Data Provided: 3 sheets of linear-linear graph paper per candidate

The University Of Sheffield.

DEPARTMENT OF ELECTRONIC AND ELECTRICAL ENGINEERING

Spring Semester 2010-2011 (2 hours)

EEE102 Power Networks 1

Answer **THREE** questions. **No marks will be awarded for solutions to a fourth question.** Solutions will be considered in the order that they are presented in the answer book. Trial answers will be ignored if they are clearly crossed out. **The numbers given after each section of a question indicate the relative weighting of that section.**

1. A single-phase transformer with a primary to secondary turns ratio of 12:1 has the following measured parameters:

Primary winding resistance	$R_1 = 9\Omega$
Primary winding leakage reactance	$X_1 = 11\Omega$
Secondary winding resistance	$R_2 = 0.06\Omega$
Secondary winding leakage reactance	$X_2 = 0.09\Omega$
Magnetising reactance	$X_m = 2.8k\Omega$
Core Loss resistance	$R_m = 43k\Omega$

(Note: The secondary reactance and resistance given are non-referred values)

The transformer primary is connected to a 3300 Vrms, 50Hz, sinusoidal AC supply. The secondary is connected to a load which has an impedance of $Z = (4+j3)\Omega$.

a. Listing any assumptions that you make, draw an equivalent circuit for the transformer including numerical values for all impedances. The transformer secondary impedance and the load should be referred to the primary side. **(4)**

b. Calculate the magnitude and phase of the no-load current drawn by the transformer when the secondary load is disconnected. **(3)**

c. Calculate the transformer core losses when the secondary load is disconnected. **(1)**

d. With the secondary load connected, calculate the following:

i) Magnitude and phase of the actual load current.
ii) Magnitude and phase of the primary input current.
iii) Magnitude and phase of the output voltage.
iv) Voltage regulation.
v) Copper loss in the transformer windings.
vi) Real component of the output power and the transformer efficiency. **(12)**

2. Figure 2.1 shows a schematic of an inductor which is based on a circular core of mean diameter 120mm, cross-sectional area of 200mm^2 and a relative magnetic permeability of 600. The core includes a 1mm long air gap which has the same 200mm^2 cross-sectional area. The inductor is equipped with a coil with 300 series turns.

[The permeability of free space $\mu_0=4\pi\times10^{-7}$ Hm^{-1}]

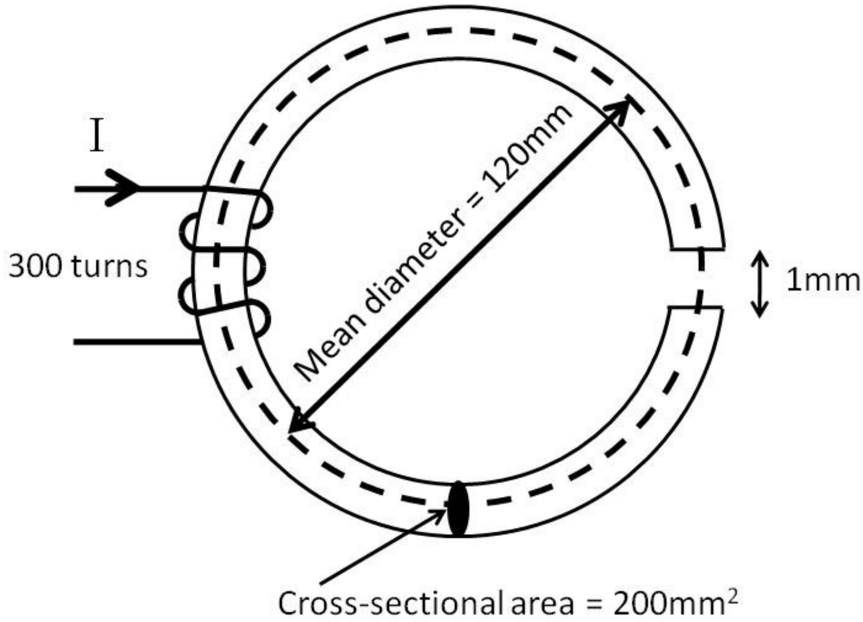

Figure 2.1 Inductor dimensions and coil details

a. Calculate the self inductance of the inductor. **(4)**

b. Calculate the magnitude of DC current which is required to produce a flux density in the core of 1.2T. **(1)**

c. The coil has a resistance of 2Ω and is connected to a 115 Vrms sinusoidal AC variable frequency supply on an aircraft. The frequency of the supply can vary between 380Hz and 800Hz during a typical flight. Calculate the following:

i) The magnitudes and phases of the currents for supply frequency of 380Hz and 800Hz.

ii) The copper loss in the coil for supply frequencies of 380Hz and 800Hz.

iii) The peak flux density in the core for supply frequencies of 380Hz and 800Hz. **(6)**

d. If the core begins to magnetically saturate at 1.6T, calculate the minimum AC supply frequency which can be applied to the coil to avoid the onset of saturation (the magnitude of the voltage supply remains at the same 115 Vrms value) **(5)**

e. The manufacturer of the inductor receives a request from a customer to double the inductance. The inductor manufacturer chooses to meet this request by reducing the length of the airgap in the core, leaving all other dimensions and the number of turns on the coil fixed. Calculate the new airgap length which will be required to satisfy the customer request (*Hint: You may neglect the effect on the core reluctance of the change in airgap length*). **(4)**

3. A large shopping centre has an incoming 3-phase, 11kVrms (line to line), 50Hz sinusoidal AC supply which is connected to various loads within the centre. The effective impedance per phase of the combined loads when the centre is operating at full capacity is $16+j6.4\Omega$. The loads are all star connected.

a. Calculate the magnitude and phase of the line current drawn by the centre when operating at full capacity. **(3)**

b. Calculate the real power, the VAr and the VA drawn by the centre when operating at full capacity. **(4)**

c. In order to improve the power factor to 0.98 lagging for the centre when operating at full capacity with the same real power, a three-phase star-connected set of capacitors is connected in parallel with the centre electrical loads. Calculate the values of the capacitors which would be required to achieve this improved power factor. **(5)**

d. Calculate the VA supplied to the centre when the power factor correction capacitors are installed and hence the line current drawn. **(2)**

e. When the shopping centre is closed to the public overnight, the power requirement is reduced such that the effective impedance per phase is $32+j9.4\Omega$. In order to improve the power factor during both full capacity in the daytime and overnight on reduced load it is proposed to divide the capacitor bank in part (c) into two parts such that a proportion of it can be switched out of the circuit overnight. Calculate the value of capacitance which must be switched out of circuit when the centre is closed to achieve a power factor of 1.0. **(6)**

4. Figure 4.1 shows the current waveform which is imposed through a load over a 15s cycle. It consists of 5 distinct intervals (0-2s, 2-5s, 5-7s, 7-12s and 12-15s). The load has a resistance of 2Ω and an inductance of 2H.

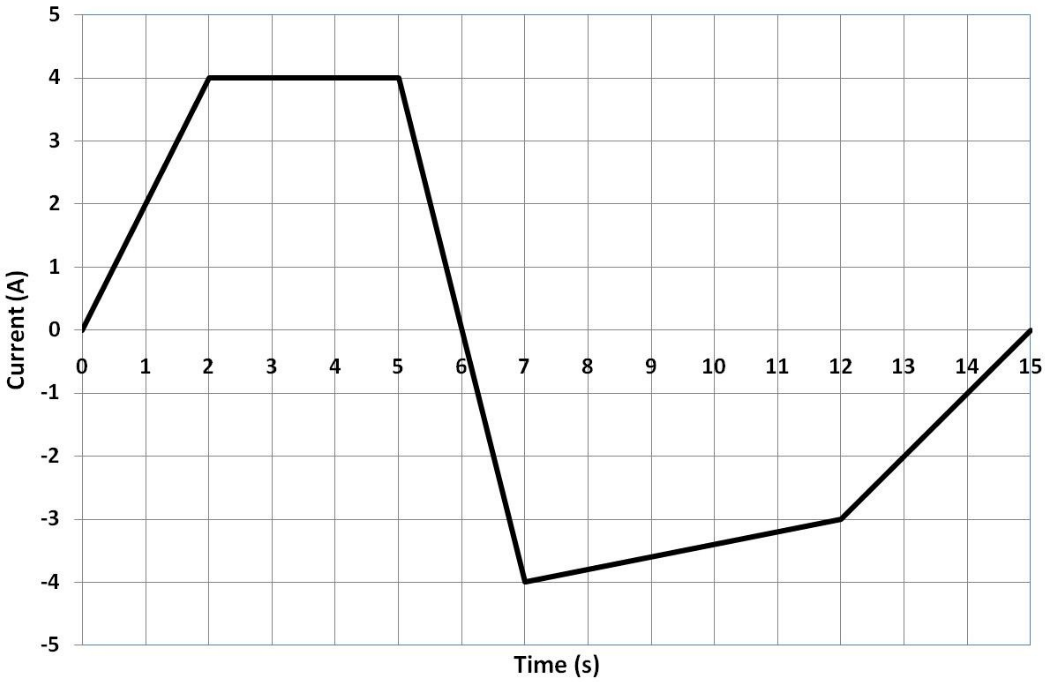

Figure 4.1 – Current waveform applied to load over a 15 second period

a. Plot (using the graph paper provided) separate voltage waveforms across the resistor, the inductor and the total load. **(9)**

b. Calculate the total energy dissipated by the load over the 15s period (*Hint: you may find it easier to reset time to zero at the start of each of the 5 intervals which make up the 15s cycle*) **(9)**

c. Calculate the peak energy stored in the inductance during the 15 second cycle. **(2)**

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