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CMRIT

Internal Assesment Test –III

Sub:	Transformers & Generators (T&G)							Code:	18EE33
Date:	14/10/2019	Duration:	90 mins	Max Marks:	50	Sem:	3rd	Branch:	EEE

Answer any five full questions. Sketch figures wherever necessary.

		Marks	OBE CO	OBE Level
1	What is synchronization of alternator? What are the conditions for proper synchronization of an alternator? How 3φ alternator is synchronized?	10	CO6	L3
2.a	Write a note on V curves and Inverted V curves of alternator.	04	CO5	L1
2.b	Write a short note on power angle characteristics of an alternator	06	CO6	L2
3	With neat diagram explain slip test to determine direct axis reactance and quadrature axis reactance of a salient pole synchronous generator.	10	CO5	L3
4	With a phasor diagram , explain the concept of two reaction theory in a salient pole alternator	10	CO5	L3

5 A 4.5 MVA , Y connected alternator rated at 4750 V at 50 Hz has the OCC given by the following data : (10, CO6, L4)

If in A	50	100	150	200	250	300	350	400	450
Voc(line)	1620	3150	4160	4750	5130	5370	5550	5650	5750

A field current of 200 A is found necessary to circulate I_{FL} on SC of alternator. Calculate by i) EMF method ii) MMF method. The voltage regulation at full load 0.8 pf lagging. Neglect resistance and comment on your result.

		Marks	CO	Level
6 a	Derive the expression for synchronizing power	05	CO5	L3
6 b	A 3 phase star connected alternator supplies a current of 10A having phase angle of 30^0 lagging at 400 V. Find the load angle and components of armature current I_d and I_q, if X_d=10 Ω and X_q=6.5 Ω. Assume armature resistance to be negligible.	05	CO5	L4
7	Name the various methods for determining voltage regulation of alternator. Explain any one of the methods in detail.	10	CO6	L3
8	A 4 pole 3-phase 50Hz, star connected alternator has 60 slots with 4 conductors/slot. Find the phase voltage induced for a flux/pole of 0.943 wb. The coils are short pitched by i) 3 slots, ii) 2 slots and iii) 0 slots	10	CO5	L4

*******All the Best******

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1.

10.4 Methods of Synchronisation

Synchronization : The process of switching of alternator to another alternator or bus bar without any interuption is called synchronization.

(or)

Two alternators connected in parallel without interruption.

Necessary Condition for synchronization.

-> Terminal voltage of incoming machine should be same as that of bus bar voltage.
[Incoming machine – The machine which is to be synchronized]

-> Frequency must be same as that of the incoming machine as well as that of bus bar. Speeds have to be adjusted properly [$f = PN/120$]

-> The phase of alternator voltages must be identical with that of bus bar voltage.

The above conditions have to be satisfied for better synchronization.

The first condition can be satisfied by using voltmeter.

Lamp method can be used for next two conditions.

Synchroscope : Special device for synchronizing machines.

Synchronization of three phase Alternators

The setup for synchronization of alternators is shown in Fig 10.4.6.

The phase sequence must be same.

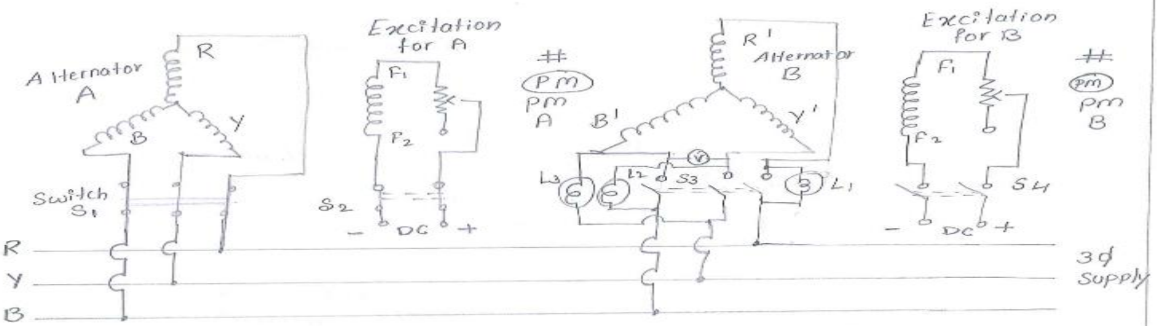

Fig. 10.4.6 Sychronization of Alternators.

-> If the phase sequence is same for incoming machine and bus bar, the lamps would dark out or glow up simultaneously.

-> Alternator A is connected to bus bars, so it is setup to run at synchronous speed and excitation is adjusted to build up rated voltage.

-> Alternator B is connected to bus bar so it has to be synchronized with Alternator A

Synchronization process has following steps :

1. Adjust the speed of Alternator B to synchronous speed using prime mover B.
2. The field excitation is set up such that induced emf of B is equal to induced emf of A. This can be verified using Voltmeter.

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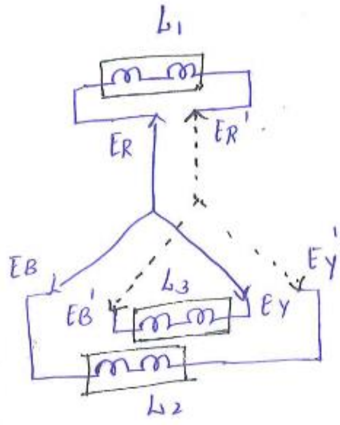
3. The lamp pairs are connected in such a way that pair L_1 is straight connected while L_2 & L_3 are cross connected as shown in fig 10.4.7.



10.4.7

The lamp pairs are supplied by two supplies i.e voltage supply by bus bar and supply generated by alternator B.

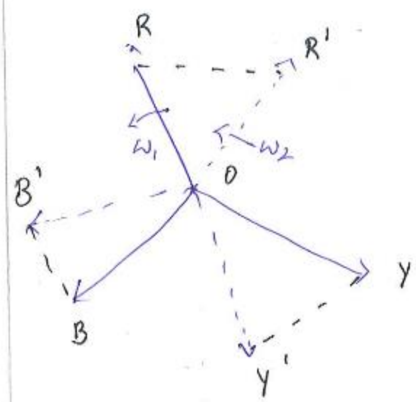
The bus bar voltages are represented by OR OY & OB while that of alternator B are OR', OY' and OB'.

The resultants of theses are voltages across lamp pair.

like $E_{RR'}$ is across L_1

$E_{YB'}$ is across L_2

$E_{Y'B}$ is across L_3



→ If there is a difference between two frequencies due to difference in speeds of alternators the lamps will become dark & bright in sequence. This sequence tells wheather incoming alternator frequency is less or more.

Sequence L_1, L_2, L_3 tells that machine B is faster

Sequence $L_3 L_2, L_1$ tells that machine B is slower.

Prime mover is used to adjust speed accordingly to match the frequencies.

If lamp pair is becoming dark & bright simultaneously it indicates incorrect phase sequence., that can be corrected by interchanging the leads.

2.a.

10.3 V- curves, Parallel operation of generators and load sharing.

→ The graph of armature current against the field current for various constant output powers is called V-curves of sync. generator.

→ Consider a variable excitation constant load, P_1, P_2, P_3 & P_4 are constant power lines.

Consider a constant power line P_1, shown in fig 10.3.1.

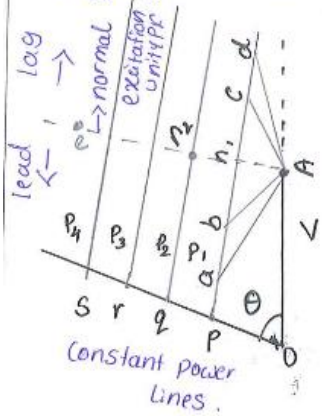
There are two phasors one proportional to armature current and another proportional to excitation [field current].

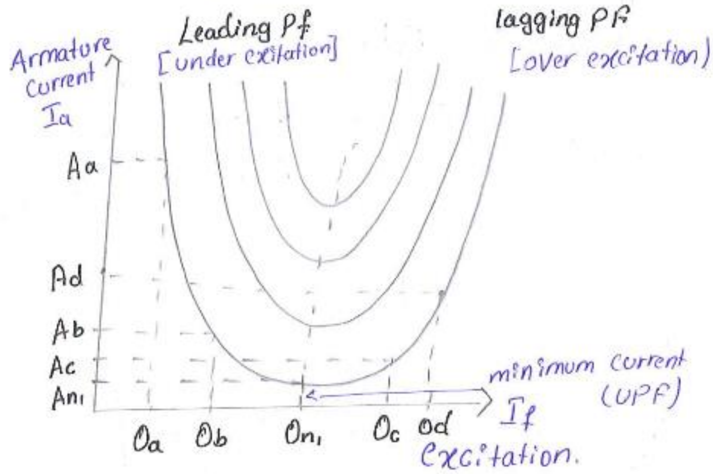
Aa, Ab, An_1, Ac & Ad → are proportional to armature current

Oa, Ob, On_1, Oc & Od → Proportional to excitation.

An_1 is unity power factor & represents min. current.

Phasors below this represent leading PF and above represent lagging PF currents.





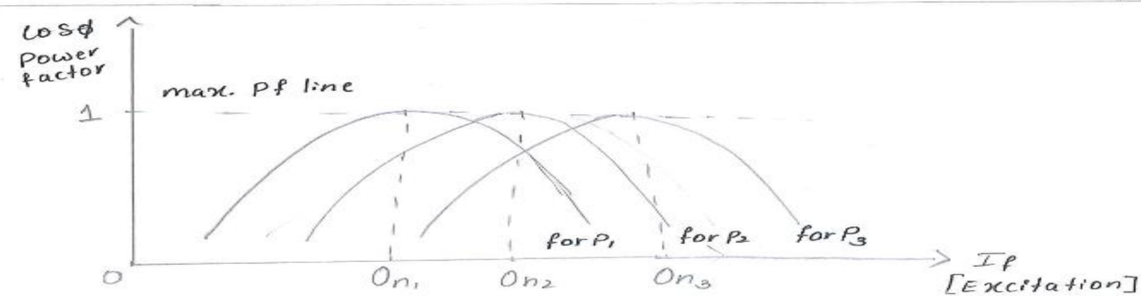
The V curve for constant power starts from minimum excitation for which current is max. but leading. This is under excitation

As excitation goes on increasing current decreases & reaches minimum, ~~Further if excitation is increased, current increases but this time with lagging Pf.~~ This is normal excitation and unity Pf condition.

Further if excitation is increased current increases but now Pf is lagging in nature This is over excitation.

Inverted V curve: If the graph of power factor [$\cos\phi$] is plotted against the field current [excitation], the shape of the graph is like Inverted V.

As power increases, the excitation required for max. power factor increases.

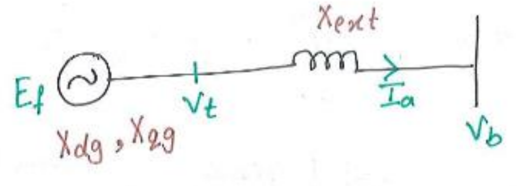


2.b.

9.6 Power angle Characteristics (Power angle Curve)

The one-line diagram of Salient pole synchronous machine Connected to infinite bus-bar of voltage V_b through a reactance X_{ext}. (as shown in fig 9.6.1)

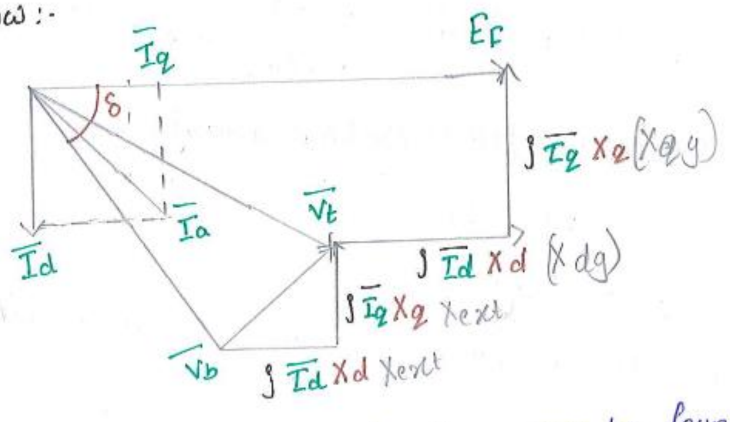
The same one-line diagram is applicable for non-salient pole machine just $X_d = X_q$



$$X_d = X_{dg} + X_{ext}$$
$$X_q = X_{qg} + X_{ext}$$

The resistance part of Generator and winding are ignored.

The phasor diagram for above one-line diagram is as shown below:-



The real power delivered to bus-bars can be found from above phasor diagram.

$$P_e = I_d V_b \sin\delta + I_q V_b \cos\delta \quad ---> 9.6.1$$

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From phasor,

$$I_d X_d + V_b \cos\delta = E_f \Rightarrow I_d = \frac{E_f - V_b \cos\delta}{X_d} \quad \text{------} \rightarrow 9.6.2$$

$$V_b \sin\delta = I_q X_q \Rightarrow I_q = \frac{V_b \sin\delta}{X_q} \quad \text{------} \rightarrow 9.6.3$$

Substitute 9.6.2. & 9.6.3 in eqn 9.6.1

$$P_e = \frac{E_f - V_b \cos\delta}{X_d} V_b \sin\delta + \frac{V_b \sin\delta}{X_q} V_b \cos\delta$$

$$P_e = \frac{E_f V_b \sin\delta}{X_d} + \frac{V_b^2 \sin\delta\cos\delta}{X_q} - \frac{V_b^2 \sin\delta\cos\delta}{X_d}$$

$$P_e = \frac{E_f V_b \sin\delta}{X_d} + V_b^2 \left[\frac{\sin 2\delta}{2 X_q} - \frac{\sin 2\delta}{2 X_d} \right]$$

$$\boxed{P_e = \frac{E_f V_b \sin\delta}{X_d} + V_b^2 \frac{X_d - X_q}{2 X_d X_q} \sin 2\delta}$$

$\rightarrow$ 9.6.4

Reluctance power $\rightarrow$ $V_b^2 \frac{X_d - X_q}{2 X_d X_q} \sin 2\delta$

For a non-salient pole / cylindrical generator

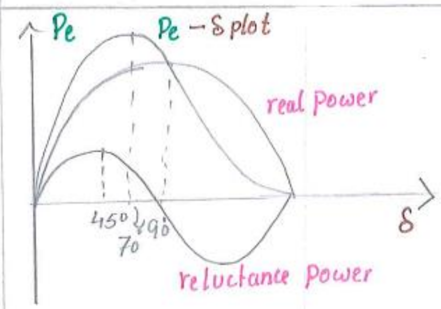
$$X_d = X_q$$

reluctance power = 0

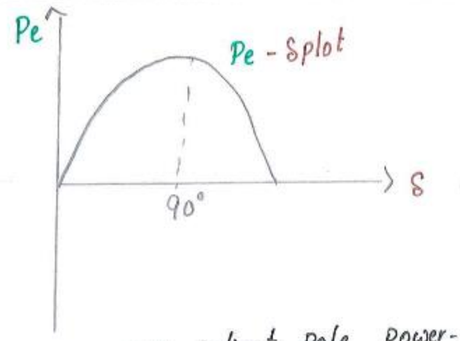
$\therefore$ reluctance Power varies as $\sin 2\delta$. $\therefore$ max. value occurs at 45°.

A sync. motor with salient poles but no field winding is known as reluctance Power.

It is used for low-power Constant Speed applications where Special arrangements for dc excitation would be



Salient pole power-angle diagram



non-salient pole power-angle diagram

For salient pole max. power occurs at $\delta = 70°$.
For non-salient pole max. power occurs at $\delta = 90°$

$$P_e = \frac{E_f V_b \sin\delta}{X_d} + \frac{V_b^2}{2}\frac{X_d - X_q}{X_d X_q}\sin 2\delta$$

(or)

$$P_e = \frac{E_f V_b \sin\delta}{X_d} - \frac{V_b^2}{2}\frac{X_q - X_d}{X_d X_q}\sin 2\delta$$

→ For salient pole Alternator

$$P_e = \frac{E_f V_b \sin\delta}{X_d}$$

→ For non-salient pole Alternator ($X_d = X_q$)

3.

10-6 Slip test, Determination of X_d & X_q

Method of determination of X_d & X_q is called slip test.

→ Normally alternator is run at synchronous speed and voltage excitation is provided through field winding and voltage gets induced in armature.

→ But while conducting slip test, alternator is run at speed less than synchronous speed and field is kept open and a very low value of voltage is given to alternator's armature using a 3-phase supply.

→ The three phase currents drawn by armature produce a rotating flux, hence armature mmf wave is rotating at sync. speed, the armature is not rotating.

→ The rotor is made to rotate less than sync. speed. So the armature mmf moves slowly past the field poles at

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a slip speed $(n_s - n)$

→ For stator mmf aligned with d-axis, flux ϕ_d is setup and effective reactance offered by alternator is X_d.

→ For stator mmf aligned with q-axis, flux ϕ_q is setup and effective reactance offered by alternator is X_q.

→ because of non-uniform air gap, the current drawn by armature also varies.

→ Along q-axis current drawn is maximum and minimum along d-axis. while the voltage at terminals is maximum at d-axis minimum at q-axis.

Hence the reactances.

$$X_d = \frac{\text{maximum voltage}}{\text{minimum current}}$$

$$X_q = \frac{\text{minimum voltage}}{\text{maximum current}}$$

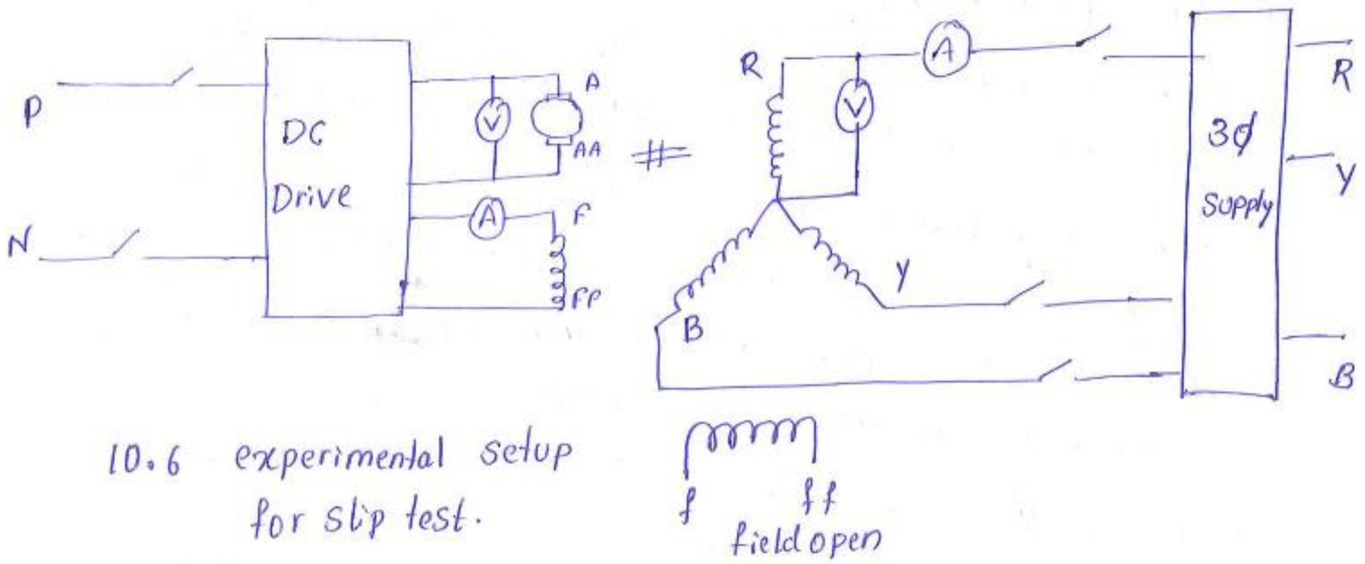
$$I_d = I_a \sin\psi$$

$$I_q = I_a \cos\psi$$

$$\tan\psi = \frac{V_t \sin\phi + I_a X_q}{V_t \cos\phi + I_a R_a} \qquad \delta = \psi - \phi \quad \text{- lagging pf}$$

$$\tan\psi = \frac{V_t \sin\phi - I_a X_q}{V_t \cos\phi + I_a R_a} \qquad \delta = \psi + \phi \quad \text{- leading pf}$$

$$E_f = V_t \cos\delta + I_q R_a + I_d X_d$$

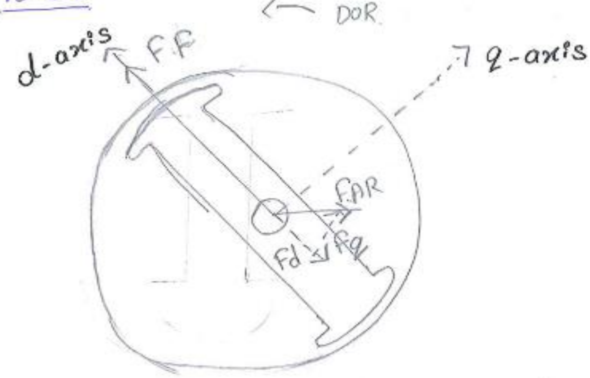


10.6 experimental setup for slip test.

10.2 Two-reaction theory

Cylindrical pole alternators have uniform air gap, because of this field flux as well as armature flux vary sinusoidally in air gap, hence reactance remains constant.
But in salient pole alternators the length of air gap varies and reluctance also varies, because of this armature flux and field flux cannot vary sinusoidally so the reluctance on which mmfs act are different in case of salient pole alternators

The cross sectional view of salient pole machine is shown in 10.2.1.



10.2.1 Salient-pole synchronous machine.

The reluctance offered by to mmf wave is lowest when it is aligned along the field pole axis - direct axis reactance. and highest when it is aligned 90° to field axis - quadrature axis reactance.

The theory behind this analysis of distributing effects caused by salient pole construction is called - Two reaction theory.

Component acting along direct axis → Can be magnetizing or demagnetizing

Component acting along quadrature axis → Cross magnetizing.

The stator mmf wave and flux distribution in air gap along direct axis and quadrature axis of pole is shown in fig. 10.2.2.

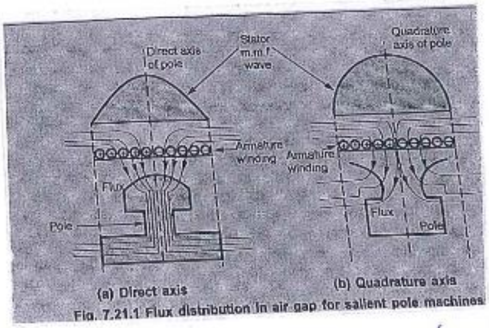


Fig. 7.21.1 Flux distribution in air gap for salient pole machines

10.2.2.

The air gap is least in the centre of poles and gradually increases as we move away from centre, because of this shape the mmf will be sinusoidal.

When current flows through armature it produces its own mmf wave - F_{AR}

F_{AR} is resolved it two components one along d-axis and one along q-axis. F_d - direct axis, F_q - quadrature axis

I_a is also resolved into two components. I_d - direct axis, I_q - quadrature axis

F_{AR} F_d & F_q positions are shown in fig 10.2.1.

The field flux F_f is along d-axis.

The phasor diagram for all the quantities is shown in fig 10.2.3

→ F_f is along d-axis

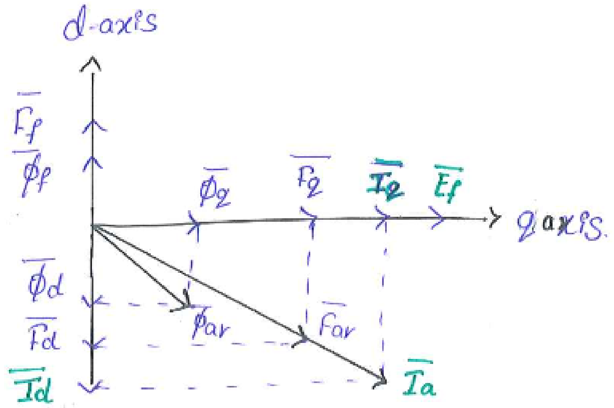
F_d is 180° opposite to F_f.

F_d causes flux ϕ_d and hence current I_d

E_f leads I_d by angle 90°

E_f - excitation emf due to $\vec{F_f}$

The quadrature axis is 90° from d-axis. and along E_f.



10.2.3 - Phasor diagram.

The flux Components/Pole produced by d-axis & q-axis of armature reaction mmf are

$$\phi_d = P_d F_d$$
$$= P_d K_{ar} I_d \rightarrow (1)$$

P_d - Permeance along d-axis.

K_{ar} - armature reaction Coefficient.

$$\phi_q = P_q F_q$$
$$P_q K_{ar} I_q \rightarrow (2)$$

P_q - permeance along q-axis

$P_d > P_q$

ϕ_{ar} is the resultant of ϕ_d & ϕ_q and is not in phase with $\bar{F}_{ar}$ and $\bar{I}_a$ because $P_d > P_q$ and also it lags or leads I_a ~~by~~ depending upon magnitude of permeance. P_d & P_q.

Emf induced by ϕ_d & ϕ_q are.

$$\bar{E}_d = K_e \phi_d \angle -90° = -j K_e \phi_d$$
$$\bar{E}_q = K_e \phi_q \angle -90° = -j K_e \phi_q$$

[b/c induced emf lags flux by 90°]

K_e - emf constant of armature winding.

So, the EMF resultant in the machine is given by

$$\overline{E_r} = \overline{E_f} + \overline{E_d} + \overline{E_q}$$

$$= \overline{E_f} - j K_e \phi_d - j K_e \phi_q$$

substitute ① & ②

$$\overline{E_r} = \overline{E_f} - j K_e P_d K_{ar} \overline{I_d} - j K_e P_q K_{ar} \overline{I_q}$$

$X_d^{ar} = K_e P_d K_{ar}$ – reactance equivalent to d-axis component of armature reaction

$X_q^{ar} = K_e P_q K_{ar}$ – reactance equivalent to q-axis component of armature reaction

& $X_d^{ar} > X_q^{ar}$ $\because$ $P_d > P_q$

$$\therefore \overline{E_r} = \overline{E_f} - j X_d^{ar} \overline{I_d} - j X_q^{ar} \overline{I_q}$$

$$\boxed{\overline{E_f} = \overline{E_r} + j X_d^{ar} \overline{I_d} + j X_q^{ar} \overline{I_q}}$$

For cylindrical-rotor machine

$X_d^{ar} = X_q^{ar} = X^{ar}$

$$\boxed{\overline{E_f} = \overline{E_r} + j(I_d + I_q) X^{ar}}$$

The resultant emf $\overline{E_r}$

$$\overline{E_r} = \overline{V_t} + \overline{I_a} R_a + j I_a X_\ell \qquad \overline{I_a} = \overline{I_q} + \overline{I_d}$$

So,

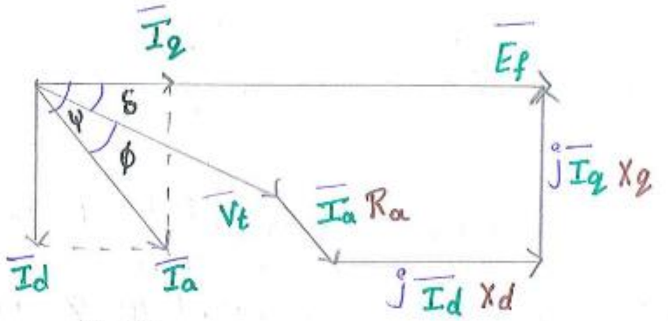
$$\overline{E_f} = \overline{V_t} + \overline{I_a} R_a + j(X_d^{ar} + X_\ell)\overline{I_d} + j(X_q^{ar} + X_\ell)\overline{I_q}$$

$X_d^{ar} + X_\ell = X_d$ – d-axis sync. reactance $\qquad X_d > X_q$

$X_q^{ar} + X_\ell = X_q$ – q-axis sync. reactance.

$$\boxed{\overline{E_f} = \overline{V_t} + \overline{I_a}R_a + j\,\overline{I_d}X_d + j\,\overline{I_q}X_q} \rightarrow (3)$$

The phasor diagram depicting currents & voltages as per eqⁿ (3) is drawn in fig 10.2.4.



10.2.4.

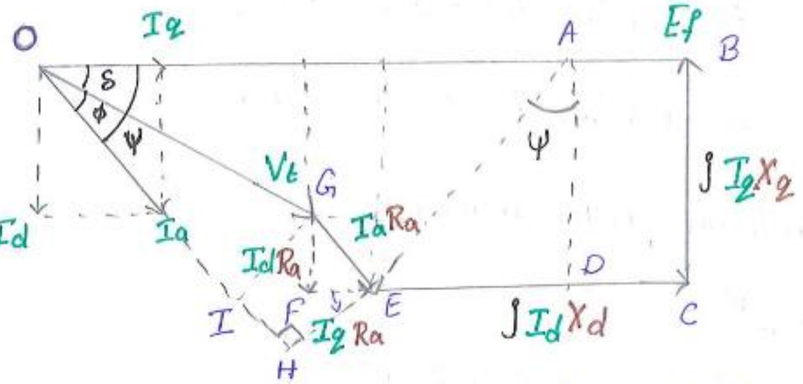
$\overline{I_d} = \overline{I_a}\sin\psi \rightarrow (4)$

$\overline{I_q} = \overline{I_a}\cos\psi \rightarrow (5)$

The drop I_aR_a has two components

$I_dR_d \rightarrow$ drop due to R_a in phase with I_d

$I_qR_a \rightarrow$ drop due to R_a in phase with I_q



$$\cos\psi = \frac{DA}{AE} = \frac{I_qX_q}{AE} \rightarrow (6)$$

from eqⁿ (5)

$$\cos\psi = \frac{\overline{I_q}}{\overline{I_a}} \rightarrow (7)$$

from (6) & (7)

$$\frac{I_q}{I_a} = \frac{I_qX_q}{AE}$$

$$AE = I_aX_q$$

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$\tan\psi = \frac{AH}{OH}$ (from Δ^{le} OAH)

$AH = AE + EH$ $(EH = QI)$

$AH = I_a X_q + V_t \sin\phi$

$OH = OI + HI$

$OH = V_t \cos\phi + I_a R_a$

$I_d = I_a \sin\psi$

$I_q = I_a \cos\psi$

$$\tan\psi = \frac{V_t \sin\phi + I_a X_q}{V_t \cos\phi + I_a R_a}$$

$$\delta = \psi - \phi$$

} for lagging pf

$$E_f \quad V_t \cos\delta + I_q R_a + I_d X_d$$

$$\tan\psi = \frac{V_t \sin\phi - I_a X_q}{V_t \cos\phi + I_a R_a}$$

$$\delta = \psi + \phi$$

} for lead pf.

5.

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(5) EMF method

$$E_{ph} = \sqrt{(V_t \cos\phi + I_a R_a)^2 + (V_t \sin\phi \pm I_a X_s)^2}$$

$V_t = \frac{4750}{\sqrt{3}} = 2742.41\,V$

$\cos\phi = 0.8$

$\sin\phi = 0.6$

$I_a = ?$

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

$4.5 \times 10^6 = \sqrt{3}\,(4750)\,(I_L)\,(0.8)$

$I_L = I_{ph} = I_a = 683.70\,A$

$V_{oc} = V_t = 2742.41\,V$

$I_{sc} = I_a = 683.70\,A$

$Z_s = \frac{V_{oc}}{I_{sc}}$

$= \frac{2742.41}{683.70} = 4.01\,\Omega$

$R_a = 0$

so,

$X_s = Z_s$

$X_s = 4.01\,\Omega$

$+ \rightarrow$ lagging

$$E_{ph} = \sqrt{((2742.4)0.8 + 0)^2 + ((0.6)(2742.4) + (683.7)(4.01))^2}$$

$E_{ph} = 4905.07\,V$

$$\%R = \frac{E_{ph} - V_{ph}}{V_{ph}} \times 100 \qquad \frac{4905.07 - 2742.41}{2742.41} \times 100$$

$\%R = 78.85\%$

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mmf method

$$F_R = \sqrt{F_o^2 + F_{AR}^2 + 2 F_o F_{AR} \sin\phi}$$

$F_o = 200\ A$

$F_{AR} = 200\ A$

$$F_R = \sqrt{(200)^2 + (200)^2 + 2(200)(200)(0.6)}$$

$F_R = 357.77\ A$

$E_0 = 5550\ V$

$$\%R = \frac{E_0 - V}{V} \times 100$$

$$= \frac{5550 - 4750}{4750} \times 100$$

$\%R = 16.84\ \%$

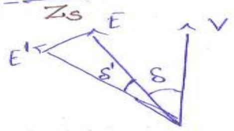
6.a.

Expression for Synchronizing Power (P_{sy})

-> Consider an alternator operating at an power angle δ. E leads V by δ.

-> let power input be increased so that it will operate @ new power angle $\delta + \delta'$.

-> The current flowing in machine $I_{sy} = \frac{E_{sy}}{Z_s}$



The initial input of alternator,

$$P_{i1} = \frac{E}{Z_s}\left[E\cos\theta - V\cos(\theta + \delta)\right]$$

The new power input P_{i2} is given by,

$$P_{i2} = \frac{E}{Z_s}\left[E\cos\theta - V\cos(\theta + \delta \pm \delta')\right]$$

$$P_{sy} = P_{i2} - P_{i1}$$

$$= \left\{\frac{E}{Z_s}\left[E\cos\theta - V\cos(\theta + \delta \pm \delta')\right] - \frac{E}{Z_s}\left[E\cos\theta - V\cos(\theta+\delta)\right]\right\}$$

$$= \frac{E}{Z_s}\left[-V\cos(\theta + \delta + \delta') + V\cos(\theta + \delta)\right] \quad \text{considering } \delta + \delta'$$

$$= \frac{EV}{Z_s}\left[\cos(\theta+\delta) - [\cos((\theta+\delta) + \delta')]\right]$$

$$= \frac{EV}{Z_s}\left[\cos(\theta+\delta) - \cos(\theta+\delta)\cos\delta' + \sin(\theta+\delta)\sin\delta'\right]$$

$$= \frac{EV}{Z_s}\left[\cos(\theta+\delta) - \cos(\theta+\delta)\left[1 - \cos\delta'\right]\right]$$

$$= \frac{EV}{Z_s}\left[\sin(\theta+\delta)\sin\delta' + \cos(\theta+\delta)\left[1 - \cos\delta'\right]\right]$$

$$= \frac{EV}{Z_s}\left[\sin(\theta+\delta)\sin\delta' + \cos(\theta+\delta)\left[2\sin^2\frac{\delta'}{2}\right]\right]$$

δ' is small the $\delta'/2$ is very small.

`

So,

$$P_{sy} = \frac{EV}{Z_s} \sin(\theta+\delta)\sin\delta'$$

ignoring R_a

$Z_s = X_s$

$$P_{sy} = \frac{EV}{X_s} \sin(\theta+\delta)\sin\delta'$$

if $\theta = 90°$

$$\boxed{P_{sy} = \frac{EV}{X_s} \cos\delta \sin\delta'}$$

considering δ' & δ very small

$$P_{sy} = \frac{EV}{X_s} \cos\delta$$

Torque

$$\boxed{T_{sy} = \frac{P_{sy}}{\left(\frac{2\pi N_s}{60}\right)}}$$

6.b.

6b. Given

$I_a = 10\ A$

$\phi = 30$

$V_L = 400V$

$X_d = 10\Omega$

$X_q = 6.5\Omega$

$V_t = \frac{400}{\sqrt{3}} = 230.94V$

$\cos\phi = 0.866$

$\sin\phi =$

$$\tan\psi = \left(\frac{V_t \sin\phi + I_a X_q}{V_t \cos\phi + I_a R_a}\right)$$

$$= \left(\frac{230.94(0.5) + (10)(6.5)}{(230.94)(0.866) + 0}\right)$$

$$\boxed{\psi = 42.06°}$$

$$\delta = \psi - \phi$$

$$= 42.06 - 30$$

$$\boxed{\delta = 12.06°}$$

load angle $= 12.06°$

$$I_d = I_a \sin\psi = (10)(\sin(42.06)) = 6.69\ A$$

$$I_q = I_a \cos\psi = 10 \cos(42.06) = 7.42A$$

Components of armature current

$I_d = 6.69A$
$I_q = 7.42A$

`

7.

9.5 Voltage Regulation by EMF, MMF and ZPF method:-

Regulation can be found by
- Direct loading
- Indirect loading

Direct loading method is used to determine regulation of small machines.

Direct loading method:- Alternator is driven at synchronous speed and the terminal voltage is adjusted to its rated value V. The load is varied until the power and current ratings of rated values at desired power factor. Then entire load is thrown off while the speed and field excitation are kept constant.

The open-circuit or no-load voltage E_0 is read.

Hence, regulation can be found from

$$\%\,reg = \frac{E_0 - V}{V} \times 100$$

In Case Of large machines direct loading would be costly. Hence we use Indirect methods to determine no-load voltage E_o.

Following are the Indirect Loading methods.

1. EMF method or Synchronous Impedance method
2. MMF method or Ampere-turn method
3. Zero power factor or potier method

EMF or Synchronous Impedance method:-

To determine regulation from EMF method requires following data

1. Armature resistance per phase (R_a)
2. Open Circuit Characteristics which is graph of open Circuit Voltage against the field current.
3. Short Circuit Characteristics which is graph of Short Circuit current against field Current.

Circuit diagram

The Circuit diagram to perform open circuit as well as Short circuit test on alternator is shown in Fig. 9.5.1. (Page-97)
The alternator is Coupled to prime mover Capable of driving the alternator at its synchronous speed.
The armature is connected to the terminals of a Switch. The other terminals of the switch are short circuited through an ammeter. The voltmeter is connected across the lines to measure open Circuit voltage.

The field winding is connected to suitable DC supply with the rectifier and single phase AC supply.

Et

Open Circuit test:-

Procedure :-

i) Adjust speed to Synchronous Speed using prime mover
ii) The TPST switch is kept open
iii) Turn on 1-ϕ AC supply and energize field of alternator
iv) Vary the field current using 1-ϕ Auto transformer
v) Note down the Voltmeter reading (V_{oc}) for different values of field current.

Tabular coloumn (i)

I_f	V_{oc}	V_{oc} phase = $V_{oc}/\sqrt{3}$

Short Circuit test:-

-> Bring 1-ϕ Autotransformer to Zero position.
-> Close TPST switch, this will short circuit armature.
-> Field excitation is increased Gradually and full load current is obtained through armature winding.
-> Note down field current required for bringing full load current in armature.

Tabular coloumn (ii)

I_f (A)	Short Circuit armature current per phase (I_{asc}) A

The Values Obtained from Table (i) and Table (ii) are plotted which gives us open circuit characteristics [OCC] and short circuit characteristics [SCC] as shown in fig 9.5.2.

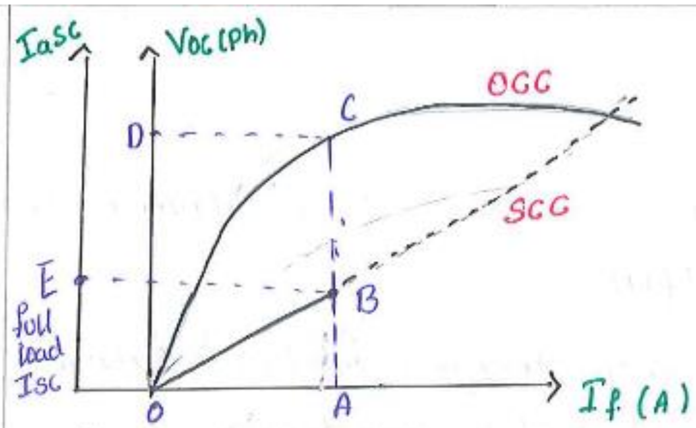


Fig 9.5.2. OCC & SCC

SCC is a straight line so with one point we can project it on both sides.

We can determine Z_s Value using the above graph so,

$$Z_s = \left. \frac{V_{oc(ph)}}{I_{asc\,ph}} \right|_{\text{for same } I_f}$$

$$Z_s = \left. \frac{OD}{OE} \right|_{\text{for same } I_f\,(OA)}$$

Regulation Calculations :

Armature resistance is measured by applying DC voltage across two terminals and measuring corresponding current. as shown in fig 9.5.3

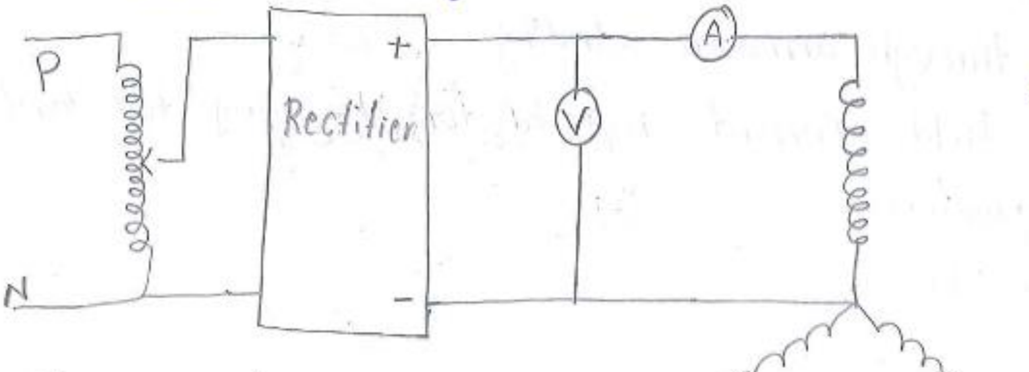


Fig 9.5.3

Tabular coloumn.

Sl.No	V	I	$R_{dc} = V/I$
1			
2			
3			

R_{dc} avg.

$R_a = 1.2\, R_{dc}$

or

$R_a = 1.6\, R_{dc}$ (in General)

Now $Z_s = \sqrt{(R_a)^2 + (X_s)^2}$

$$X_s = \sqrt{Z_s^2 - R_a^2}$$

Then we know that

$$E_{ph} = \sqrt{(V_{ph}\cos\phi + I_a R_a)^2 + (V_{ph}\sin\phi \pm I_a X_s)^2}$$

$+ \rightarrow$ lagging power factor
$- \rightarrow$ leading power factor

$$\therefore \quad \%\,\text{Regulation} = \frac{E_{ph} - V_{ph}}{V_{ph}} * 100$$

V_{ph} - phase value of rated voltage.

8.

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Q3.

8. Given

$P = 4$

3ϕ

$f = 50$

$S = 60$

$Z/s = 4$

$\phi = 0.943 Wb$

i) Coils are short pitched by 3 slots

$E_{ph} = 4.44 f \phi T_{ph} K_p K_d.$

$Z/s = 4$

$Z = 4 * S$

$Z = 4 * 60 = 240$

$T = \frac{Z}{2} = \frac{240}{2} = 120$

$T_{ph} = \frac{120}{3} = 40.$

$\beta = \frac{180}{n} = \frac{180}{15}$

$n = S/P = 60/4$

$n = 15$

$\beta = 12°$

$K_p = \cos(\alpha/2)$

$K_d = \frac{\sin(m\beta/2)}{m \sin(\beta/2)}$

α = no. of slots short pitched $* \beta$

$= 3(12)$

$\alpha = 36°.$

$m = S/P/ph = 15/3$

$m = 5$

$K_p = \cos(36/2)$

$K_p = 0.951$

$K_d = \frac{\sin(5(12)/2)}{5 \sin(12/2)}$

$K_d = 0.9566$

$E_{ph} = 4.44(50)(0.943)(40)(0.951)(0.9566) = 7617.90V$

ii) Short pitched by 2 slots.

$\alpha = 2 * 12 = 24^\circ$

$K_p = \cos(24/2) = 0.9781$

$E_{ph} = 4.44(50)(0.943)(40)(0.9781)(0.9566)$

$E_{ph} = 7834.18\ V$

iii) Short pitched by 0 slots. $\alpha = 0$

$K_p = 1$

$E_{ph} = 4.44(50)(0.943)(40)(0.9566)(1)$

$E_{ph} = 8010.41\ V$

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