
UNIVERSITI SAINS MALAYSIA

Second Semester Examination
2013/2014 Academic Session

June 2014

EEK 368 – ELECTRICAL MACHINES & DRIVES
[MESIN DAN PACUAN ELEKTRIK]

Duration : 3 hours
Masa : 3 jam

Please check that this examination paper consists of **EIGHT (8)** pages of printed material before you begin the examination.

*[Sila pastikan bahawa kertas peperiksaan ini mengandungi **LAPAN (8)** muka surat bercetak sebelum anda memulakan peperiksaan ini]*

Instructions: This question paper consists **LIMA (5)** questions. Answer **ALL** questions. All questions carry the same marks.

Arahan: Kertas soalan ini mengandungi **LIMA (5)** soalan. Jawab **SEMUA** soalan. Semua soalan membawa jumlah markah yang sama]

Answer to any question must start on a new page.

[Mulakan jawapan anda untuk setiap soalan pada muka surat yang baru]

“In the event of any discrepancies, the English version shall be used”.

[Sekiranya terdapat sebarang percanggahan pada soalan peperiksaan, versi Bahasa Inggeris hendaklah diguna pakai]

1. A separately excited brushed dc motor is connected to a 240V dc source. During full-load operation, it is observed that the motor develops 20Nm of output torque and the motor speed is 1000rpm. Assume that the armature resistance R_a is 1Ω , the field losses are zero and the rotational losses are also zero.

Sebuah motor AT pengujaan terpisah disambungkan ke bekalan dc 240V. Semasa operasi beban penuh, diperhatikan motor tersebut menghasilkan 20Nm tork keluaran dan kelajuan motor ialah 1000rpm. Andaikan bahawa perintang angker R_a ialah 1Ω , kehilangan medan adalah sifar dan kehilangan putaran juga adalah sifar.

- (a) Calculate the armature current I_a
Kirakan arus angker I_a (40 marks/markah)
- (b) Calculate the motor efficiency
Kirakan kecekapan motor (30 marks/markah)
- (c) If the field current is reduced by 25%, calculate the motor speed at full-load condition.
Jika arus medan dikurangkan sebanyak 25%, kirakan kelajuan motor pada operasi beban penuh. (30 marks/markah)

2. (a) A separately excited brushed dc motor is used to drive a conveyor belt. Assume that the armature resistance R_a is 1Ω . When the conveyor belt is loaded at 150Nm , and the armature terminals are connected to a 300Vdc supply, the motor speed is 800rpm . Calculate the armature current I_a

Sebuah motor AT pengujaan terpisah digunakan memicu sabuk penyampai. Andaikan bahawa perintang angker R_a ialah 1Ω . Bila sabuk penyampai dibebankan dengan 150Nm , dan pangkalan angker disambungkan ke bekalan dc 300V , kelajuan motor adalah 800rpm . Kirakan arus angker I_a

(25 marks/markah)

- (b) A full-wave SCR converter is now used to control the motor. At 150Nm , the triggering angle α is adjusted such that the motor speed is at 400rpm . Assume that the armature current is continuous and the ac source is 240Vrms . Calculate the average terminal voltage of the motor and the triggering angle α .

Sebuah penukar gelombang penuh digunakan sekarang untuk mengawal motor tersebut. Pada 150Nm , sudut pemicuan α diubah supaya kelajuan motor ialah 400rpm . Andaikan bahawa arus angker adalah berterusan dan bekalan ac ialah 240Vrms . Kirakan purata voltan pangkalan motor dan sudut pemicuan α .

(25 marks/markah)

- (c) Calculate new triggering angle α if the motor speed is increased from 400rpm to 500rpm . Assume that the current is still in continuous mode and the load torque on conveyor is unchanged.

Kirakan sudut pemicuan baru α jika kelajuan motor dinaikkan dari 400rpm ke 500rpm . Andaikan arus masih lagi dalam mod berterusan dan tork beban pada sabuk penyampai tidak berubah.

(25 marks/markah)

- (d) From part (c), calculate motor speed if the field current is suddenly decreased by 20%. Does the motor speed decrease or increase? Assume that triggering angle α is unchanged and current is continuous.

Dari bahagian (c), kirakan kelajuan motor jika arus medan tiba-tiba dikurangkan sebanyak 20%. Apakah kelajuan motor berkurangan atau bertambah? Andaikan bahawa sudut pemucuan α tidak berubah dan arus berterusan.

(25 marks/markah)

3. (a) Give types of brushed dc motors.

Namakan jenis-jenis mesin berus AT.

(20 marks/markah)

- (b) Give three methods which are famously used to control the speed and torque of brushed dc motors.

Berikan kaedah-kaedah yang popular digunakan untuk mengawal kelajuan dan tork mesin berus AT.

(15 marks/markah)

- (c) Give explanations or reasons why and how a full-wave SCR converter is often used to control the speed and torque of brushed dc motors.

Berikan penerangan atau sebab kenapa dan bagaimana penukar SCR gelombang penuh selalu digunakan untuk mengawal kelajuan dan tork mesin berus AT.

(15 marks/markah)

- (d) A 3.3 kV, 1000 kW, 3-phase, 24 pole, 50 Hz, star connected synchronous motor has a synchronous reactance of $3.24\text{-}\Omega$ per phase; the resistance being negligible. Its field excitation is adjusted to result in unity PF operation at rated load. Estimate the maximum power that motor can deliver with its excitation remaining constant at this value.

Motor segerak, 3.3 kV, 1000 kW, 3-fasa, 24-kutub, 50 Hz, sambungan-bintang mempunyai reaktan segerak $3.24\text{-}\Omega$ per fasa; perintang boleh diabaikan. Medan pengujaan diselaraskan bagi menghasilkan operasi factor kuasa uniti pada kadar beban. Anggarkan kuasa maksimum yang motor boleh hantarkan dengan medan pengujaan tetap pada nilai yang sama.

(15 marks/markah)

- (e) A 480-V, 100-kW, 50-Hz, four-pole, star-connected synchronous motor has an armature resistance of $0.08\text{-}\Omega$ and synchronous reactance of $1.0\text{-}\Omega$. The motor is operating at full load and its rated power factor is 0.85-PF leading. The efficiency of motor at full-load is 91 percent. Estimate the

Motor segerak, 480-V, 100-kW, 50-Hz, 4-kutub, sambungan-bintang mempunyai perintang angker $0.08\text{-}\Omega$ dan reaktan segerak $1.0\text{-}\Omega$. Motor beroperasi pada beban penuh dan kadar penuh factor kuasanya ialah 0.85 kehadapan. Kecekapan motor pada beban penuh ialah 91 peratus. Anggarkan:

- (i) armature current I_A ,
arus angker I_A , (5 marks/markah)
- (ii) induced voltage,
voltan teraruh, (10 marks/markah)
- (iii) power converted P_{conv} , and
kuasa penukaran P_{conv} , dan (10 marks/markah)

(iv) mechanical, core and stray losses (i.e. $P_m + P_{core} + P_{stray}$).

Kehilangan mekanik, teras dan sesat (i.e. $P_m + P_{core} + P_{stray}$).

(10 marks/markah)

4. (a) Sketch the power flow diagram of an induction motor. Label the diagram properly showing input and output powers and all other power losses.

Lakarkan gambarajah aliran kuasa motor aruhan. Labelkan gambarajah tersebut dengan betul menunjukkan kuasa masukan, kuasa keluaran dan semua kuasa kehilangan yang lain.

(10 marks/markah)

- (b) A 440 V, 50 Hz, six-pole, star connected squirrel cage induction motor has the following equivalent circuit parameters:

Sebuah motor aruhan sangkar tupai, 440 V, 50 Hz, enam-kutub, sambungan bintang, mempunyai parameter litar setara seperti berikut:

$$R_1 = 0.082\Omega, R_2 = 0.07\Omega, X_1 = 0.19\Omega, X_2 = 0.18\Omega, \quad \text{and } X_m = 7.2\Omega$$

$$P_{mech} = 1.3\text{ kW}, P_{misc} = 150\text{ W}, \text{ and } P_{core} = 1.4\text{ kW}$$

The motor is driving a rated load at a speed of 960 rpm. Estimate the:

Motor memandu beban kadar pada kelajuan 960 rpm. Anggarkan:

- (i) line current I_L ,
arus talian I_L , (25 marks/markah)

- (ii) stator power factor,
faktor kuasa stator, (5 marks/markah)

- (iii) stator copper losses P_{SCL} ,
kehilangan tembaga stator P_{SCL} , (10 marks/markah)
- (iv) air gap power P_{AG} ,
kuasa sela udara P_{AG} , (10 marks/markah)
- (iv) power converted P_{CONV} ,
kuasa tukaran P_{CONV} , (10 marks/markah)
- (v) induced torque τ_{ind} ,
tork janaan τ_{ind} , (15 marks/markah)
- (vi) load torque τ_{load}
tork beban τ_{load} (15 marks/markah)

5. (a) A three-phase, 50-Hz, four pole, star connected induction motor has the following data: $R_s = 0.4\Omega$, $R_r = 0.2\Omega$, $X_s = 0.85\Omega$, $X_r = 0.75\Omega$, and $X_m = 24\Omega$, all quantities being referred to the stator side.

The motor is operated with stator voltage control using a three-phase ac voltage controller having an input supply voltage of 440 line-to-line. The firing angle is $\alpha = 60^\circ$. Motor is driving a load whose load torque obeys the equation $T_{ld}S^2 = 0.12$. Estimate the slip and air-gap power using small slip approximation.

Sebuah motor aruhan tiga-fasa, 50-Hz, empat-kutub, sambungan bintang mempunyai data: $R_s = 0.4\Omega$, $R_r = 0.2\Omega$, $X_s = 0.85\Omega$, $X_r = 0.75\Omega$, dan $X_m = 24\Omega$, semua kuantiti dinisbahkan kepada pemegun.

Motor ini dikendalikan dengan kawalan voltan stator, menggunakan tiga-fasa pengawal voltan ac mempunyai bekalan voltan masukan 440 talian-ke-talian. Sudut tembakan adalah $\alpha = 60^\circ$. Motor memandu beban yang tork bebannya mematuhi persamaan $T_{ld}S^2 = 0.12$. Anggarkan slip dan kuasa sela udara menggunakan anggaran slip kecil.

(60 marks/markah)

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- (b) A three phase, 50-kW, 1470-rpm, 400-V, 50-Hz, 4-pole, star connected induction motor has following parameters;

Sebuah motor aruhan tiga-fasa, 50-kW, 1470-rpm, 400-V, 50-Hz, 4-kutub, sambungan bintang mempunyai parameter berikut:

$$R_s = 0.42 \Omega, R_r = 0.23 \Omega, X_s = 0.95 \Omega, X_r = 0.85 \Omega, \text{ and } X_m = 28 \Omega$$

All the quantities are referred to stator side.

The motor is operated with frequency control. The slip for maximum torque at the given supply frequency is 0.12. Estimate the

Semua kuantiti dinisbahkan kepada bahagian pemegun. Motor dikendalikan dengan kawalan frekuensi. Slip untuk tork maksimum pada frekuensi bekalan yang diberikan ialah 0.12. Anggarkan:

- (i) supply frequency,
frekuensi bekalan, (10 marks/markah)
- (ii) break down torque, and
pecahan tork (20 marks/markah)
- (iii) speed at the maximum torque,
kelajuan pada tork maksimum (10 marks/markah)

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