University of Jordan
Dept. of Elect. Engg.

Electric Machines 371
Mid Examination

3.5.2009
Time 90 Minutes

Name(in Arabic) **Student No.** **Section**

1. A 4-pole, dc generator having a total number of conductors of 600 and a flux per pole of 0.01 Wb. Total number of slots =20 and a speed of 1000 rpm. Neglect the winding resistance. Find the induced emf and the torque in case a load of 10Ω is connected across the terminals for the following cases:

8 marks

(i) Lap, retrogressive, duplex, double layer winding

$a = 4 \times 2 = 8$ $\quad K = \frac{600 \times 4}{2\pi \times 8} = \frac{150}{\pi}$

$E_a = \frac{150}{\pi} \times 0.01 \times 1000 \times \frac{2\pi}{60} = 50V$ $\quad T = \frac{\frac{50 \times 50}{10}}{\frac{2\pi}{60} \times 1000} = 2.387$

EMF = 50 **Torque =** 2.387 Nm

(ii) Lap, progressive, simplex, double layer winding

$a = 4$ $\quad K = \frac{600 \times 4}{2\pi \times 4} = \frac{300}{\pi}$

$E_a = \frac{300}{\pi} \times 0.01 \times 1000 \times \frac{2\pi}{60} = 100V$ $\quad T = \frac{\frac{100 \times 100}{10}}{\frac{2\pi}{60} \times 1000} = 9.55 Nm$

EMF = 100 **Torque =** 9.55 Nm

(iii) Wave, progressive, simplex, single layer

$a = 2$ $\quad K = \frac{600}{\pi}$

$E_a = \frac{600}{\pi} \times 0.01 \times 1000 \times \frac{2\pi}{60} = 200V$ $\quad T = \frac{\frac{200 \times 200}{10}}{\frac{2\pi}{60} \times 1000} = 38.197$

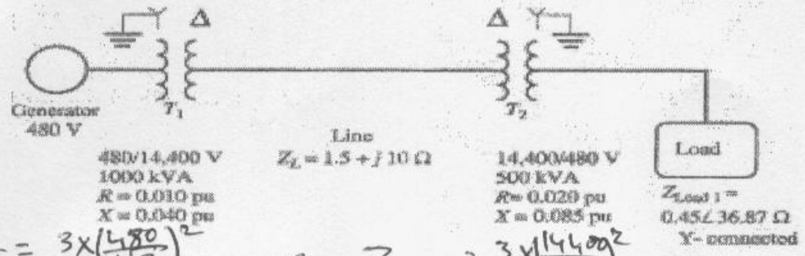
EMF = 200 V **Torque =** 38.197 Nm

(iv) Wave, retrogressive, simplex, double layer winding

$a = 2$ Same as (iii)

EMF = 200 V **Torque =** 38.197 Nm

2. The figure below shows a power system consisting of a three-phase 480-V 60-Hz generator supplying a load through a transmission line with a pair of transformers at either end. **8 marks**



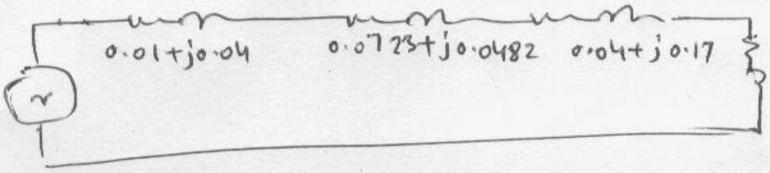
$S_{BASE} = 1000$ KVA

$Z_{BASE} = \dfrac{3\times\left(\frac{480}{\sqrt{3}}\right)^2}{1000\,000} = 0.238$ $\quad Z_{BASE2} = \dfrac{3\times\left(\frac{14400}{\sqrt{3}}\right)^2}{1000000} = 207.4$ $\quad Z_{BASE3} = Z_{BASE1}$

$I_{BASE} = \dfrac{1000\,000}{\sqrt{3}\times 480} = 1202.8$ $\quad I_{BASE} = \dfrac{1000000}{\sqrt{3}\times 14400} = 40.09$ A

(a) Sketch the per-phase equivalent circuit of this power system.

0.5
0.5
0.5
0.5



$1.513 + j1.134 = \dfrac{0.45\angle 36.87}{0.238}$ Ω

1

(b) Find the real power *P*, reactive power *Q*, and apparent power *S* supplied by the generator. What is the power factor of the generator?

$Z_{eq} = (0.01 + 0.04 + 0.0723 + 1.513) + j(0.04 + 0.17 + 0.0482 + 1.134)$

$= 1.5702 + j1.3922 = 2.099\angle 41.6°$

1 $\quad I = \dfrac{1}{2.099\angle 41.6} = 0.4765\angle -41.6$ A $\qquad \cos 41.6 = 0.748$ lagg

0.5 $\quad P = 1\times 0.4765\cos 41.6 = 0.356$ pu $\rightarrow$ 356 kW

0.5 $\quad Q = 1\times 0.4765\sin 41.6 = 0.316$ pu $\rightarrow$ 316 KVAR

0.5 $\quad S = 1\times 0.4765 = 0.4765$ pu $\rightarrow$ 476.5 KVA

0.5

(c) What are the transmission losses (transformer plus transmission line losses) in this system

1 $\quad P_{loss} = 0.4765^2\,[0.01 + 0.04 + 0.0723] = 0.0577 = 0.0131$ p.u.

$= 0.0131 \times 1000000 = 13.1$ KW

(d) What is the magnitude of the current flowing in each phase of the generator and in the transmission line?

1 $\quad I_{gen} = 0.4765 \times 1202.8 = 573$ A

1 $\quad I_{TL} = 0.4765 \times 40.09 = 19.1$ A

3. A 300V shunt dc motor with $R_a = 0.15\ \Omega$, $R_F = 40\ \Omega$, $R_{adj} = 20\ \Omega$. It draws a total current of 105A while running at a speed of 1200rpm. Neglect rotational losses.

7marks

(i) Calculate the **Torque** and **Efficiency** at this speed

$$I_F = \frac{300}{20+40} = 5A$$

$$I_a = 105 - 5 = 100A$$

$$E_a = 300 - 100 \times 0.15 = 285$$

$$T = \frac{285 \times 100}{1200 \times \frac{2\pi}{60}} = \underline{226.8}$$

$$\eta = \frac{285 \times 100}{300 \times 105} = \underline{90.47\%}$$

(ii) The resistance R_{adj} is removed while the load torque is reduced to 75% of its original value. Calculate the **new speed** and the **new efficiency**. Consider that the motor operates in the linear region of the characteristics.

$$I_{F2} = \frac{300}{40} = 7.5A$$

$$E_{a2} = 300 - I_{a2} \times 0.15$$

$$\frac{E_{a2}}{E_{a1}} = \frac{I_{F2}}{I_{F1}} \cdot \frac{n_2}{n_1} \qquad \frac{E_{a2}}{285} = \frac{7.5}{5} \cdot \frac{n_2}{1200}$$

$$\frac{T_1}{T_2} = \frac{I_{F1}}{I_{F2}} \cdot \frac{I_{a1}}{I_{a2}} = \frac{1}{0.75} = \frac{5}{7.5} \times \frac{100}{I_{a2}}$$

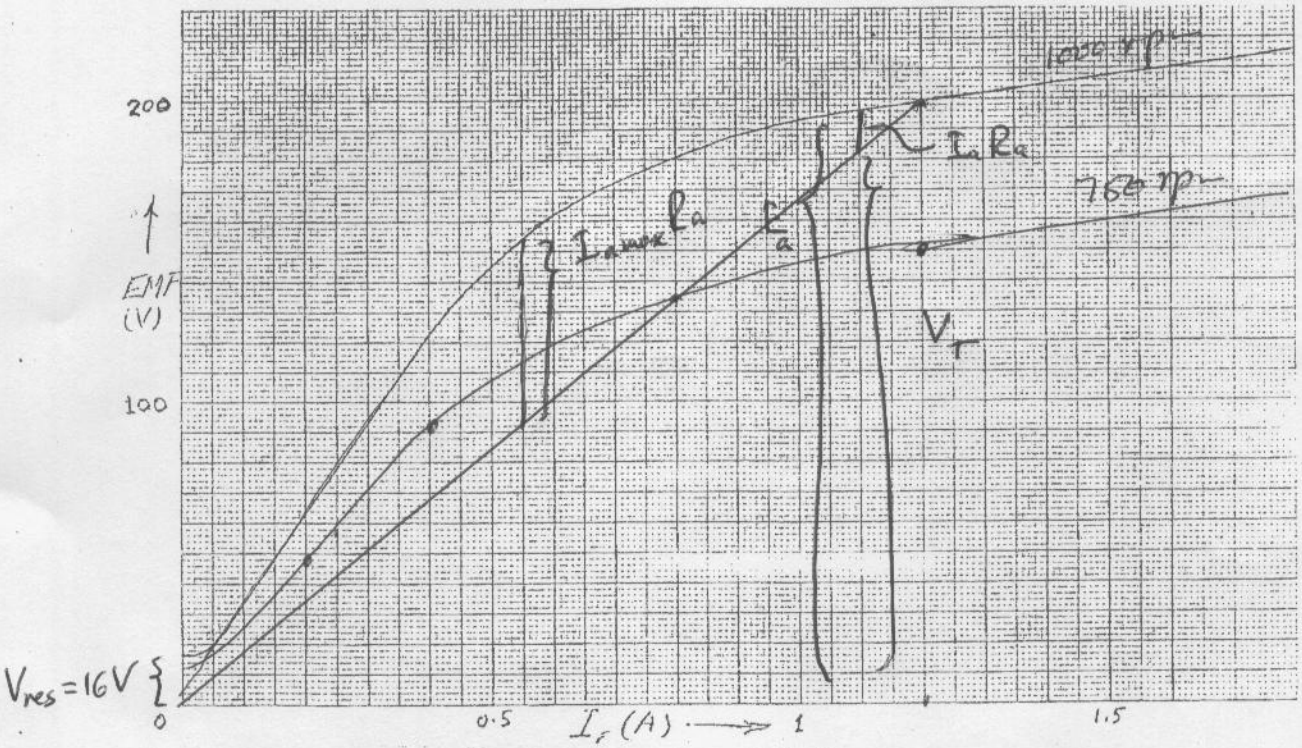
$$I_{a2} = 50A$$

$$E_{a2} = 300 - 50 \times 0.15 = 292.5V$$

$$n_2 = \frac{1200 \times 5}{7.5 \times 285} \times 292.5 = \underline{821}\ rpm$$

$$\eta = \frac{292.5 \times 50}{300 \times 57.5} = \underline{84.78\%}$$

4. A 9KW, 180V, 1000rpm shunt dc generator has an armature resistance R_a =0.3Ω and a shunt field winding resistance of 60Ω. The characteristics of the machine is shown below. Neglect the armature reaction. **7marks**



(i) Find the field control (external resistance) necessary to make the no load induced emf = 200V when the generator operates as a shunt generator.

$\frac{200}{1.2} = 166.6\,\Omega$

→ $166.6 - 60 = 106.6\,\Omega$

$\frac{9000}{180} = 50\,A$

$50 \times 0.3 = 15V$

→ $E_a = 197V$

→ $V_T = 182V$

$I_{max}R = 60V = I_{max} \times 0.3$

→ $I_{max} = 200\,A$

→ → $R_{critical} = \frac{120}{0.4} = 300\,\Omega$

→ $I_{sc} = \frac{16}{0.3} = 53.3\,A = \frac{V_{res}}{R_a}$

→ Critical Resistance is the shunt resistance above which no emf is induced in the armature