EE306

Problem session # 2

Solution

2014/2015

141

P1)

$$I_2 = \frac{150 \times 10^3}{240} = 625 \text{ A}$$

$$\frac{I_2}{a} = 62.5 \angle -36.8° = 50 - j37.5 \text{ A}$$

$$aV_2 = 2400 \angle 0° = 2400 + j0 \text{ V}$$

$$a^2R_2 = 0.2\ \Omega \quad \text{and} \quad a^2X_2 = 0.45\ \Omega$$

Hence

$$E_1 = (2400 + j0) + (50 - j37.5)(0.2 + j0.45)$$
$$= 2427 + j15 = 2427 \angle 0.35° \text{ V}$$

$$I_m = \frac{2427 \angle 0.35°}{1550 \angle 90°} = 1.56 \angle -89.65 = 0.0095 - j1.56 \text{ A}$$

$$I_c = \frac{2427 + j15}{10{,}000} \approx 0.2427 + j0 \text{ A}$$

$$I_0 = I_c + I_m = 0.25 - j1.56 \text{ A}$$

$$I_1 = I_0 + \frac{I_2}{a} = 50.25 - j39.06 = 63.65 \angle -37.850° \text{ A}$$

Thus, the primary voltage is

$$V_1 = (2427 + j15) + (50.25 - j39.06)(0.2 + j0.45)$$
$$= 2455 + j30 = 2455 \angle 0.7° \text{ V}$$

$$VR = \frac{2455 - 2400}{2400} * 100 = 2.3\ \%$$

$$P_i = I_c^2 R_c\ ,\ P_{Cu} = I_1^2 R_1 + I_2^2 R_2$$

$$P_i + P_{Cu} = 2.18 \text{ KW}, \quad P_{O/P} = 150 * 0.8 = 120 \text{ KW}$$

$$\eta = \frac{120}{120 + 2.18} * 100 = 98.2\%$$

P2

<u>O.C</u>

$R_c' = \frac{(120)^2}{80} = 180\,\Omega$, $a = \frac{450}{120} = 3.75$

$R_c = a^2 R_c' = \underline{\underline{2530\,\Omega}}$

$I_c' = \frac{120}{R_c'} = 0.667\,A$, $I_m' = \sqrt{I_o^2 - I_c'} = 4.15\,A$

$X_m' = \frac{120}{I_m'} = 28.94\,\Omega$

$X_m = a^2 X_m' = \underline{\underline{407\,\Omega}}$

<u>S.C</u>

$Z_{e_1} = \frac{9.65}{22.2} = 0.435\,\Omega$

$R_{e_1} = \frac{120}{(22.2)^2} = \underline{\underline{0.243\,\Omega}}$

$X_{e_1} = \sqrt{Z_{e_1}^2 - R_{e_1}^2} = \underline{\underline{0.361\,\Omega}}$

$I_{1FL} = \frac{10000}{450} = 22.2\,A$

Voltage Drop $\simeq I_1(R_{e_1}\cos\phi + X_{e_1}\sin\phi) \simeq 9.2\,V$

$VR = \frac{9.2}{450} * 100 = 2.04\,\%$

$\eta_{FL} = \frac{10000 * 0.8}{10000 * 0.8 + 80 + 120} * 100 = 97.57\%$

<u>at half load</u>

$\eta = \frac{\frac{1}{2} * 10000 * 0.8}{\frac{1}{2} * 10000 * 0.8 + 80 + (\frac{1}{2})^2 * 120} * 100 = 97.34\%$

P3

(a) $I_t = \frac{P_{rated}}{V_t} = \frac{10{,}000}{250} = 40\ A$

$I_f = \frac{V_t}{R_f} = \frac{250}{125} = 2\ A$

$I_a = I_t + I_f = 40 + 2 = 42\ A$

$E_a = V_t + R_a I_a = 250 + (0.2)(42) = 258.4\ V$

(b) $\omega_m = \frac{2\pi n}{60} = \frac{2\pi(1750)}{60} = 183.26\ rad/sec$

$P_{dev} = E_a I_a = (258.4)(42) = 10{,}852.8\ W$

$T_e = \frac{P_{dev}}{\omega_m} = \frac{10{,}852.8}{183.26} = 59.2\ N\text{-}m$

(c) $VR = \frac{E_a - V_t}{V_t} \times 100 = \frac{258.4 - 250}{250} \times 100 = 3.36\%$

(d) $P_{cu} = I_a^2 R_a + I_f^2 R_f = (42)^2(0.2) + (2)^2(125) = 852.8\ W$

$P_{out} = 10{,}000\ W$

$P_{in} = P_{out} + P_{cu} + P_{rotational} = 10{,}000 + 852.8 + 450 = 11{,}302.8\ W$

$\eta = \frac{P_{out}}{P_{in}} = \frac{10{,}000}{11{,}302.8}\ 100\% = 88.5\%$

P4

III) The no Load Saturation curve for a speed of 1500 rpm

a) $\frac{E_1}{E} = \frac{K_a \phi_{p_1} \omega_{m_1}}{K_a \phi_p \omega_m} \Longrightarrow E = E_1 \frac{\omega_m}{\omega_{m_1}}$

$E = E_1 \frac{1500}{1800}$ (for a given field current the speed affects E proportionaly $E \propto$ Speed)

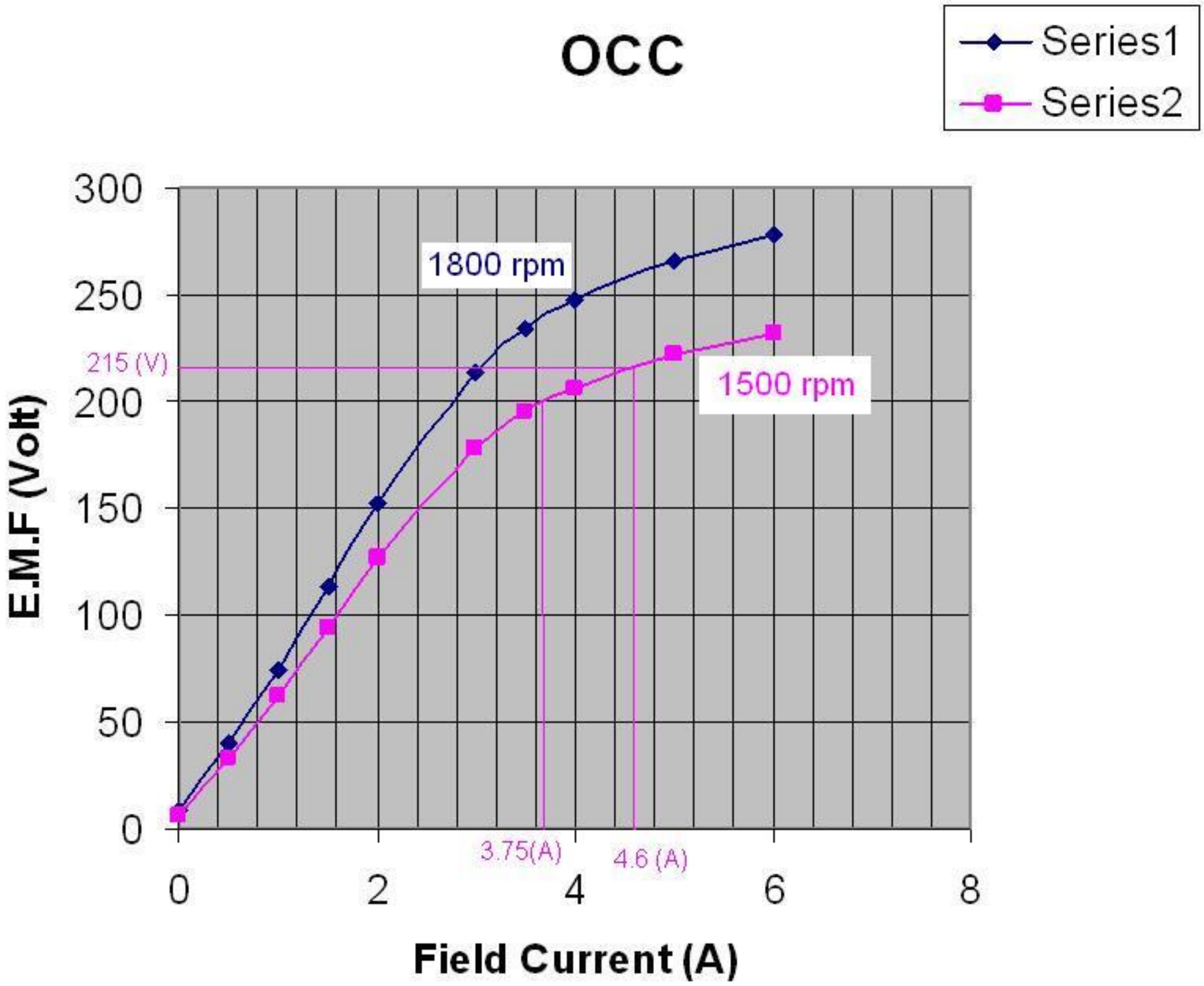
(V) E	6.67	33.33	61.67	94.17	126.7	177.5	195	206.7	221.7	231.7
(A) I_f	0	0.5	1.0	1.5	2.0	3.0	3.5	4.0	5.0	6.0

Both Plots are attached

b) when $I_f = 4.6$ A, $E = 215$ V at 1500 rpm. taken from the graph

E at 1000 rpm is $215 \times \frac{1000 \text{rpm}}{1500} = 143.33$ V

c) For a given field current, $E = 120$V at 900 rpm, this is equivalent to $E = 120 \times \frac{1500}{900} = 200$ V at 1500 rpm. From the graph the corresponding field current is 3.75 Amp.



OCC
Series1
Series2
1800 rpm
1500 rpm
215 (V)
3.75(A)
4.6 (A)
300
250
200
150
100
50
0
0
2
4
6
8
E.M.F (Volt)
Field Current (A)

P5:

ⓐ $$I_f = \frac{V_t}{R_f} = \frac{220}{110} = 2\,A$$

$$I_{a,NL} = I_{t,NL} - I_f = 5 - 2 = 3\,A$$

$$E_{a,NL} = V_t - R_a I_{a,NL} = 220 - (0.15)(3) = 219.55\ V$$

$$I_{t,L} = \frac{P}{V_t} = \frac{12{,}000}{220} = 54.54\,A$$

$$I_{a,L} = 54.54 - 2 = 52.54\,A$$

$$E_{a,L} = 220 - (0.15)(52.54) = 211.82\ V$$

$$\frac{E_{a,L}}{E_{a,NL}} = \frac{K_a \phi\, \omega_{m,L}}{K_a \phi\, \omega_{m,NL}} = \frac{K_a \phi\, (2\pi n_L/60)}{K_a \phi\, (2\pi n_{NL}/60)} = \frac{n_L}{n_{NL}}$$

$$n_L = \left(\frac{E_{a,L}}{E_{a,NL}}\right) n_{NL} = \left(\frac{211.82}{219.55}\right)(1200) = 1158\ \text{rpm}$$

ⓑ $$P_{ew,L} = E_{a,L}\, I_{a,L} = (211.82)(52.54) = 11{,}129\ W$$

$$\omega_{m,L} = \frac{2\pi n_L}{60} = \frac{2\pi(1158)}{60} = 121.26\ \text{rad/sec}$$

$$T_e = \frac{P_{ew}}{\omega_{m,L}} = \frac{11{,}129}{121.26} = 91.8\ \text{N-m}$$

ⓒ $$P_{rotational} = P_{ew,NL} = E_{a,NL}\, I_{a,NL} = (219.55)(3) = 658.65\,W$$

$$P_{out,L} = P_{ew,L} - P_{rotational} = E_{a,L} I_{a,L} - P_{rotational}$$

$$= (211.82)(52.54) - 658.65 = 10{,}470\ W$$

$$\eta = \frac{P_{out,L}}{P_{in}} = \frac{10{,}470}{12{,}000}\,100\,\% = 87.25\,\%$$

P6:

(a) $E_a = V_t - (R_a + R_s) I_a = 230 - (0.25 + 0.10)(40) = 216\ V$

$P_{dev} = E_a I_a = (216)(40) = 8640\ W$

$\omega_m = \frac{2\pi n}{60} = \frac{2\pi(1200)}{60} = 125.66\ rad/sec$

$T_e = \frac{P_{dev}}{\omega_m} = \frac{8640}{125.66} = 68.8\ N\text{-}m$

(b) $E_a' = 230 - (0.25 + 0.10)(20) = 223\ V$

$\frac{E_a'}{E_a} = \frac{K_a \phi' \omega_m'}{K_a \phi \omega_m} = \frac{K_a' I_a' (2\pi n'/60)}{K_a' I_a (2\pi n/60)} = \frac{I_a' n'}{I_a n}$

$n' = \left(\frac{E_a'}{E_a}\right)\left(\frac{I_a}{I_a'}\right) n = \left(\frac{223}{216}\right)\left(\frac{40}{20}\right)(1200) = 2478\ rpm \left(\frac{2\pi}{60}\right) = 259.5\ rad/s$

$P_{dev}' = E_a' I_a' = (223)(20) = 4460\ W$

$T_e' = \frac{P_{dev}'}{\omega_m'} = \frac{4460}{259.5} = 17.2\ N\text{-}m$