?

(a) 6 Ω (b). 5.7 Ω (c). 2.2 Ω (d). 1.9 Ω

Sol: 240V, $I_{a1} = 40$ A, $N_1 = 1500$ rpm

$R_a = 0.3\,\Omega$; $R_e = ?$ to obtain rated torque at 1000 rpm. $= N_2$.

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

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

$$E_{b1} = V - I_{a1} R_1$$

$$= 240 - 40 \times 0.3$$

$$= 228\text{ V}$$

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

$$\frac{N_2}{N_1} = \frac{E_{b2}}{E_{b1}} \times \frac{\phi_1}{\phi_2} = \frac{E_{b2}}{E_{b1}} \times \frac{I_{a1}}{I_{a2}} = \frac{E_{b2}}{E_{b1}}$$

$$\frac{1000}{1500} = \frac{E_{b2}}{228} \rightarrow E_{b2} = 152.$$

$$\therefore 152 = 240 - 40(0.3 + R_e)$$

$$\Rightarrow R_e = 1.9\,\Omega.$$

G'05

Q. A 50 kW dc shunt motor is loaded to draw rated arm. current at any given speed when driven –

(a). At half the rated speed by arm. volt control

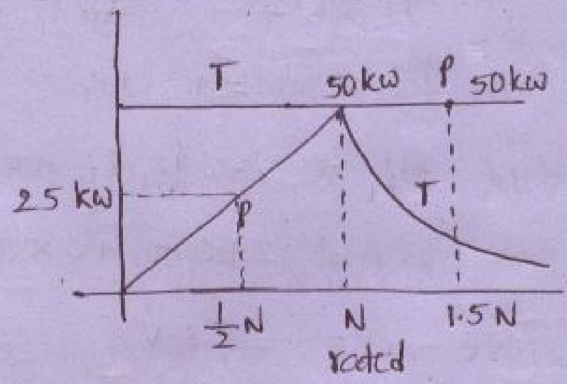
(b). At 1.5 times rated speed by field control.

The res. power developed by motor are res.ly —

(a). 25 kW, 75 kW (b). 25 kW, 50 kW

(c). 50 kW, 75 kW (d). 50 kW, 50 kW

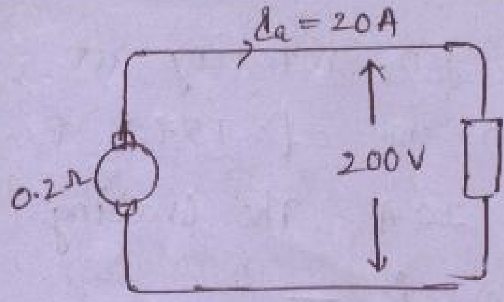
Sol:

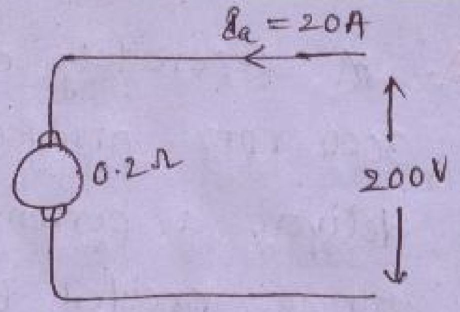


G'06

Q. A 220V, dc m/c supplies 20 A, at 200V as a generator; the arm. resistance is 0.2 Ω. If the m/c is now operated as motor at the same terminal volt & current but with flux increased by 10% the ratio of motor speed to generator speed is —

(a). 0.87 (b). 0.95 (c). 0.96 (d) 1.06





N_g $\qquad\qquad$ $\phi_m = 1.1\phi_g$; N_m

$E_g = 200 + 20 \times 0.2 = 204\text{ V}$ $\qquad\qquad$ $E_m = 200 - 20 \times 0.2 = 196\text{ V}$

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

$$= \frac{196}{204} \times \frac{1}{1.1} = 0.87.$$

DRDO

Q. A seperately exc. dc gen. having arm. resis. of 0.1Ω supplies 4 kw at a terminal voltage of 200 V, If the m/c is now operated as a motor at the same terminal voltage & same arm. current with flux / pole being increased by 10%. The ratio of generator speed to motor speed will appr. ly —

(a). 0.09 $\quad$ (b) 0.11 $\quad$ (c). 1.04 $\quad$ ✓(d). 1.12

Q. A seperately exc. dc gen. rotating at 3000 rpm produces an emf of 157 V & delivers a current of 20 A. The braking torque excited by arm. is —

(a) 0.17 Nm (b). 10 Nm (c). 12 Nm

(d). 12.5 Nm

Sol: $N = 3000$ rpm , $E = 157$ V

$I_a = 20$ A , → $T_B = ?$

Braking torque (or) Electromagnetic torque

$$T_{em} = T_B = \frac{E_g I_a}{\omega}$$

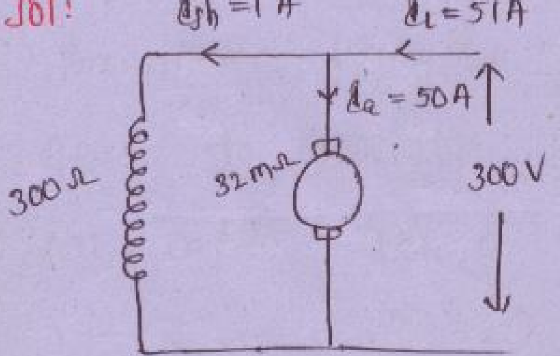
$$= \frac{157 \times 20}{2\pi \times \frac{3000}{60}} = 10 \text{ Nm}$$

Q. A 300V, dc shunt motor draws a line current of 51 A. The arm & field resistances are 32 mΩ & 300 Ω res.ly. Assuming 1 Hp = 746 W. The mech. power developed by motor is —

(a) 20 Hp (b) 20.1 Hp (c) 20.4 Hp

(d). 20.5 Hp

Sol:



$$E_b = V - I_a R_a$$

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

$$= 298.4 \text{ V}$$

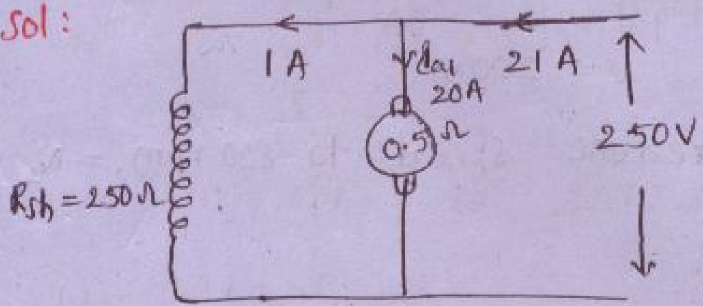
$$P_{mech} = E_b I_a$$

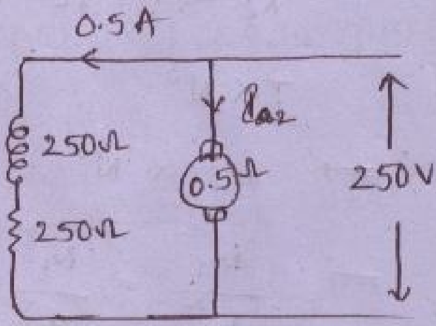
$$= 298.4 \times 50 \text{ W}$$

$$= \frac{298.4 \times 50}{746} = 20 \text{ Hp}.$$

Q. A 250 V, dc shunt motor has an arm. resistance of 0.5 Ω & field resistance of 250 Ω, when driving a const. torque load, at 600 rpm, motor draws 21. A. The new speed of the motor if an additional 250Ω connected in the field ckt —

Sol:





$N_1 = 600$ rpm

$T_1 = T_2$

$N_2 = ?$

$I_{f_1} \cdot I_{a_1} = I_{f_2} \cdot I_{a_2}$

$\Rightarrow I_{sh_1} \cdot I_{a_1} = I_{sh_2} \cdot I_{a_2}$

$\Rightarrow 1 \times 20 = 0.5 \times I_{a_2}$

$\Rightarrow I_{a_2} = 40$ A.

$E_{b_1} = 250 - 20 \times 0.5$

$= 240$V

$$\frac{N_2}{N_1} = \frac{E_{b_2}}{E_{b_1}} \times \frac{I_{sh_1}}{I_{sh_2}}$$

$$\Rightarrow \frac{N_2}{600} = \frac{230}{240} \times \frac{1}{0.5} \Rightarrow N_2 = 1150 \text{ rpm}.$$

Q: A dc series motor driving a fan load when the load torque is proportional to N^3. The resistance of arm & field is 1Ω and motor takes 10 A at 1000 rpm when operating from 200 V. The value of resistance inserted in series with arm. to reduce arm. speed 800 rpm.

Sol: $T \propto N^3$, $R_a + R_{se} = 1\Omega$, $I_{a_1} = 10A$

$N_1 = 1000$ rpm. $V = 200V$

$R_e = ?$ to reduce speed to 800 rpm. $= N_2$

$T \propto N^3$

$\Rightarrow I_a^2 \propto N^3$.

$$\Rightarrow \frac{I_{a_1}^2}{I_{a_2}^2} = \frac{N_1^3}{N_2^3}$$

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

$$= 7.15 A.$$

$E_{b_1} = 200 - 10 \times 1 = 190 V$

$E_{b_2} = 200 - 7.15(1 + R_e)$

$$\frac{N_2}{N_1} = \frac{E_{b_2}}{E_{b_1}} \times \frac{I_{a_1}}{I_{a_2}}$$

$$\rightarrow \frac{800}{1000} = \frac{E_{b_2}}{190} \times \frac{10}{7.15}$$

$\Rightarrow E_{b_2} = 108.76 V$

$\Rightarrow \quad 108.76 = 200 - 7.15(1 + R_e)$

$\Rightarrow \quad R_e = 11.74\ \Omega.$

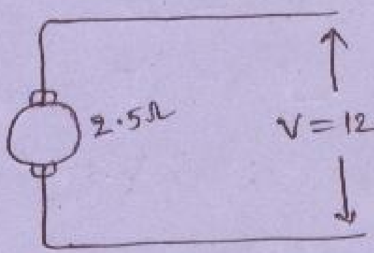
G100
a

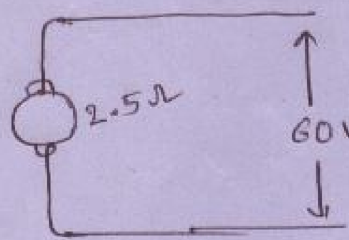
A permanent magnet dc commutator motor has NL speed of 6000 rpm, when connected to 120 V dc supply, the arm resistance is 2.5 Ω and other losses may be neglected. The speed of the motor if supply voltage of 60V developing a torque 0.5 Nm is —

(a). 3000 rpm (b). 2673 rpm (c) 2836 rpm

(d) 5346 rpm.

Sol:





$N_1 = 6000$ rpm $\qquad T = 0.5$ Nm, $N_2 = ?$

$E_{b1} = V = 120V$

$\because$ NL losses neglected $\therefore I_a = 0$

$E_{b1} = \dfrac{\phi Z N}{60}\left(\dfrac{P}{A}\right) = 120$

$\Rightarrow \dfrac{\phi Z}{60} \cdot \dfrac{P}{A} = 0.02$

$\Rightarrow \dfrac{\phi Z P}{A} = 60 \times 0.02$

$= 1.2$

$T = \dfrac{E_{b2} \cdot I_{a2}}{\omega}$

$= \dfrac{\dfrac{\phi Z N_2}{60} \times \dfrac{P}{A} \times I_{a2}}{2\pi \dfrac{N_2}{60}}$

$= \dfrac{\phi Z P}{2\pi A} \cdot I_{a2}$

$\Rightarrow 0.5 = \dfrac{1}{2\pi}(1.2)\, I_{a2}$

$\Rightarrow I_{a2} = 2.61$ A

$$E_{b2} = V - I_{a2} \cdot R_a$$

$$= 60 - 2.61 \times 2.5$$

$$= 53.47 \text{ V}$$

$$\frac{N_2}{N_1} = \frac{E_{b2}}{E_{b1}} \times \frac{\phi_1}{\phi_2} \quad [\because \phi_1 = \phi_2]$$

$$\Rightarrow \frac{N_2}{6000} = \frac{53.47}{120} \Rightarrow N_2 = 2673 \text{ rpm.}$$

Q. A 230 V, 250 rpm, 100 A seperately exc. dc motor has an arm resistance of 0.5 Ω. The motor is connected to 230 V dc supply and rated dc voltage applied to the field wdg. It is driving a load whose speed torque char. given by $T_L = 500 - 10\omega$. ω – is the rotational speed expressed in rad/sec. and T_L = load torque in Nm. Find ss speed at which the motor drive the load and arm. current drawn by it from the source, neglect rotational losses of m/c.

Sol:

230 V, 250 rpm, 100 A, $R_a = 0.5\,\Omega$

$V = 230V$. Sep. exc. dc motor.

$T_L = 500 - 10\omega \Rightarrow N = ?,\ I_a = ?$

At rated condition ie 250 rpm,

$E_b = 230 - 100 \times 0.5$

$= 180V$

$\Rightarrow E_b = k\omega$

$\Rightarrow k = \frac{E_b}{\omega}$

$= \frac{180}{2\pi \times \frac{250}{60}} = 6.87$ V/rad/sec

For sep. exc. & shunt m/c

$E_b = k\omega$

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

Let

ω_m = Actual speed of the motor.

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

$k = \frac{T}{I_a} = Nm/Amp.$

$T_{em} = J\frac{d\omega}{dt} + B\omega + T_L$

$J\frac{d\omega}{dt} = 0$, $B\omega = 0$

$T_{em} = \frac{E_b I_a}{\omega_m}$

$= \frac{k\omega_m \cdot I_a}{\omega_m} = k \cdot I_a$

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

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

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

$\Rightarrow \omega_m = 31.5$ rad/sec

$= 31.5 \times \frac{60}{2\pi}$

$= 301$ rpm.

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

$= ~~6.87~~ \left[\frac{230 - 6.87 \times 31.5}{0.5}\right]$

$= 26.9$ A

Q. A 250V dc series motor has arm & series field resistance of 0.25 Ω, 0.15 Ω res. The current for developing 80 Nm at 1200 rpm is ___

(a). 86.4 A (b). 43.2 A

(c). (20+1) A (d). 50 A.

Sol:

250V, $R_a = 0.25\,\Omega$, $R_{se} = 0.15\,\Omega$

$I_a = ?$ for $T = 80\,Nm$, $N = 1200$ rpm.

$$T_e = \frac{E_b I_a}{\omega}$$

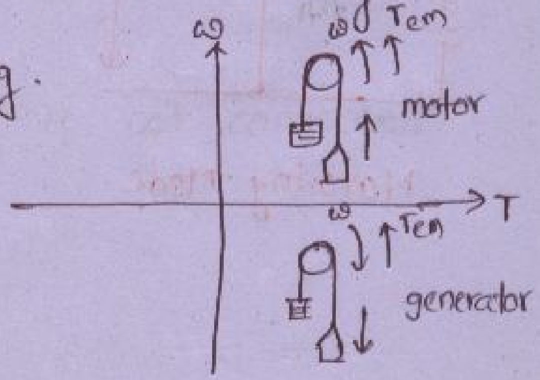
$$\Rightarrow T_e \cdot \omega = E_b \cdot I_a$$

$$\Rightarrow 80 \times 2\pi \times \frac{1200}{60} = (250 - I_a \times 0.4) \cdot I_a$$

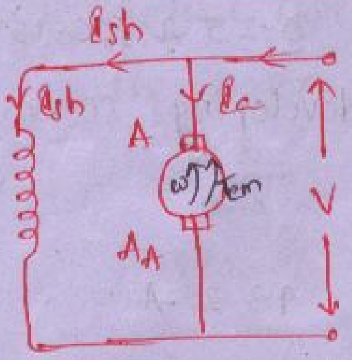
$$\Rightarrow I_a = 43.2\,A$$

ELECTRIC BRAKING:

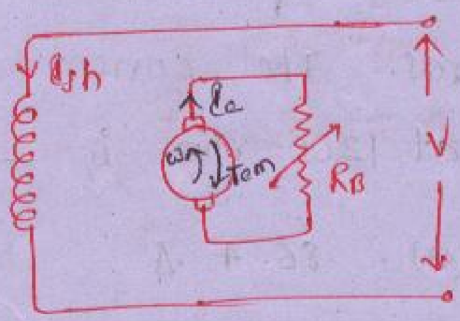
1. Dynamic braking (or) Resistance (or) Rheostatic braking.
2. plugging (or) Reverse current braking
3. Regenerative braking.



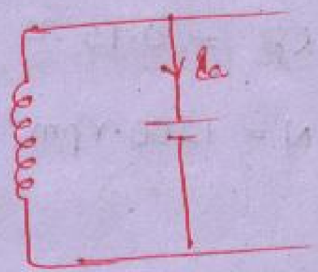
DYNAMIC BRAKING :

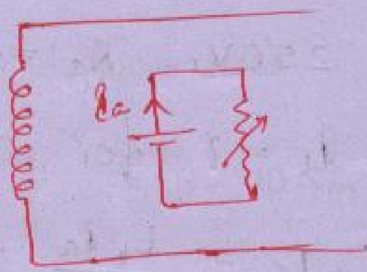


Motoring Mode



Braking mode



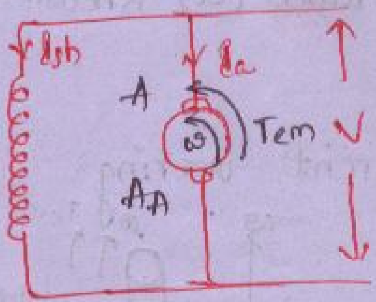


Braking torque $T_B = \frac{E_b \cdot I_a}{\omega}$

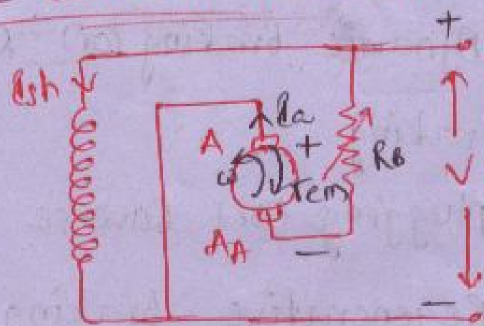
$$= \frac{\frac{\phi Z N}{60} \times \frac{P}{A} \cdot I_a}{2\pi \frac{N}{60}}$$

$$\propto \phi I_a$$

PLUGGING : (or) REVERSE CURRENT BRAKING :-



Motoring Mode



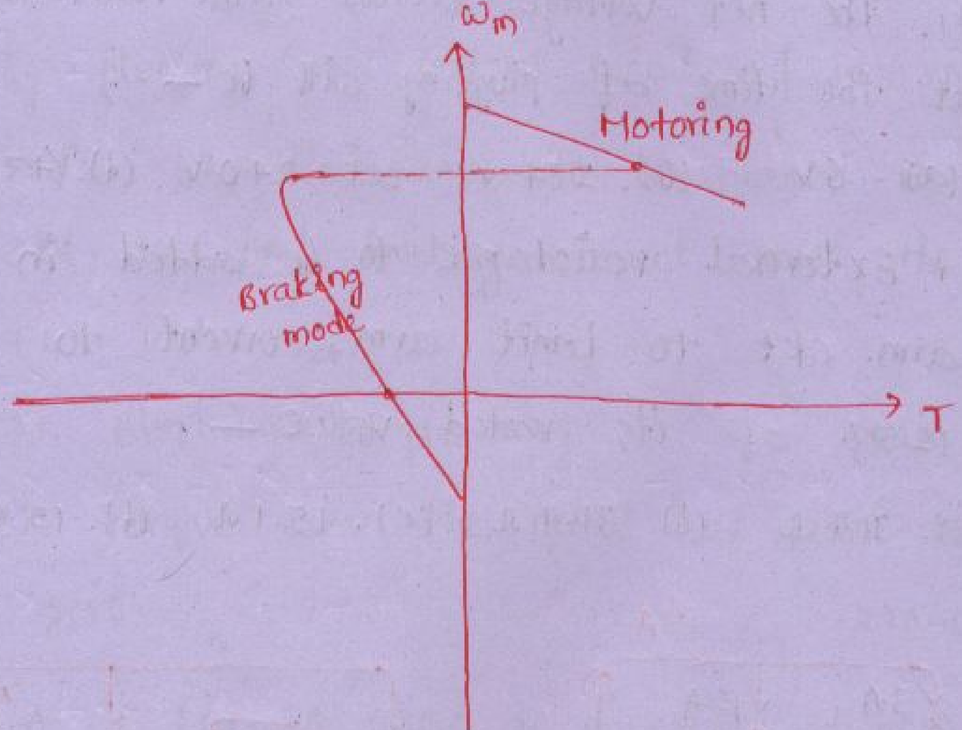
Plugging mode

{ when current reverses, so that torque also reverses }

R_B is inserted to limit current during plugging. $I_a = \frac{V+E_b}{R_a+R_B}$ → current during plugging.

At standstill, $N=0, \Rightarrow E_b=0$

$\Rightarrow I_a = \frac{V}{R_a+R_B}$.



Under this method, braking torque is also available when motor is stopped. Then supply has to be disconnected and mech. brakes are applied

Otherwise if supply is not connected properly due to

plugging is faster compared with dynamic braking.

Q. A 240 V dc shunt motor draws 15 A while supplying the rated load at rated speed of 80 rad/sec. The arm. resistance is 0.5 Ω & field wdg resistance is 80 Ω.

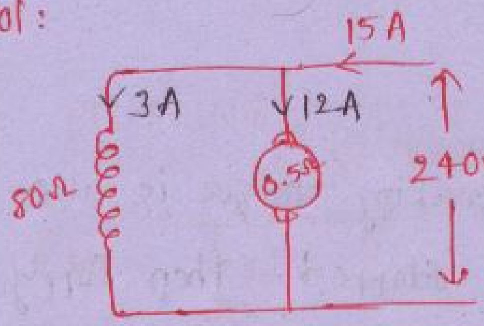
(1). The net voltage across arm. resistance at the time of plugging will be —

(a). 6 V (b). 234 V (c). 240 V (d). (470+4) V

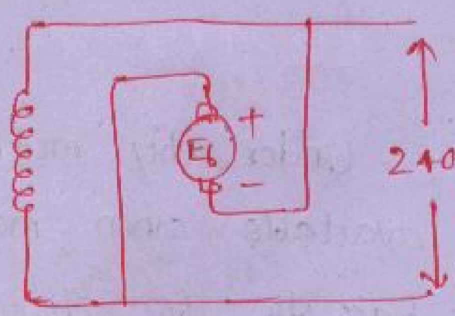
(2). External resistance to be added in arm. ckt to limit arm. current to 125% of its rated value —

(a). 31.1 Ω (b) 31.9 Ω (c). 15.1 Ω (d). 15.9 Ω

Sol:



During motoring



During plugging

$E_b = 240 - 12 \times 0.5$

$= 234V$

∴ Net voltage across the arm, & arm. resistance

$= 240 + 234$

$=$

$I_a = 12 \times 12.5$

Q. A 220V, 970, 100A dc shunt motor has an arm. resistance of 0.05 Ω, it is braked by plugging from initial speed of 1000 rpm. calc. (1). Resistance to be placed in arm. ckt to limit braking current twice the FL value — ? 1.16

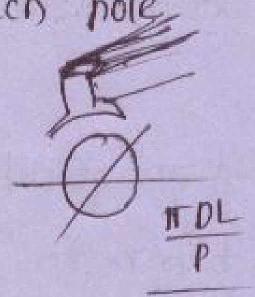
(2). Braking torque — ? 423.3 Nm

(3). Torque when the speed has fallen to zero 210.7 Nm

Q. A 10 kW, 4 pole, dc generator develop an emf of 200V at 1500 rpm, the arm. has lap connected wdg. The avg. flux density over a pole pitch is 0.9 T. If the length and dia. of arm are 0.25m & 0.2m res.ly. Then the no. of arm. turns required will be — ? 114

$\phi_{av} = B_{av} \times$ Area under each pole

$= B_{av} \times \frac{\pi DL}{P}$



$E_g = \frac{\phi Z N}{60} \cdot \frac{P}{A} = 200V$

$T = \frac{Z}{2}$.