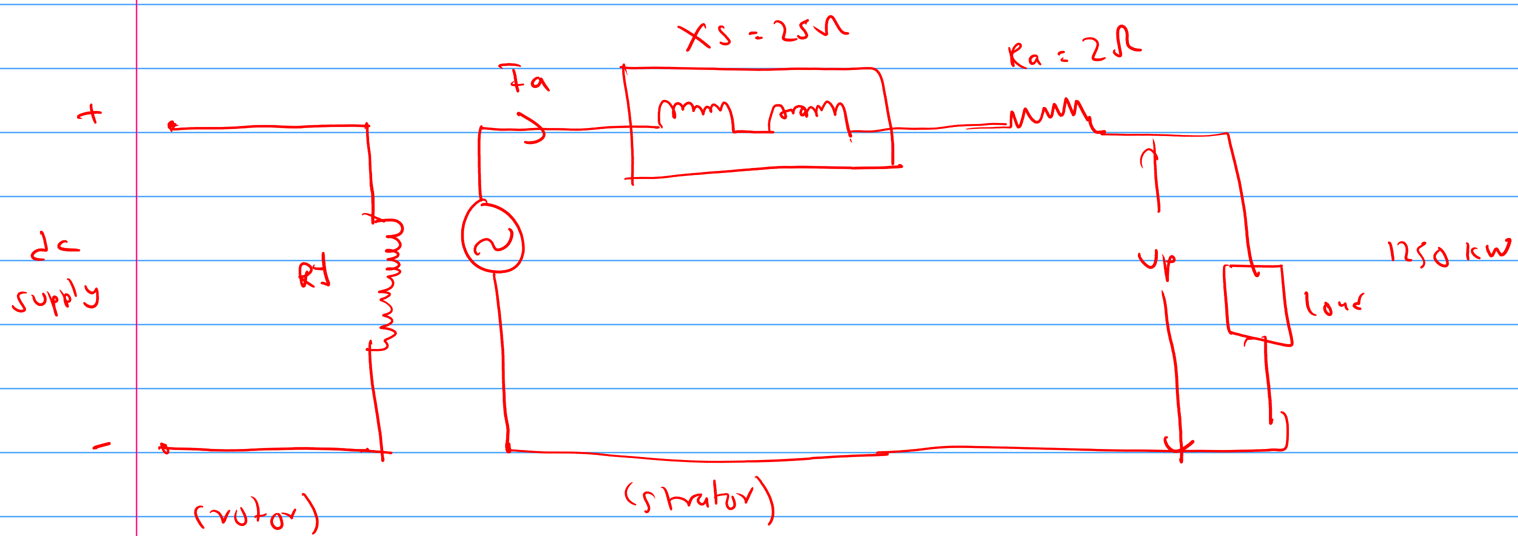
Synchronous generator numericals

① A 3ϕ star connected alternator (generator) is rated as 1500 kVA, 12000 V. The armature effective resistance and synchronous reactance are 2Ω and 25Ω respectively. Calculate the emf generated and percentage voltage regulation for a load of 1250 kW at pf

(i) 0.75 leading (ii) 0.75 lagging (iii) unity p.f

Soln:-



(i) p.f at 0.75 leading (capacitive)

$\cos\phi = 0.75$

$\phi = 41.409°$

$V_L = 12000$ V

$P = 1250$ kW

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

$1250 \times 10^3 = \sqrt{3} \times 12000 \times I_a \times 0.75$

$I_a = 80.1875$ A

$\therefore \tilde{I_a} = 80.1875 \angle 41.4°$

$V_p = \frac{V_L}{\sqrt{3}} = 6928.203V$ (star)

$\tilde{V}_p = 6928.203 \angle 0^\circ$

$\tilde{E} = \tilde{I}_a R_a + j \tilde{I}_a X_s + V_p$

or $\tilde{E} = (80.1875 \angle 41.4^\circ] \times 2 + j (80.1875 \angle 41.4^\circ) \times 25 + 6928.203 \angle 0^\circ$

$\therefore \tilde{E} = 5944.89 \angle 15.71$

$\% \ V.R = \frac{|E| - |V|}{|V|} \times 100\%$

$= \frac{5944.89 - 6928.203}{6928.203} \times 100\%$

$= -14.19\%$

(ii) p.f at 0.75 lag

$\cos\phi = 0.75$, $\phi = 41.4096^\circ$ (lag)

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

or $1250 \times 10^3 = \sqrt{3} \times 12{,}000 \times I_a \times 0.75$

$I_a = 80.1875$

$\therefore \tilde{I}_a = 80.1875 \angle -41.4^\circ$ & lags

$$\tilde{E} = \tilde{I}_a R_a + j\tilde{I}_a X_s + \tilde{V}_p$$

or $\tilde{E} = (80.1875 \angle -41.4^\circ) \times 2 + j(80.1875 \angle -41.4^\circ) \times 25$

$+ 6928.203 \angle 0^\circ$

$\therefore \tilde{E} = 8490.062 \angle 9.475^\circ \ V$

$$\% \ V.R = \frac{|E| - |V|}{|V|} \times 100\%$$

$$= \frac{8490.062 - 6928.203}{6928.203} \times 100\%$$

$$= 22.54\%$$

(ii) unit p.f

$\cos\phi = 1 \qquad \phi = 0^\circ$

$V_p = \frac{V_L}{\sqrt{3}} = 6928.203$

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

or $I_a = 60.14065 \ A$

$\tilde{V}_p = 6928.203 \angle 0^\circ$

$\therefore \tilde{I}_a = 60.14065 \angle 0^\circ$

$$\tilde{E} = \tilde{I}_a R_a + j\tilde{I}_a X_s + \tilde{V}_p$$

$= (60.14 \angle 0^\circ) \times 2 + j(60.14 \angle 0^\circ) \times 25 +$

$6928.203 \angle 0^\circ$

$\therefore \quad \tilde{E} = 7207.058 \angle 12.04^\circ \text{ V}$

$$\%\ VR = \frac{|E| - |V|}{|V|} \times 100\%$$

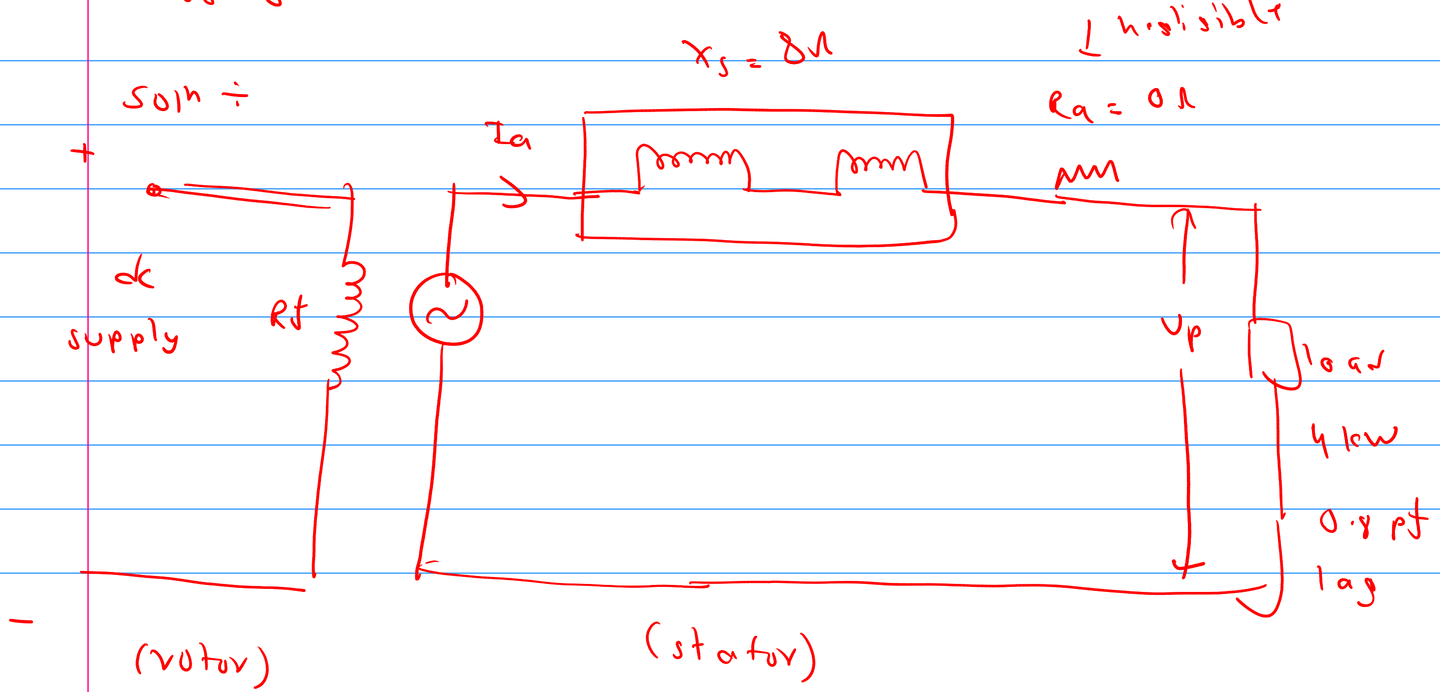
$$= \frac{7207.058 - 6928.203}{6928.203} \times 100\%$$

$$= 4.024\ \%$$

② A 3ϕ, 5 kVA 208V 4-pole, 50Hz star connected synchronous machine has negligible stator winding resistance and a synchronous reactance of 8Ω/ phase. The machine is operated as generator in parallel with 3ϕ 208V and 50Hz supply then

(i) Determine the excitation voltage (E) and power angle (δ) when machine is delivering rated kVA at 0.8 pf lagging.

Soln ÷



$\cos\phi = 0.8$

$\phi = 36.8698^\circ$

$P = 5\,kVA \times \cos\phi$

$= 5 \times 0.8$

$= 4\,kW$

$V_L = 208\,V$

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

or $4\times10^3 = \sqrt{3} \times 208 \times I_a \times 0.8$

$\therefore I_a = 13.87\,A$

$\therefore \tilde{I_a} = 13.87 \angle -36.86^\circ\,A$

$V_p = \dfrac{V_L}{\sqrt{3}} = \dfrac{208}{\sqrt{3}} = 120.088\,V$

$\tilde{V_p} = 120.088 \angle 0^\circ$

$\tilde{E} = \cancel{\tilde{I_a} R_a} + j\,\tilde{I_a} X_s + \tilde{V_p}$

or $\tilde{E} = j\,(13.87 \angle -36.86) \times 8 + 120.088 \angle 0^\circ$

or $\tilde{E} = 206.68 \angle 25.43^\circ\,V$

angle between E and V

power angle $(\delta) = 25.43 - 0$

$= 25.43^\circ$

A 3ϕ, 50 Hz 20 pole sollent pole alternator with star connected winding has 180 slots on the stator. Each slot consists of 8 conductors. The flux per pole is 25 mwb and sinusoidally distributed. The coils are full pitched.

Calculate

$N_s = \frac{120f}{P}$

(i) The speed of the alternator
(ii) winding factor $\rightarrow K_w = K_p \cdot K_d$
(iii) Generated emf per phase $\rightarrow E_{rms}/ph$
(iv) line voltage $\rightarrow E_{rms}/line$

Soln:

$K_p = \cos\alpha/2$

full pitched $\alpha = 0$; short pitched $\alpha < 180^\circ$

(i) $f = 50 Hz$

$P = 20$

no of slots $(s) = 180$

flux per pole $(\phi) = 25 \times 10^{-3}$ wb

full pitched

$K_p = \cos 0 = 1$

$N = \frac{120f}{P} = \frac{120 \times 50}{20} = 300$ rpm

(ii) $K_w = K_p \cdot K_d$

$$k_d = \frac{\sin \frac{m\beta}{2}}{m \sin\left(\frac{\beta}{2}\right)}$$

m = no of slots per pole per phase

$$= \frac{180}{20 \times 3} \quad (180 \text{ slots}, 20 \text{ pole}, 3 \text{ phase})$$

$$= 3$$

$$\beta = \frac{360^\circ \times (P/2)}{\text{no of slots}} = \frac{360^\circ \times (20/2)}{180}$$

$$= 20^\circ$$

$$k_d = \frac{\sin\left(\frac{3 \times 20}{2}\right)}{3 \times \sin\left(\frac{20}{2}\right)} \approx 0.959$$

$$\therefore k_w = k_p \cdot k_d = 1 \times 0.959 = 0.959$$

(ii) Generate (phase) EMF, E_{ph}

$$E_{ph} = 4.44 f \phi_m N_{ph} k_w$$

$f = 50\,Hz$, $\phi_m = 25 \times 10^{-3}\,Wb$, N_{ph} = total series turns per phase

$k_w = 0.96$

180 slots are 3 phases $\Rightarrow$ 60 slots per phase

each slot has 8 conductor $\Rightarrow$ 60×8 conductors per phase

$= 480$

Two conductor in series form one turn so, $N_{ph} = \frac{480}{2}$

$= 240$

$E_{ph} = 4.44 \times 50 \times 25 \times 10^{-3} \times 240 \times 0.96$

$= 1277.388\,V$

(iv) line voltage, E_{rms} line

$E_L = \sqrt{3} \times E_{ph} = 2212.500\,V$