ANTU ROY
M230635EE

PED Assignment-4

1. Given data

Induction motor

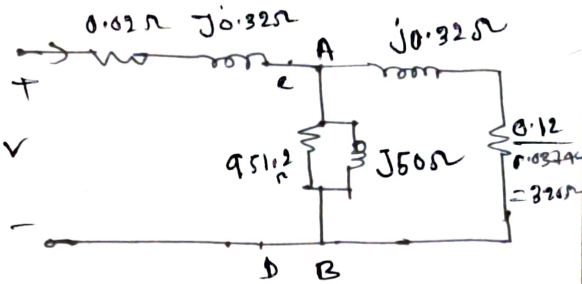
2000 hp, 2300 V ; 3-phase, Star

$P = 4$, $f = 60$ Hz ; $S_f = 0.03746$

$R_s = 0.02\Omega$, $R_r = 0.12$

$R_c = 451.2\Omega$; $X_m = 50\Omega$

$X_{ls} = X_{lr} = 0.32\Omega$



i) $\eta = ?$

ii) $C_{ph} \Rightarrow ?$ to obtain p.f = 1

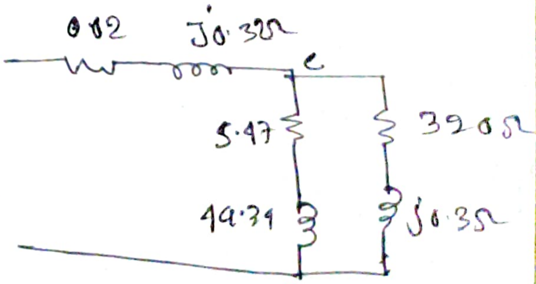
$$Z_{AB} = j50\Omega \parallel 451.2\Omega$$

$$= \frac{j50 \times 451.2}{j50 + 451.2}$$

$$= \frac{22560\angle 90^\circ}{453.961\angle 6.323}$$

$$= 49.695\angle 83.677$$

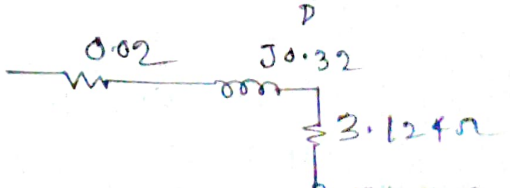
$$= (5.47 + j49.39)\,\Omega$$



$$Z_{CD} = (5.47 + j49.39) \parallel (320 + j0.32)$$

$$= \frac{(49.695\angle 83.677) \times (3.215\angle 5.71)}{8.67 + j49.71}$$

$$= \frac{159.769\angle 89.187}{50.46\angle 80.106}$$



$$= 3.166\angle 9.281 = 3.124 + j0.51\Omega$$

$$I = \frac{2300/\sqrt{3}}{3.144 + j0.83}$$

$$= \frac{1327.90}{3.251 \angle 14.758}$$

$$I = 408.45 \angle -14.78$$

$$I_2 = \frac{5.47 + j49.39}{50.46 \angle 80.106} * \boxed{408.45 \angle -14.788}$$

$$= \frac{49.695 \angle 83.699}{50.46 \angle 80.106} \; 408.45 \angle -14.788$$

$$I_2 = 402.25 \angle -11.2$$

$$Pg = 3 I_2^2 \frac{R_2}{S}$$

$$= 3(402.25)^2 \times 3.20$$

$$= 1553.328 \, kW$$

$$Pg = = Pg(1-S) = 1553.328(1-0.037)$$

$$= 1495.140 \, kW$$

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

$$= \sqrt{3} \times 230.0 \times 408.45 \cos(14.788)$$

$$= 1573.232 \, kW$$

$$\eta = \frac{P o/p}{P i/p} = \frac{1495.140}{1573.252}$$

$$= 95.03\%$$

ii) Reactive power supplied by the capacitor bank

$Q_c = Q_1 - Q_2$

$= P\tan\phi_1 - P\tan\phi_2$

$= P[\tan(14.785) - \tan(\cos^{-1}(1))]$

$= 1573.252(0.263)$

$= 415.318\,KVAR$

$$Q_c = \frac{(V_{ph})^2}{1/\omega C} \Rightarrow C_{ph} = \frac{Q_{cph}}{V_{ph}^2 \cdot \omega}$$

$$= \frac{138.43}{\left(\frac{2300}{\sqrt{3}}\right)^2 \times 2\pi \times 60}$$

$C_{ph} = 20.82\,mF$

2. 3-ph star connected

$f = 60\,Hz$, 2000 ph, stator phase resistance, $R_s = 0.02$

Test results,

No load: 2300V, 26.55A, 11.617 kW

Locked rotor: 462.68V, 407.75A, 319.22 kW

Eq circuit, of $I_m = ?$

From No load Test:

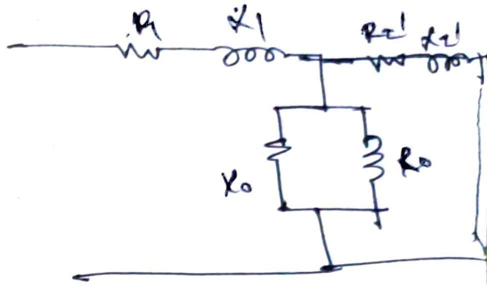
$P_0 = \sqrt{3}\,V I_0 \cos\phi_0$

$$11617 = 2300 \times 26.55 \times \sqrt{3} \cos\phi_0$$

$$\cos\phi_0 = \frac{11617}{\sqrt{3} \times 2300 \times 26.55}$$

$$\phi_0 = 0.109.$$

$$\sin\phi_0 = 0.9939$$



$$I_\mu = I_0 \sin\phi_0 = 26.389\ A$$

$$I_w = I_0 \cos\phi = 2.893\ A$$

$$R_0 = \frac{V_0}{I_w} = \frac{2300}{2.893} = 794.79\,\Omega$$

$$X_0 = \frac{V}{I_\mu} = \frac{2300}{26.389} = 87.15\,\Omega$$

From blocked rotor test;-

$$P = 3 I_{sc}^2 R_{01}$$

$$R_{01} = \frac{319.22 \times 10^3}{3 \times (407.75)^2} = 0.64\,\Omega$$

$$Z_{01} = \frac{V_{sc}/\sqrt{3}}{I_{sc}} = \frac{462.68/\sqrt{3}}{407.75} = 0.655\,\Omega$$

$$X_{01} = \sqrt{Z_{01}^2 - R_{01}^2} = 0.1399\,\Omega$$

$$X_{01} = X_1 + X_2' \Rightarrow$$

$$X_1 = X_2' = \frac{X_{01}}{2} = 0.069\,\Omega$$

$$R_2' = (R_{01} - R_1) \cdot \left[\frac{X_2 + X_0}{X_0}\right]^2$$

$$= (0.64 - 0.02)\left[\frac{0.069 + 87.15}{87.15}\right]^2$$

$R_2' = 0.62\,\Omega$

3. Given data

$460V$, $25HP$, $60Hz$, 4 pole

$R1 = 0.641\Omega$, $R2 = 0.332$, $X1 = 1.106\Omega$, $X2 = 0.464\Omega$

$Xm = 26.3\Omega$

Rotational Losses $= 1100W$

Slip $= 2.2\%$ @ rated voltage & frequency

a) Speed = ? b) Stator current = ?

c) p.f = ? d) Pconv & Pout = ?

e) Tind & Tload = ? f) η = ?

From Equivalent ckt

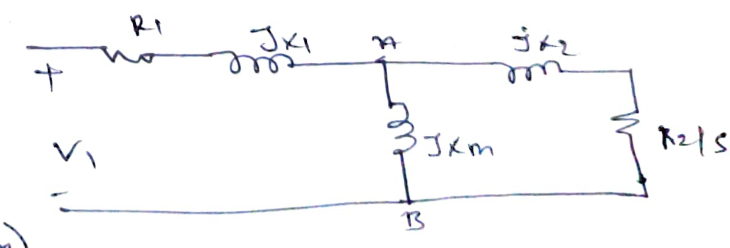


Fig: Equivalent ckt

$S = 0.022$

$$Z_{AB} = \left(\frac{R_2}{S} + jX_2\right) \parallel (jX_m)$$

$$= (15 + j0.464) \parallel (j26.3)$$

$$= \frac{(15 + j0.414)(j26.3)}{15 + j26.764}$$

$= 12.85 \angle 31.04$

$= 11 \cdot j6.62$

i) $N_r = N_s(1-s)$

$= \frac{120f}{P}(1-s)$

$= 1760.4$ rpm

ii) Stator current $= \frac{460/\sqrt{3}}{(0.641+11) + j(11.06+6.62)}$

$= \frac{265.58}{13.97 \angle 33.571}$

$= \frac{265.58}{11.641 + j7.26}$

$I = 19.01 \angle -33.571$

$I_L = 19.01A = I_{ph}$

iii) $pf = \cos\phi = \cos 3351$

$pf = 0.833$

Air Gap power, $P_{gd} = 3I^2R_2$

$= 3 \times 19.01^2 \times 11$

$= 11.925$ kW

iv) $P_{sh} = P_d - $ rotational loss

$P_d = P_g(1-s) = 11.663 \cdot kW$

$P_{sh} = 11.663 - 1.1 = 10.563\ kW$

$P_{sh} = 10.563\ kW$

v) $T_{ind} = \dfrac{P_d}{\omega_r}$

$= \dfrac{11633}{2\pi(1760.4)/60}$

$= 63.26\ N\text{-}m$

$T_{sh} = \dfrac{P_{sh}}{\omega_r} = \dfrac{10563}{2\pi(1760.4)/60}$

$= 57.29\ N\text{-}m$

vi) $P_{in} = \sqrt{3}\, V_L I_L \cos\phi$

$= \sqrt{3} \times 460 \times 14.01 \times \cos(33.571)$

$= 12.616\ kW$

$\eta = \dfrac{P_{o/p}}{P_{i/p}} = \dfrac{P_{sh}}{P_{in}} = \dfrac{10.563}{12.616}$

$\eta = 83.72\%$