Tutorial Sheet – No 5

(Transformers 1)

This tutorial sheet introduces some of the principles of transformer applications and solution techniques. The questions use the ideal ratios:

$$\frac{V_1}{V_2} = \frac{N_1}{N_2} \quad \textbf{\textit{and}} \quad \frac{I_1}{I_2} = \frac{N_2}{N_1}$$

These give good 'first order' answers in many circumstances, but more accurate equivalent circuit models are needed to predict the actual performance of a transformer. The next tutorial sheet will introduce the use of the equivalent circuit.

1 An ideal transformer has 1200 turns on its primary winding and 300 turns on the secondary. If 110V_{rms} is applied to the primary winding and a current of 4A_{rms} flows in the circuit connected to the secondary, calculate the current in the primary winding, the voltage across the secondary winding and the VA rating of the device.

(1A_{rms}; 27.5V_{rms}; 110VA)

2 An ideal transformer has 100 turns on its primary winding and 350 turns on the secondary. Calculate the output voltage if 240V_{rms} is applied to the input. If a load of 1000Ω is placed across the secondary winding, calculate the currents flowing in the primary and secondary windings.

(840V_{rms}; 2.94A_{rms}; 0.84A_{rms})

3 If the 240V_{rms} input voltage in question 2 is now applied to the 350 turn winding and the 1000Ω load is transferred to the 100 turn winding, calculate the new output voltage and the current in each winding.

(68.6V_{rms}; 19.6mA_{rms}; 68.6mA_{rms})

4 An ideal transformer has a turns ratio of 6:1 (pri:sec) and a maximum rating of 1200VA. The secondary load consists of **either** a resistor or an inductor and in each case the maximum allowable current is 2A_{rms}. If the loads are adjusted so that they take maximum current at the full transformer rating, calculate the input voltage, input current and phase angle in each case and the power dissipated in each load.

(For resistor load: 3600V_{rms}; 0.333$\angle$0°A_{rms}; 1200W,
For inductor load: 3600V_{rms}; 0.333$\angle$-90°A_{rms}; 0W)

5 A transformer has 1200 turns on the primary and a maximum allowable flux density in the core of 1.2T. If the primary is driven from a 50Hz sinusoidal supply and has a core cross-sectional area of 300mm^2, calculate the maximum allowable rms input voltage.

(95.9 V_{rms})

6 A transformer for the American market is designed to work at 60Hz and has a turns ratio of 8:1 (pri:sec), with 1900 turns on the primary winding. The core has a cross-sectional area of 500mm^2 and a maximum flux density of 1.2T before saturation. If the input voltage is 240V_{rms}, calculate the output voltage and maximum core flux density in each case if the input frequency is changed to 40Hz, 50Hz, 80Hz and 100Hz. If the supply voltage is subject to a ±10% variation, at which frequencies may the transformer be safely used without exceeding the maximum allowable flux density in the core.

(30 V_{rms} for all frequencies; 1.42T; 1.14T; 0.71T; 0.57T; 52.2Hz and above safe)

7 From the results of question 6 deduce which of the following is safe to do in practice, given that modern transformers are designed to operate near to saturation.
(a) Operate a transformer designed for 60Hz from a 50Hz supply
(b) Operate a transformer designed for 50Hz from a 60Hz supply

((a) dangerous, (b) safe)

8 For safety reasons, an instrument transformer is to be used in making voltage measurements on a $10kV_{rms}$ a.c. system. The transformer primary is connected to the High Voltage (HV) system and readings are to be taken on the Low Voltage (LV) side using a suitably scaled voltmeter. The meter has a full scale deflection of $50V_{rms}$ and an impedance of 5kΩ and is connected to the secondary of the transformer. Choose a suitable turns ratio for the transformer such that $10kV_{rms}$ input gives full scale deflection of the meter. Also calculate the current drawn from the test system by the measuring circuit.

(200:1; $50\mu A_{rms}$)

9 A two-winding transformer has 400 primary turns and 300 secondary turns. The primary is connected to a 50 Hz, $240V_{rms}$ a.c. supply and the secondary to a load of 8kVA.

(a) Calculate the load voltage, the load current and the transformer primary input current.

(b) Calculate the cross-sectional area required for the core of the transformer to limit its peak flux density to 1.5T.

($180V_{rms}$; $44.4A_{rms}$; $33.3A_{rms}$; $18cm^2$)

10 An audio-frequency amplifier can be represented as an emf source in series with an output resistance of 500Ω. If the loudspeaker load can be considered as a resistance of 8Ω, calculate the matching transformer turns-ratio which, when placed between the amplifier and load, will permit maximum power transfer to the speaker. [Prove the maximum power condition from circuit analysis].

(For maximum power transfer, source impedance = referred load impedance; Ratio required = 7.9:1)

11 A current transformer is to be used as a current probe system for use with an oscilloscope. The transformer primary is connected **in series** with the circuit in which the current is to be measured and its secondary is connected to a load resistor. The voltage across this resistor provides the oscilloscope input signal. The primary winding has two turns and the secondary 250 turns and the secondary load resistor has a resistance of 12.5Ω. If the circuit being monitored carries a current of $50A_{rms}$ calculate the transformer output voltage and hence the sensitivity of the probe.

($5V_{rms}$; $0.1V_{rms}$ per amp of measured current)