ELG 3316 : *Electric Machines & Power Systems*

Mid-Term Examination Fall 2012

Date : 31st October 2012 Time : 14:30-15:45 (75 Minutes)

- Closed book examination. The only information sheets allowed are those included with the examination question paper.
- Calculators are allowed.
- There are **three questions** with unequal weights, totaling 61 marks. You should attempt **all** questions.
- It is strongly recommended that you write down your solutions step by step. This is the only way it is possible for you to earn marks step by step.
- **Units** must be given with all **final** numerical answers. Marks will be subtracted if units are omitted.
- Some questions require explanations rather than numerical calculations. Use the number of assigned marks as an indication of what is required. If such a question is worth 3 marks, then the answer must contain three independent pieces of information to earn all 3 marks.
- Read the questions carefully. This will prevent you from providing answers to questions that were not asked.
- Cheating will be penalised in accordance with University of Ottawa regulations.

Question 1 (12)

(a). What is meant by "saturation" of a magnetic core, and why is it disadvantageous? **[2]**

The physical magnetic circuit shown in Fig.1 has a uniform rectangular cross-section of area $A_o = 150$ cm^2. Except for the air gap and the one limb of relative permeability 1200, the rest of the core material can be considered to have infinite permeability. Fringing fields and other flux leakage can be ignored.

(b). Draw the equivalent magnetic circuit in terms of reluctances and MMFs. Symbols used in answering the question in (c) below must be shown on this diagram. **[3]**

(c). Determine the winding current I_w needed to produce a flux density of 0.5 T in the air gap. **[7]**

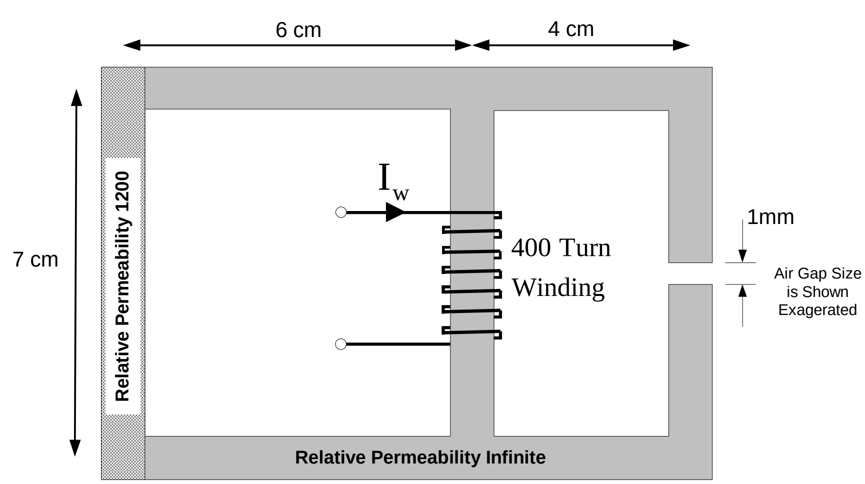

Fig.1 : Sketch of Physical Magnetic Circuit

<u>Question 2</u> (28)

(a). Describe three mechanisms that contribute to power losses in a transformer. **[2]**

(b). You overhear an inexperienced engineer saying : "Power transformers have non-linear ferromagnetic cores. Nevertheless, if the voltage applied to the primary winding is a sinusoid of frequency 60 Hz, then the current in the primary winding will also be a 60Hz sinusoid". <u>Explain</u> whether the above statement is true or false. (No marks for simply stating "true" or "false"). **[3]**

(c). A single-phase supply voltage $\tilde{V}_s$ is connected to one end of a long power cable, which the cable supplier tells us can be represented by a series impedance $R_{TL} + jX_{TL} = 3.2 + j0.4\ \Omega$ at 60Hz. The other end of the cable is connected to a step-down 5 kVA, 600/120 volt transformer. The transformer's equivalent circuit referred to the low voltage side has $R_{eq} = 0.12\Omega$ and $X_{eq} = 0.5\Omega$. The transformer core loss, and magnetization current, are negligible. The load connected to the secondary of the transformer consumes 4.5kW at 0.93 lagging power factor. The voltage magnitude $\left|\tilde{V}_{load}\right|$ across the load is measured to be 115 volts.

(i). Draw an appropriately labelled equivalent circuit of the above single-phase power system, with the values of all components shown on the circuit diagram. You must retain the symbols already defined in the question statement. All symbols used in answering the various parts of this question must be indicated on the circuit diagram. **[4]**

(ii). Determine the magnitude of the supply voltage? **[10]**

(iii). Calculate the power loss in the transformer windings (the "copper loss"). **[3]**

(iv). What is the efficiency (η_t) of the transformer, and the efficiency (η_s) of the overall power system (that is, including both the cable and the transformer)? **[3]**

(v). What will the magnitude of the voltage across the transformer secondary terminals be if the load were to be disconnected? <u>Explain</u>. **[3]**

All voltage and current symbols used in your solution must be indicated on the circuit diagram.

Question 3 (21)

(a). What advantage does a three-phase system have over a single-phase one as far as the time-dependence of power flow is concerned? Explain briefly. **[2]**

(b). The following three-phase balanced loads are connected in parallel across a three-phase wye-connected source of 480 volts :

Three-Phase Load#1 - Wye-connected load with line current magnitude of 58 A at 0.85 lagging power factor.

Three-Phase Load#2 - Delta-connected load that consumes a total of 80 kW at 0.8 lagging power factor.

(i). Draw the appropriately labelled per-phase circuit for this power system. Symbols used in answering the sub-questions below must be shown in this diagram. **[4]**

(ii). What is the magnitude of the line current supplied by the source? **[13]**

(iii). What is the magnitude of the phase current of Load#1? **[1]**

(iv). What is the magnitude of the phase current of Load#2? **[1]**

Some General Information

$\mu_o = 4\pi \times 10^{-7}$ H/m $\quad \lambda = N\Phi \quad L = \lambda / i \quad \Re = \ell / \mu A \quad e = d\lambda / dt \quad \sin x = \cos(x - 90^o)$

$I_L = \sqrt{3}\, I_P$ (Delta) $\quad V_{LL} = \sqrt{3} V_P$ (Wye) $\quad Z_Y = Z_\Delta / 3 \quad \phi_{\text{pf}} = \phi_{\text{v}} - \phi_{\text{i}}$

$\tilde{V}_{ab} = \sqrt{3}\, \tilde{V}_a e^{j30^\circ}$ (Wye Source) $\quad \tilde{I}_a = \sqrt{3}\, \tilde{I}_{ab} e^{-j30^\circ}$ (Delta Source) $\quad \tilde{S} = \tilde{V}\tilde{I}^* = P + jQ$

$$\frac{\tilde{E}_1}{\tilde{E}_2} = \frac{N_1}{N_2} = \frac{\tilde{I}_2}{\tilde{I}_2'} \qquad Z_2' = \left(\frac{N_1}{N_2}\right)^2 Z_2 \qquad i_1 = i_m + (N_2 / N_1) i_2$$