PRINCE OF SONGKLA UNIVERSITY

FACULTY OF ENGINEERING

Final Examination: Semester 2 Academic Year: 2549

Date: 24 February 2550 Time: 9.00-12.00

Subject: 211-221 Fundamentals of Electrical Machines Room: A401, A403

คำสั่ง - ข้อสอบมีทั้งหมด 5 ข้อ

- อนุญาตให้ใช้เครื่องคิดเลข และ Dictionary ได้
- ห้ามนำโน๊ต ตำราเรียน เข้าห้องสอบ

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1. In a 20 kVA 1200/120 V single-phase transformer, the resistance of primary winding is 0.242 Ω and the resistance of secondary winding is 0.076 Ω. Determine

   a. the secondary current and primary current

   b. the equivalent resistance in primary terms.

   c. the equivalent resistance in secondary terms. (15 คะแนน)

2. In a 50 kVA 2400/240 V transformer. the core losses and copper losses are 680 W. and 760 W, respectively. Calculate

   a. The efficiency of this transformer at full load, when the power factor is 0.866 lagging

   b. maximum efficiency when power factor is 0.866 (15 คะแนน)

3. A short-circuit test was performed on a 10 kVA 2400/240 V transformer with the following data ;

   $V_{sc} = 138$ V , $I_{sc} = 4.17$ A , $P_{sc} = 202$ W

   Calculate ;

   a. The equivalent parameters in primary terms (R_{eH}, X_{eH}, Z_{eH})

   b. The voltage regulation when supplying full load at a power factor 0.866 lagging

   (20 คะแนน)

4. A three-phase 125 hp 440 V 60 Hz eight-pole Y-connected induction motor has the following electric circuit parameters on a per phase basis referred to stator

$R_s = 0.068 \ \Omega$ $\qquad X_s = X_R' = 0.224 \ \Omega$

$R_R' = 0.052 \ \Omega$ $\qquad X_m = 7.68 \ \Omega$

The rotational losses are 2400 W. For a slip of 3% determine

a. The line current and the power factor

b. The shaft torque

c. The efficiency (25 คะแนน)

5. A 5 hp 220 V 60 Hz four-pole Y-connected three-phase induction motor was tested and the following data were obtained

No-load test : $V_{NL} = 220$ V, $P_{NL} = 340$ W, $I_{NL} = 6.2$ A

Blocked-rotor test : $V_{BR} = 49.4$ V, $P_{BR} = 360$ W , $I_{BR} = 13.9$ A

The dc resistance measurement on the stator winding gives a 4.0 V drop between terminals, when dc current flows 13.9 A. Calculate

a. The equivalent parameters(R_e , Z_e , X_e) in stator terms

b. The rotational loss

c. The efficiency of the motor when operating at a slip of 0.04

(25 คะแนน)

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Transformer

no load current $I_o = I_m + I_e$

$E_P = 4.44 f N_P \phi_m$

$E_S = 4.44 f N_S \phi_m$

turn ratio $a = \frac{E_P}{E_S} = \frac{N_P}{N_S}$, $\frac{I_S}{I_P} = a$

Equivalent Circuit

$R_{eP} = R_P + a^2 R_S$
$X_{eP} = X_P + a^2 X_S$ } in primary term.

$R_{eS} = R_S + \frac{R_P}{a^2}$
$X_{eS} = X_S + \frac{X_P}{a^2}$ } in secondary term.

Open-Circuit test

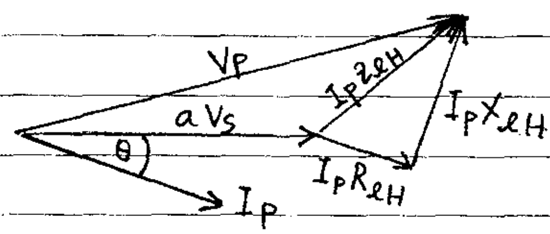
ค่าที่อ่านได้จาก watt-meter คือค่า core losses

Short-Circuit Test

$R_{eH} = \frac{P_{se}}{I_{se}^2}$, $Z_{eH} = \frac{V_{se}}{I_{se}}$, $X_{eH} = \sqrt{Z_{eH}^2 - R_{eH}^2}$

Voltage Regulation

voltage regulation $= \frac{V_{no\text{-}load} - V_{full\text{-}load}}{V_{full\text{-}load}} \times 100\%$



Efficiency

$\eta = \frac{\text{output power}}{\text{input Power}} = \frac{\text{output power}}{\text{output power + losses}}$

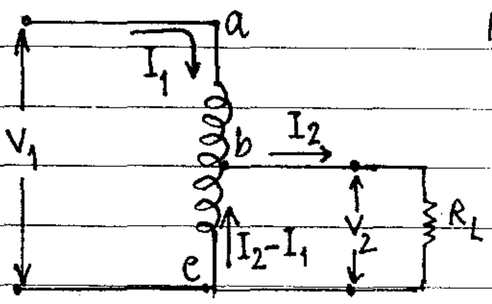
$$\eta = \frac{kVA_{out} \times PF}{kVA_{out} \times PF + \text{copper losses} + \text{core loss}}$$

The efficiency is maximum when the copper losses equal the core losses

All-day Energy Efficiency

$$\eta_e = \frac{\text{energy output over 24 hours}}{\text{energy input over 24 hours}}$$

Autotransformer



$P_c = V_2 I_1$ = Conducted power to load through ab

$P_{tr} = V_2(I_2 - I_1)$ = transformed power to load through bc

Induction Motor

synchronous speed $n_s = \frac{120f}{P}$ r/min

Slip $S = \frac{n_s - n_r}{n_s} \times 100\%$

rotor speed $n_r = (1 - S) \times N_s$ r/min

rotor power input (RPI) = rotor copper loss (RCL) + rotor power developed (RPD)

เมื่อ RPI (per phase) $= I_R^2 \frac{R_R}{S}$

$RCL = I_R^2 R_R$

$RPD = I_R^2 R_R \frac{1-S}{S} = RPI(1-S)$

developed torque $T_d = \frac{RPD}{\omega_r}$ N-m.

เมื่อ $\omega_r = \frac{2\pi n_r}{60}$ rad/s

~~shaft torque $T = \frac{RPD - P_{rot}}{\omega_r}$~~

Maximum Torque

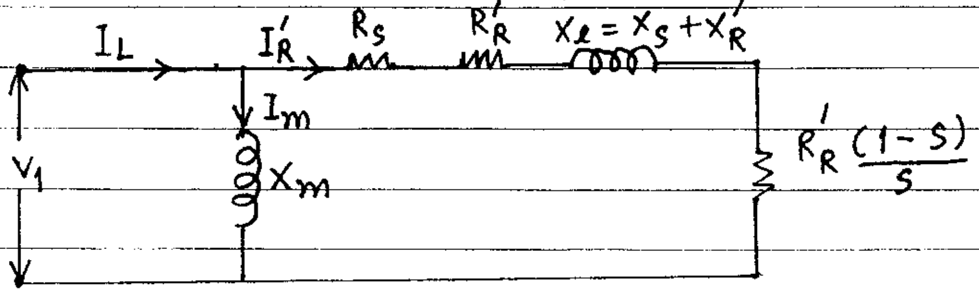
$$S_{mt} = \frac{R'_R}{\sqrt{R_S^2 + (X_S + X'_R)^2}}$$

$$T_{mt} = \frac{RPD_{mt} - P_{rot}}{\omega_{r\,mt}}$$

$$P_{out} = RPD - P_{rot}$$

P_{rot} = rotational loss = friction, windage and core losses

Equivalent circuit per phase of Induction motor



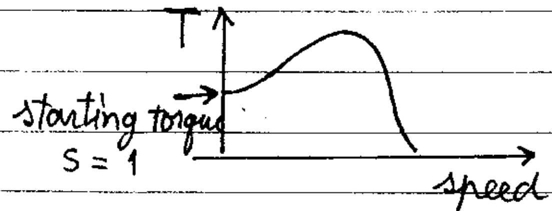
เมื่อ stator winding ถูกต่อแบบ Y และเมื่อสมมติว่าพิกัด voltage ของมอเตอร์ คือ 220 V. , V_1 คือ phase voltage $= \frac{220}{\sqrt{3}}$ V.

$$I_R' = \frac{V_1}{\left(R_S + \frac{R_R'}{S}\right) + j(X_S + X_R')}$$

$$I_m = \frac{V_1}{jX_m} \quad , \quad I_L = I_m + I_R'$$

Starting Torque

$$T_{st} = \frac{RPI_{st}}{\omega_S}$$



เมื่อ $\omega_S = \frac{2\pi n_s}{60}$

Maximum Torque

$$S_{mt} = \frac{R_R'}{\sqrt{R_S^2 + (X_S + X_R')^2}}$$

$$T_{mt} = \frac{RPD_{mt} - P_{rot}}{\omega_{r\,mt}}$$

No-load test

$$P_{NL} = P_c + P_{fr+w} + 3 I_{NL}^2 R_S$$

$$P_{rot} = P_{NL} - 3 I_{NL}^2 R_S$$

เมื่อ $P_{rot} = P_C + P_{fr+\omega}$ = friction + windage + core losses

$$X_m = \frac{V_{NL}}{\sqrt{3}\, I_{NL}}$$

Blocked Rotor Test

$$Z_e = \frac{V_{BR}}{\sqrt{3}\, I_{BR}} = \sqrt{(R_S + R_R') + j(X_S + X_R')}$$

$$R_e = \frac{P_{BR}}{3 I_{BR}^2} = R_S + R_R'$$

$$X_e = \sqrt{Z_e^2 - R_e^2} = X_S + X_R'$$

$$X_S = X_R' = 0.5 X_e$$