SULIT

UNIVERSITI TEKNOLOGI MALAYSIA
PEPERIKSAAN AKHIR
SEMESTER 2
SESI 2010/2011

KOD MATAPELAJARAN	:	**SEE 3433**
MATA PELAJARAN	:	**MESIN ELEKTRIK**
PENSYARAH	:	**NIK DIN MUHAMAD (01)** **DR. AWANG JUSOH (02)**
KURSUS	:	**SEE**
SEKSYEN	:	**01 and 02**
MASA	:	**2 JAM 30 MINIT**
TARIKH	:	

ARAHAN KEPADA CALON :

JAWAB EMPAT (4) SOALAN SAHAJA. SEMUA PENGIRAAN HENDAKLAH DITUNJUKKAN DENGAN JELAS.

KERTAS SOALAN INI TERDIRI DARIPADA 9 (SEMBILAN) MUKA SURAT SAHAJA

Question 1

(a) By considering linear electromechanical energy systems and with the help of equations, explain briefly the production of torque in a singly excited and a doubly excited electromechanical energy system. [6 marks]

(b) In the electromagnetic relay system, the flux linkage λ and current i relationship is given by:

$$i = k\lambda^2 e^{2x}$$

Evaluate the electromechanical energy force, f_m when λ = 2 V.s, x = 1 m and k = 6 A/(V.s)^2 [6 marks]

(c) An elementary two-pole cylindrical rotating machine with a uniform air gap is shown in Figure Q1(c). The mutual inductance between the rotor and the stator is given by

$$L_{12} = 0.5\cos\theta \quad \text{H}$$

A DC current source $i_1 = 4\,A$ is applied to the rotor and an AC current source $i_2 = 8\sin(10t)\ A$ is applied to the stator.

(i) Write the general equation of the torque for the machine in Figure Q1(c) as functions of i_1, i_2 and L_{12}. [2 marks]

(ii) Derive the developed torque when the rotor is locked at $\theta = 60°$. Also, determine the average torque produced by the machine. [5 marks]

(iii) Derive the developed torque when the rotor can freely rotate. Let $\theta = 60°$ at $t = 0$ and ω_m = 10 rad/s. Also, determine the average torque developed by the machine. [6 marks]

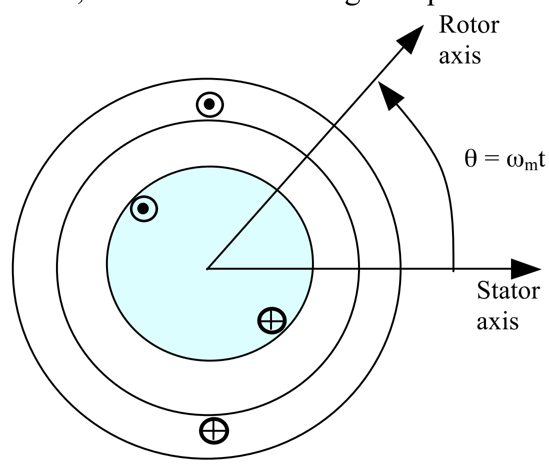


Figure Q1(c)

Question 2

(a) Show typical $V_t - I_a$ characteristics of differentially compounded and cumulatively compounded DC generators. Explain briefly their characteristics. [6 marks]

(b) A six pole DC machine has a wave winding of 300 turns. The flux per pole is 0.025 Wb. The DC machine rotates at 1000 rpm.

(i) Determine the generated voltage, E_a.

(ii) Determine the kW rating of the machine if the rated current through the turn is 25 A.

[5 marks]

(c) A 10 kW, 100 V, 800 rpm, $R_a = 0.1\ \Omega$ DC machine operated as shunt self-excited generator has a magnetization characteristic at 800 rpm as shown in Figure 2(c) in *Attachment Q2(c)*. The shunt field winding resistance $R_{fw} = 100\ \Omega$ and the number of turns $N_f = 1200$ turns per pole. The rated field current $I_f = 0.8$ A. The machine is provided with a series winding with $R_{sr} = 0.04\ \Omega$ so that it can operate as a compound DC machine as well.

(i) Draw an equivalent circuit of the compound DC machine. Label all key quantities.

[3 marks]

(ii) The machine is operated as a shunt generator at 800 rpm and the no load terminal voltage is adjusted to 100 V. Determine the full load terminal voltage. Assume the effect of armature reaction at full-load is $I_{f(AR)} = 0.05$ A. [4 marks]

(iii) The machine is operated as a compound DC machine at 800 rpm so that the terminal voltage of 100 V can be achieved at no load as well as at full load (i.e., zero voltage regulation). How many series turns per pole, N_{sr} are required to obtain this zero voltage regulation. Assume the effect of armature reaction at full-load is $I_{f(AR)} = 0.05$ A. [7 marks]

You must submit *Attachment Q2(c)* with your answer booklet

Question 3

(a) Explain briefly the terminal voltage control for controlling the speed of a separately excited DC motor. [4 marks]

(b) Explain briefly the effect of armature reaction on the operation of a DC motor and a DC generator. [4 marks]

(c) A 10 kW, 100 V, 800 rpm, $R_a = 0.1\ \Omega$ DC machine operated as shunt self-excited generator has a magnetization characteristic at 800 rpm as shown in Figure 3(c) in *Attachment Q3(c)*. The shunt field winding resistance $R_{fw} = 100\ \Omega$ and the number of turns $N_f = 1200$ turns per pole. The rated field current $I_f = 0.8$ A. The machine is provided with a series winding with the number of turns N_{sr} and negligible R_{sr} so that it can operate as a compound DC motor as well. The machine is connected to a 100 V DC supply and is operated as a shunt DC motor. At no load conditions the motor runs at 800 rpm and the armature takes 5 amperes.

(i) Find back emf E_a, field current I_f, and field resistance, R_f at no load conditions. [3 marks]

(ii) Find the speed of the motor when the rated current flows in the armature. Neglect the armature reaction effect. [4 marks]

(iii) Find the speed of the motor when the rated current flows in the armature. Consider that the effect of armature reaction at full load is 5% reduction in the air gap flux (i.e. $\phi_{FL} = 0.95\phi_{NL}$). [5 marks]

(iv) The machine is operated as a cumulatively compound DC motor so that the speed of 700 rpm can be achieved at full load. How many series turns per pole, N_{sr} are required? Assume the armature reaction effect at full load is $I_{f(AR)} = 0.15$ A. [5 marks]

You must submit *Attachment Q3(c)* with your answer booklet

Question 4

(a) Why is terminal voltage speed control for induction machine limited in operating range? [3 marks]

(b) How is torque developed in induction motor? Why is it impossible for an induction motor to operate at synchronous speed? [4 marks]

(c) The parameters for a 6-pole, 3-phase, star-connected, 415 V, 50 Hz, 950 rpm wound rotor induction machine are as follows:

$R_1 = 0.25\ \Omega$ $R'_2 = 0.20\ \Omega$

$X_1 = 0.65\ \Omega$ $X_2' = 0.60\ \Omega$ $X_m = 60\ \Omega$

The motor is connected to a 3-phase 415 V, 50Hz supply. The rotational losses are assumed constant at 1200 watts whenever the motor rotates. With the rotor terminal short circuited, find:

(i) Line current, power factor, and input power at full load. [6 marks]

(ii) Current drawn by the motor and torque at starting. [6 marks]

(iii) Motor efficiency at which maximum torque is developed. [6 marks]

Question 5

(a) Draw the power-angle characteristics and torque-speed characteristics of a synchronous machine. Label key quantities. [4 marks]

(b) With the help of a suitable phasor diagram, explain briefly how the power factor of the synchronous motor connected to infinite bus can be controlled by the field current at a constant output power. [6 marks]

(c) A star-connected 3-phase, 20 kVA, 415 V, 50 Hz, 4-pole synchronous machine has a synchronous reactance $X_s = 10\ \Omega$. The armature resistance can be neglected. The machine is connected to an infinite bus bar of 415 V, 50 Hz.

(i) The mechanical power and field current excitation are adjusted such that the machine is delivering 10 kW at a power factor of 0.8 lagging. Determine the excitation voltage E_f and the power angle δ. Draw the phasor diagram for this condition.

[5 marks]

(ii) If the field excitation current is now increased by 15 percent without changing the prime mover power, find reactive kVAr supplied by the machine. Draw the phasor diagram for this condition. [5 marks]

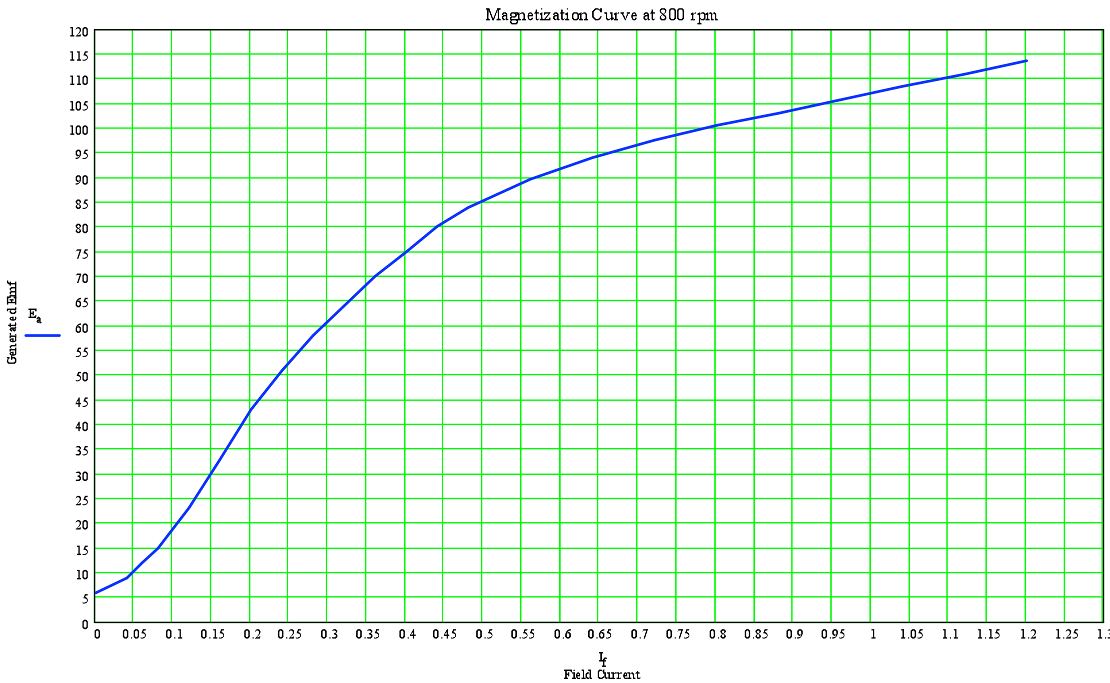
(iii) Determine the maximum power the synchronous machine can deliver for the excitation current as in (i). Draw the phasor diagram for this condition.

[5 marks]

Attachment Q2(c)

Name: ____

Seksyen: 01/02



<u>Figure Q2(c)</u>

Attachment Q3(c)

Name: ______________________________

Seksyen: 01/02

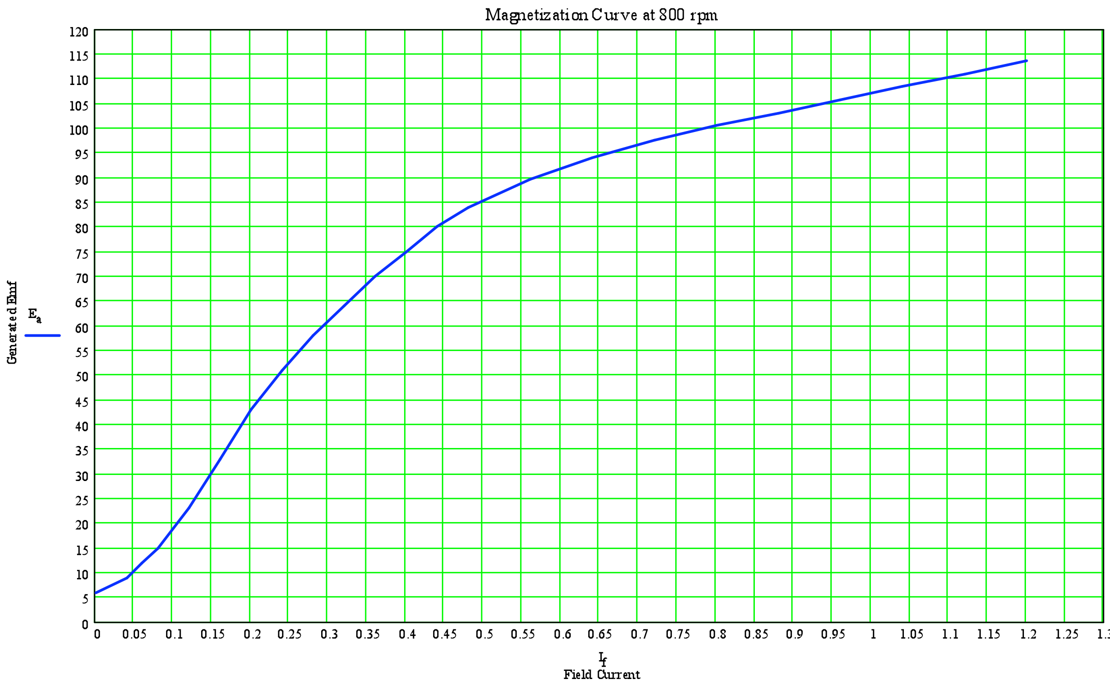


Figure Q3(c)

Potentially Useful Formulae

$$\mu_o = 4\pi \times 10^{-7}\ \text{H/m}$$

$$B = \frac{\phi}{A} = \mu H$$

$$R = \frac{l}{\mu A}$$

$$Hl = Ni$$

$$L \equiv \frac{\lambda}{i} = \frac{N\phi}{i} = \frac{N^2}{R}$$

$$\lambda \equiv N\phi = Li$$

$$e = \frac{d\lambda}{dt}$$

$$W_f = \int_0^{\lambda} i\,d\lambda$$

$$W_f' = \int_0^{i} \lambda\,di$$

$$w_f = \int_0^{B} H\,dB$$

$$w_f' = \int_0^{H} B\,dH$$

$$W_f = \frac{1}{2} i^2 L(x)$$

$$R_f = R_{fw} + R_{fc}$$

$$I_a = I_f + I_t$$

$$I_{f(eff)} = I_f - I_{f(AR)}$$

$$I_{f(eff)} = I_f \pm \frac{N_{sr}}{N_f} - I_{f(AR)}$$

$$\omega_m = -\frac{R_a}{(K_a\phi)^2} + \frac{V_t}{K_a\phi}$$

$$E_a = K_{sr} I_a \omega_m$$

$$T = K_{sr} I_a^2$$

$$\omega_m = \frac{V_t}{\sqrt{K_{sr}}\sqrt{T}} - \frac{R_a + R_{sr} + R_{ae}}{K_{sr}}$$

$$N_s = \frac{120 f}{p}$$

$$s = \frac{N_s - N_r}{N_s}$$

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

$$E_a = K_a \phi \omega_m$$

$$V_t = E_a \pm I_a R_a$$

$$K_a = \frac{Np}{\pi a}$$

$$V_t = R_f I_f$$

$$E_f = V_t \angle 0 \pm I_a j X_s$$

$$P = \frac{3 E_f V_t}{X_s} \sin\delta$$

$$P_{mech} = I_2^2 \frac{R_2}{s}(1 - s) = P_{ag}(1 - s)$$

$$P_{ag} = I_2^2 \frac{R_2}{s}$$

$$f_m = -\left.\frac{\partial W_f(\lambda, x)}{\partial x}\right|_{\lambda = \text{constant}}$$

$$\sin(x)\cos(y) = \frac{\sin(x + y)}{2} + \frac{\sin(x - y)}{2}$$

$$f_m = \left.\frac{\partial W_f'(i, x)}{\partial x}\right|_{i = \text{constant}}$$

$$T = \frac{1}{\omega_{syn}} P_{ag}$$

$$s_{T\max} = \frac{R_2}{\left[R_{Th}^2 + (X_{th} + X_2)^2\right]^{\frac{1}{2}}}$$

$$f_m = \frac{i^2}{2}\frac{d}{dx} L(x)$$

$$V_{Th} = \frac{X_m}{\left[R_1^2 + (X_1 + X_m)^2\right]^{\frac{1}{2}}} V_1$$

$$f_m = \frac{\lambda^2}{2L(x)^2}\frac{d}{dx} L(x)$$

$$Z_{Th} = \frac{jX_m(R_1 + jX_1)}{R_1 + j(X_1 + X_m)}$$

$$T = \frac{1}{2} i_1^2 \frac{dL_{11}}{d\theta} + \frac{1}{2} i_2^2 \frac{dL_{22}}{d\theta} + i_1 i_2 \frac{dL_{12}}{d\theta}$$

$$T = \frac{1}{\omega_{syn}} \frac{V_{Th}^2}{(R_{Th} + R_2/s)^2 + (X_{Th} + X_2)^2} \frac{R_2}{s}$$

$$P = E_a I_a = T\omega_m$$

$$T = K_a \phi I_a$$