Homework 2 – AC Excitation and Single-Phase Transformers

Q.1. Consider a single phase, step-down transformer with 30 kVA, 50 Hz, 2200V/220V ratings.

Part A:

a) What is the rated current at the primary side of this transformer?

b) What is the rated voltage at the secondary side of this transformer?

c) Results of some tests applied to this transformer are as follows:

Short circuit test (the instruments are placed on the high voltage side): ***74.2 Volts, 592 Watts***

Open circuit test (the instruments are placed on the low voltage side): ***4.86 Amps, 319 Watts***

Draw the complete equivalent circuit of this transformer and find all the parameters by using the test results and your answers in (a) and (b). State your assumptions and approximations clearly!

Part B: A load is connected to the secondary of the transformer in Part (A) such that the secondary voltage is 220V when 30 kVA is delivered to the load at unity power factor.

Find the ***primary voltage*** and ***primary current*** by the use of:

a) The complete equivalent circuit.

b) A simplified equivalent circuit with the exciting branch moved to the primary terminals.

c) A more simplified equivalent circuit with the exciting branch and copper loss components are neglected.

d) Compare the results of each method and comment.

Part C: Three different loads are connected to the transformer in Part (A) such that the secondary voltage is 220V. For each case, calculate the ***primary voltage*** and ***input (real) power*** by using a simplified equivalent circuit where only the exciting branch is neglected (this simplification is not the same as Part B-c).

a) Load 1: 24 kW, 0.8 power factor, lagging

b) Load 2: 24 kW, 0.8 power factor, leading

c) Load 3: 24 kW, unity power factor

d) For each load, by using the data you obtained, calculate the following and comment:

$$100 \times \frac{V_{1,load} - V_{1,no\ load}}{V_{1,rated}}$$

$$100 \times \frac{P_{out}}{P_{in}}$$

Note that what we have defined in part (d) are nothing but ***regulation*** and ***efficienc***y.

Q.2. Consider the 50 Hz single phase transformer and the B-H characteristics of its core shown in Figure 1.

$A = 35\ cm^2$, $l = 50\ cm$, $N_1 = 202$ turns, $N_2 = 38$ turns

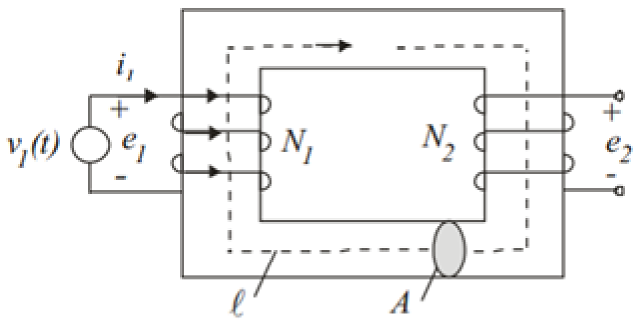

Figure 1-a: The transformer

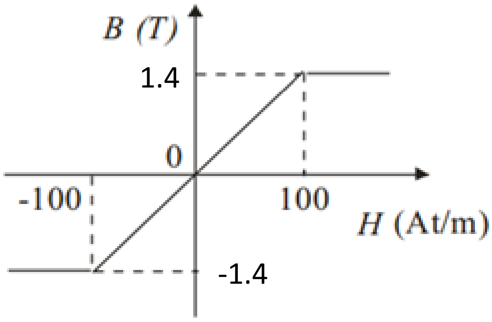

Figure 1-b: B-H Characteristics

a) At which excitation current does this transformer starts to saturate? What is the rms value of this current if the excitation is AC?

b) Starting from the definition of induced voltage (in terms of flux linkage), show that the rms value of the induced emf on the primary winding is:

$$E = 4.44\ N_1\ f\ B\ A$$

on the linear region (B < 1.4 Tesla). Define also each term.

c) Calculate the rms value of maximum primary induced voltage, E_1.

d) By neglecting the copper loss and leakage flux components, write down the time domain expression of the maximum primary terminal voltage, $v_1(t)$.

e) Calculate the rms value of the magnetization current for the conditions in part (d), I_m and write down its time domain expression, $i_m(t)$.

f) Sketch $v_1(t)$ and $i_m(t)$ on the same graph. Clearly indicate maximum points, zero crossings etc.

g) Calculate the hysteresis loss.

h) Calculate the rms value of the induced seconday voltage, E_2. Write down the time domain expression of the secondary terminal voltage, $v_2(t)$.