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Machines Assignment 5

Q:1 $I_F = 5A$, $V_T = \sqrt{3} V_\phi$

(a) from the curve $E_L = 16.5\ kV$

$$E_\phi = \frac{16.5K}{\sqrt{3}} = 9.526\ KV$$

load is delta connected with three impedence $24\angle 25^\circ\ \Omega$

$Z_\Delta = 24\angle 25^\circ\ \Omega$, $Z_Y = \frac{Z_\Delta}{3} = 8\angle 25^\circ \Rightarrow$ singl phase

$V_\phi = I_A Z_Y$, $I_A = \frac{E_{\phi A}}{R_A + jX_s + Z} = \frac{9526}{0.2 + j2.5 + 8\angle 25^\circ}$

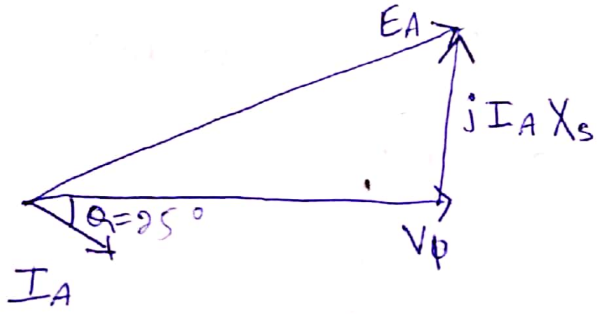
$I_A = 1003.6\angle -38.285^\circ\ A$

$V_\phi = I_A Z_Y = (1003.6\angle -38.29)(8\angle 25^\circ) = 8029\angle -13.3^\circ\ V$

$V_T = (\sqrt{3})(V_\phi) = 13.9\ KV$

(b) $E_A = V_\phi + Z_A I_A$

$E_A = 8.03K + (0.2 + j2.5)(1003.6\angle -38.285^\circ) = 9.914\angle 10.7\ KV$



(c) $P_{out} = 3 V_\phi I_A \cos\theta$

$= 3(8.029K)(1003.6)\cos(-13.3 + 38.28)$

$P_{out} = 21.9 MW$

$P_{cr} = 3 I_A^2 R_A = 3(1003.6)^2(0.2) = 6040 KW$

$P_{inp} = P_{out} + P_{cut} + P_{cor} + P_{F+W}$

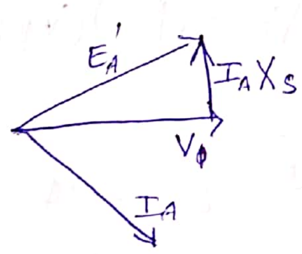
$= 21.9MW + 0.604MW + 1.5MW + 1MW$

$P_{inp} = 25MW$

$\eta = \frac{P_{out}}{P_{inp}} \times 100 \Rightarrow 87.6\%$

(d) By adding another identical delta connected load ~~be~~ to the existing generator, the load current supplied by the generator increases due to this armature reactance drop increases which results in decrease in terminal voltage

(e) $Z_\Delta = 24\angle 25^\circ \parallel 24\angle 25^\circ = 12\angle 25^\circ$



$Z_Y = \frac{Z_\Delta}{3} = 4\angle 25^\circ$

$I_A = \frac{E_A}{R_A + jX_s + Z} = \frac{9526}{0.2 + j2.5 + 4\angle 25^\circ} = 1679\angle -47.6^\circ A$

$V_\phi = I_A Z = 6715.7\angle -22.6^\circ = 6716 V$

$\boxed{V_T = \sqrt{3} V_\phi = 11.632 KV}$

(f) We can restore the terminal voltages by increasing the field current.

Q:- 2

(a) $n_m = \frac{120 f}{P} = \frac{(120)(50)}{20} = 300 \text{ rpm} = 31.4 \text{ rad s}^{-1}$

(b) $E_A = V_\phi + I_A Z$

$V_\phi = \frac{V_T}{\sqrt{3}} = 6928 V = 1\angle 0^\circ \text{ pu}$

$\because \theta = \cos^{-1}(0.85)$

$I = 1\angle -31.78 \text{ pu}$

$E_A = 1\angle 0^\circ + (1\angle -31.78)(0.1 + j0.9) = 1.714 \angle 24.55^\circ \text{ pu}$

$E_A = (1.714\angle 24.55^\circ)(6928) = 11.87\angle 24.55^\circ \text{ kV}$

(c) $\delta = 24.55^\circ$

(d) $Z_{base} = \frac{(V_{\phi\,base})^2}{\frac{S_{base}}{3}} = \frac{(6928)^2}{\frac{200M}{3}} = 0.72\ \Omega$

$R_A = (0.1)(0.72) = 0.072\ \Omega$

$X_s = (0.9)(0.72) = 0.648\ \Omega$

(e) $P_{max} = \frac{3 V_\phi E_A}{X_s} = \frac{3(6928)(11.875K)}{0.648} = 380 MW$

$I_A = \frac{S}{\sqrt{3} V_L} = \frac{200 M}{\sqrt{3}\,(12K)} = 9.622 \text{ KA}$

$P_{out} = 3 V_\phi I_A \cos\theta = 3(6928)(9622.5)(0.85)$

$P_{out} = 170 MW$

$$P = \frac{3 V_\phi E_A}{X_s} \sin\theta$$

$$P = (380)(\sin(24.55))$$

$$P = 157.8 MW$$

Reverse power $= P_{out} - P = 170M - 157.8M$

$$P_R = 12.2 MW$$

(f) $S^2 = P_{out}^2 + Q_{max}^2$

$Q_{max} = \sqrt{S^2 - P_{out}^2} = \sqrt{200^2 - (170^2)} = \sqrt{11100}$

$$Q_{max} = 105.35 \, MVAR$$

Q3 $460V$, $f = 60 Hz$

$R_1 = 0.15$, $X_m = 20\,\Omega$, $X_2 = 1.066\,\Omega$

$R_2 = 0.154\,\Omega$, $X_1 = \cancel{0.52}$ $0.852\,\Omega$, $P_{F+W} = 400 W$

$P_{misc} = 150 W$, $P_{core} = 400 W$, $S = 0.02$

(a) $I_{Line} = ?$

$$Z_2 = R_2 + X_2 + R_2 \left[\frac{1-S}{S}\right]$$

$$Z_2 = 0.154 + j1.066 + 0.154 \left[\frac{1-0.02}{0.02}\right] = j1.066 + 7.70$$

$$Z_F = Z_2 \| jX_m = \frac{jX_m Z_2}{Z_2 + jX_m} = \frac{(j20)(7.7 + j1.066)}{7.7 + j1.066 + j20}$$

$$Z_F = 6.32 \angle 28^\circ \,\Omega$$

$$I_L = I_A = \frac{V_\phi}{R_1 + jX_1 + Z_F} = \frac{266}{0.15 + j0.852 + 6.123 + j3.25}$$

$$I_L = I_A = 35.5 \angle -33^\circ \, A$$

$Z_T = R_1 + jX_1 + Z_F = 0.15 + j0.852 + 6.123 + j3.25$

$Z_T = 7.479 \angle 32.9^\circ$

impedence angle is equals to 33°

(c) $\theta = 32.9$

$PF = \cos\theta = \cos(32.9) = 0.8396$ lagging

(d) PF of rotor

$PF = \cos\left\{\tan^{-1}\frac{X_2}{R_2}\right\} = \cos\left\{\tan^{-1}\frac{1.066}{7.546}\right\} = 0.9736$ lagging

$f_r = sf_s$

$= (0.02)(60) = 1.2\ Hz$

(e) $P_{SC} = 3I_A^2R_1$

$I_A = 35.5$

$P_{SC} = 3(35.5)^2(0.15) = 567\ W$

(f) $P_{AG} = P_{in} - P_{SC} - P_{core} =$

$P_{AG} = 3I_A^2\frac{R_2}{S} = 3(35.5)^2(6.123) = 23.15\ KW$

(g) $P_{conv} = 3I_A^2R_2\left\{\frac{1-S}{S}\right\} = \frac{3I_A^2R_2}{S}[1-S] = (23.15\ KW)(1-0.07)$

$P_{conv} = 22686\ W$

(h) $P_{in} = 3V_\phi I_\phi \cos\theta = 3(266)(35.5)\cos(0+32.9) = 23.785\ KW$

$P_{out} = P_{conv} - P_{F+W} - P_{misc}$

$P_{out} = 22686 - 400 - 150 = 22136\ W$

$\eta = \frac{P_{out}}{P_{in}} \times 100 = \frac{22136}{23785} \times 100 = 93\%$

$\underline{Q4}$ 208V 60Hz

$R_1 = 0.1\,\Omega$, $R_2 = 0.07\,\Omega$

$X_m = 10\,\Omega$, $X_1 = 0.21\,\Omega$ $X_2 = 0.21\,\Omega$

$P_{\substack{misc \\ mech}} = 500W$, $P_{mis} = 0$, $P_{core} = 400\,W$, $S = 0.05$

(a) $I_L = ?$

$$Z_2 = R_2 + jX_2 + R_2\left(\frac{1-S}{S}\right) = 0.07 + j0.21 + 0.07\left[\frac{1-0.05}{0.05}\right]$$

$$Z_2 = 1.415 \angle 8.536^\circ$$

$$Z_F = Z_2 \| X_m = (1.415 \angle 8.536^\circ) \| (j10) = 1.3185 + j0.3866$$

$$V_\phi = \frac{V_L}{\sqrt{3}} = \frac{208}{\sqrt{3}} = 120V$$

$$I_L = I_A = \frac{120}{0.1 + j0.21 + 1.3185 + j0.3866} = 77.98 \angle -22.81^\circ\,A$$

(b) $P_{SCL} = 3I_A^2 R_1 = 3(77.98)^2(0.1) = 1824\,W$

(c) $P_{AG} = 3I_A^2 R_F = 3(77.98^2)(1.374) = 25000\,W$

(d) $P_{conv} = (1-S)P_{AG} = (1-0.05)(25000) = 23750\,W$

(e) $T_{ind} = \dfrac{P_{AG}}{W_{sync}}$ $\quad - \,\circ\!\!\!\circ\, -\quad$ $\omega_{sync} = n_{sync} \times \dfrac{2\pi}{60}$, $n = \dfrac{120f}{P} = 1800$ rpm

$$\omega = \frac{1800 \times 2\pi}{60} = 188.5$$

$$T = \frac{25000}{188.5} = 132.63\,Nm$$

(f) $\tau_{load} = \frac{P_{out}}{\omega_m}$

$P_{out} = P_{conv} - P_{F+W} - P_{misc}$

$= 23750 - 500 - 0 = 23250\,W$

$n = (1-0.05)(1800) = 1710$ rpm

$\omega = \frac{1710 \times 2\pi}{60} = 179.07$ rads^{-1}

$\tau = \frac{23250}{179.07} = 129.8\,Nm = \tau$