มหาวิทยาลัยสงขลานครินทร์

คณะวิศวกรรมศาสตร์

การสอบไล่ ประจำภาคการศึกษาที่ 2 **ประจำปีการศึกษา 2548**

วันที่ 27 กุมภาพันธ์ 2549 **เวลา 09.00-12.00 น.**

วิชา 211-221 Fundamentals of Electric Machines **ห้อง R200 , R201**

คำสั่ง 1. ข้อสอบมีทั้งหมด 5 ข้อ ให้ทำทุกข้อ

2. อนุญาตให้นำเครื่องคิดเลขเข้าห้องสอบได้

3. ห้ามนำโน้ต ตำราเรียน เข้าห้องสอบ

1. A transformer that can be consider ideal has 200 turns on its primary winding and 500 turns on its secondary winding. The primary is connected to a 220 V sinusoidal supply and the secondary supplies 10 kVA to a load

   a. Determine the load voltage, secondary current and primary current

   b. Find the load impedance as seen from the supply

   (20 คะแนน)

2. A 2300/208 V 500 kVA 60 Hz single-phase transformer was tested by means of the open-circuit test (on the low-voltage winding) and short-circuit test (on the high-voltage winding) The test data obtained are :

   Open – circuit test : V_{OC} = 208 V , I_{OC} = 52.5 A , P_{OC} = 3800 W

   Short – circuit test : V_{SC} = 95 V , I_{SC} = 217.4 A , P_{SC} = 6200 W

Calculate :

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

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

   c. maximum efficiency when power factor is 0.866

   (20 คะแนน)

3. 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 refered to the stator :

   $R_S = 0.068\ \Omega$ $X_S = X'_R = 0.224\ \Omega$

   $R'_R = 0.052\ \Omega$ $X_m = 7.68\ \Omega$

the rotational losses are 2400 W

Calculate

a. The starting torque

b. The slip at which maximum torque occurs

c. The speed at which maximum torque occurs

d. The maximum torque

(20 คะแนน)

4. A 7.5 hp 220 V four-pole three –phase Y connected induction motor was tested and the following data were recorded :

No – load test : V_{NL} = 220 V , P_{NL} = 320 W , I_{NL} = 6.4 A

Blocked-rotor test : V_{BR} = 46 V , P_{BR} = 605 W , I_{BR} = 18 A

The dc resistance measurement on the stator winding give a 4 V drop between terminals, when dc current flows is 7.8 A

For a slip at full load is 4%

Calculate :

a. The line current and power factor

b. The efficiency

(20 คะแนน)

5. A $\frac{1}{4}$ hp 120 V 60 Hz single – phase capacitor – start induction motor has a main winding impedance of $6\angle 45^{o}\ \Omega$ and an auxiliary winding impedance of $10\angle 15^{o}\ \Omega$

Calculate :

a. The main winding current

b. The value of capacitor which is needed in series with the starting winding to produce a 90^{o} phase shift between winding current at startup

(20 คะแนน)

NO.....
DATE.....

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

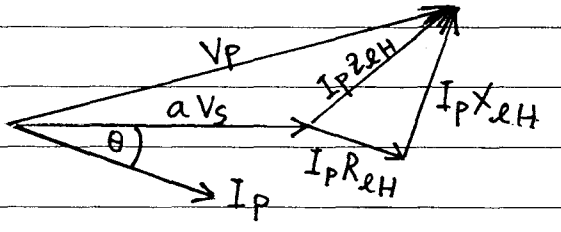
ค่าที่อ่านได้จาก Watt - meter คือค่า core losses

Short - Circuit Test

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

Voltage Regulation

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



Efficiency

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

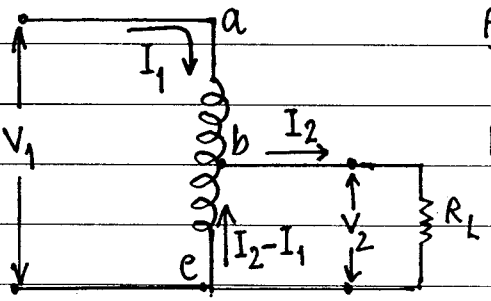
$$\eta = \frac{kVA_{out} \times PF}{kVA_{out} \times PF + \text{copper losses} + \text{core loss}}$$

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)

หรือ 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.

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

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

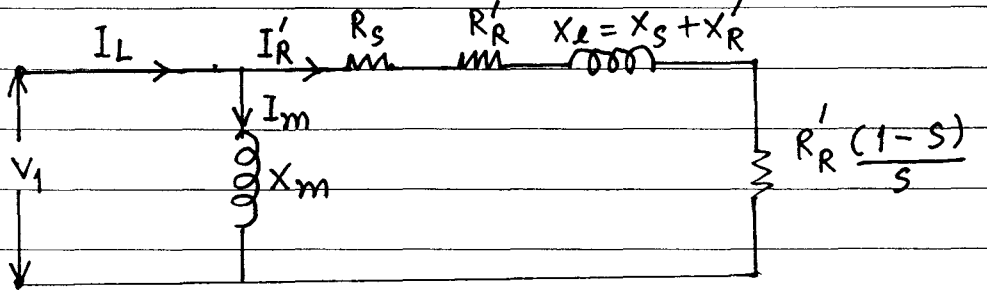
NO.....

DATE.....

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

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

Equivalent circuit per phase of Induction motor



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

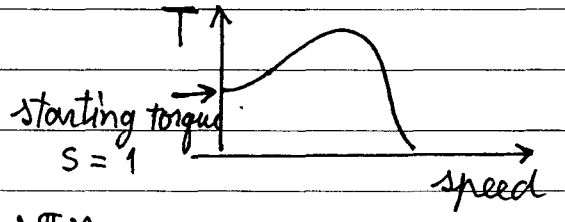
$$I'_R = \frac{V_1}{(R_S + \frac{R'_R}{s}) + j(X_S + X'_R)}$$

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

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

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

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

also $P_{rot} = P_C + P_{fr+w}$ = friction + windage + core losses

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

Blocked Rotor Test

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

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

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

$$X_S = X_R' = 0.5 X_e$$