Practice Sheet 09 EEE2031S July 2015

Single Phase Transformer

1. A 250 kVA, 11000V/400V, 50 Hz single-phase transformer has 80 turns on the secondary. Calculate: (a) the approximate values of the primary and secondary currents; (b) the approximate number of primary turns; (c) the maximum value of the flux.

Solution:

VA Rating = 250 kVA = 250000 VA; f = 50 Hz; $N_2 = 80$; $V_1 = 11000$ V; $V_2 = 400$ V;

(a) $V_1 I_1 = 250000$ VA. Therefore, $I_1 = 250000/11000 =$ **22.72 A**

$V_2 I_2 = 250000$ VA. Therefore, $I_2 = 250000/400 =$ **625 A**

(b) Let N_1 be the number of primary turns.

$N_1/N_2 = V_1/V_2$ [turns ratio = voltage ratio]

i.e., $N_1 = (V_1/V_2) \times N_2 = (11000/400) \times 80 =$ **2200**

(c) $V_1 = E_1 = 4.44 f \Phi_m N_1$

Therefore, $\Phi_m = V_1/(4.44 f N_1) = 11000/(4.44 \times 50 \times 2200) =$ **0.0225 Wb**

2. A 200 kVA, 3300V/230V, 50 Hz, single-phase transformer has 80 turns on the secondary winding. Assuming an ideal transformer, calculate (a) the primary and secondary currents on full load; (b) the maximum value of core flux; (c) the number of primary turns.

Solution:

VA Rating = 200 kVA = 200000 VA; f = 50 Hz; $N_2 = 80$; $V_1 = 3300$ V; $V_2 = 230$ V;

(a) $V_1 I_1 = 200000$ VA. Therefore, $I_1 = 200000/3300 =$ **60.61 A**

$V_2 I_2 = 200000$ VA. Therefore, $I_2 = 200000/230 =$ **869.6 A**

(b) $V_2 = E_2 = 4.44 f \Phi_m N_2$

Therefore, $\Phi_m = V_2/(4.44 f N_2) = 230/(4.44 \times 50 \times 80) =$ **0.0129 Wb**

(b) Let N_1 be the number of primary turns.

$N_1/N_2 = V_1/V_2$

i.e., $N_1 = (V_1/V_2) \times N_2 = (3300/230) \times 80 = 1147.8 \cong$ **1148**

3. A 3300/250V, 50 Hz, single-phase transformer is built on a core having an effective cross-sectional area of 125 cm^2 and 70 turns on the low voltage winding. Calculate (a) the value of the maximum flux density, (b) the number of turns on the high voltage winding.

Solution:

$V_1 = 3300$ V; $V_2 = 250$ V; f = 50 Hz; $A = 125\ cm^2 = 125 \times 10^{-4}\ m^2$

Transformer voltage rating indicates that the low voltage winding is the secondary winding.

Thus, $N_2 = 70$

Let B_m be the maximum core flux density in Wb/m^2 (Tesla)

If core cross-sectional area is A, then $\Phi_m = B_m.A$

$E_2 = V_2 = 4.44\ f\ \Phi_m\ N_2 = 4.44\ f\ B_m\ A\ N_2$

Putting all values,

$B_m = V_2/(4.44\ f\ A\ N_2) = 250/(4.44 \times 50 \times 125 \times 10^{-4} \times 70) =$ **$\underline{1.28\ Wb/m^2}$**

(b) Since high voltage winding is the primary winding, let N_1 be the number of primary turns.

$N_1/N_2 = V_1/V_2$

Therefore,

$N_1 = (V_1/V_2) \times N_2 = (3300/250) \times 70 =$ **$\underline{924}$**

4. A transformer with 800 primary turns and 200 secondary turns is supplied from a 100V AC supply. Calculate the secondary voltage and the e.m.f. per turn.

Solution:

$N_1 = 800$, $N_2 = 200$, primary voltage $V_1 = 100$ V [Since primary is connected to supply]

Let V_2 be the secondary voltage.

$V_2/V_1 = N_2/N_1$

Therefore,

$V_2 = (N_2/N_1).V_1 = (200/800) \times 100 =$ **$\underline{25\ V}$**

E.m.f. per turn $= V_1/N_1 = 100/800 =$ **$\underline{0.125V}$**

5. A transformer with an output voltage of 4200 V is supplied at 230V. If the secondary has 2000 turns, calculate the number of primary turns.

Solution:

The output voltage is the secondary voltage V_2, i.e. $V_2 = 4200$ V

The supply voltage is the primary voltage V_1, i.e. $V_1 = 230$ V

Secondary turns, $N_2 = 2000$

$N_1/N_2 = V_1/V_2$

i.e.,

$N_1 = (V_1/V_2) \times N_2 = (230/4200) \times 2000 = 109.52 \cong$ **$\underline{110}$**

6. A 25 kVA transformer has a voltage ratio of 3300/400 V. Calculate the primary and secondary currents.

Solution:

For a transformer, input volt-amperes = output volt-amperes

i.e.,

$V_1.I_1 = V_2.I_2 = 25000$ VA

$V_1 = 3300$ V, $V_2 = 400$ V

Therefore,

Primary current $I_1 = 25000/V_1 = 25000/3300 =$ **7.58 A**

Secondary current $I_2 = 25000/V_2 =$ **62.5 A**

7. A 125 kVA transformer having primary voltage of 2000V at 50 Hz has 182 primary and 40 secondary turns. Neglecting losses, calculate (a) the full load primary and secondary currents, (b) the no-load secondary induced e.m.f. and (c) the maximum flux in the core.

Solution:

VA = 125000, $V_1 = 2000$ V, $N_1 = 182$, $N_2 = 40$, f = 50 Hz

(a) $I_1 = VA/V_1 = 125000/2000 =$ **62.5 A**

From MMF balancing,

$I_1N_1 = I_2N_2$

Therefore, secondary current $I_2 = I_1.N_1/N_2 = 62.5 \times 182 / 40 =$ **284.4 A**

(b) No load secondary induced e.m.f. = $E_2 = V_2 = (N_2/N_1) \times V_1 = (40/182) \times 2000 =$ **439.56 V**

(c) Maximum core flux $\Phi_m = V_1/(4.44\ f\ N_1) = 2000/(4.44 \times 50 \times 182) =$ **0.0495 Wb**

8. For a 440V/200V transformer, the no-load power input is 80W at 440V and a power factor of 0.3 lagging. Find the no-load current, magnetising component and core loss component of no-load current.

Solution:

$V_1 = 440$ V, $V_2 = 200$ V, $\cos\phi_0 = 0.3$ (lag)

Let I_0 be the no-load current, I_{0l} is the core loss component and I_{0m} is the magnetizing component.

No load power input = $V_1.I_0.\cos\phi 0 = 80$ W

Therefore, $I_0 = 80/(440 \times 0.3) =$ **0.61 A**

Referring to the no-load phasor diagram,

$I_{0l} = I_0.\cos\phi_0 = 0.61 \times 0.3 =$ **0.183 A**

$I_{0m} = I_0.\sin\phi_0 = 0.61 \times \sqrt{(1-0.3^2)} =$ **0.582 A**

9. A 230V/110V single-phase transformer takes an input of 350 VA at no load and at rated voltage of 230V. The core loss is 110 W. Find (a) core loss component of no-load current, (b) magnetizing component of no-load current and (c) no-load power factor.

Solution:

$V_1 = 230V$, $V_2 = 110V$, input VA = 350 VA at 230V at no-load, core loss = 110 W

Let I_0 be the no-load current, I_{0l} be the core loss component of I_0 and I_{0m} is the magnetizing component of I_0.

(a) Core loss = $V_1.I_{0l} = 110$

Therefore, $I_{0l} = 110/230 =$ **0.48 A**

(b) I_0 = (no-load VA)/V_1 = 350/230 = **1.52 A**

$I_{0m} = \sqrt{(I_0^2 - I_{0l}^2)} =$ **1.44 A**

(c) No-load power factor = $I_{0l}/I_0 =$ **0.315 (lag)**

10. A single-phase transformer has 1000 turns on the primary and 200 turns on the secondary. The no-load current is 3A at a power factor of 0.2 lagging when the secondary current is 280A at a power factor of 0.8 lagging. Calculate the primary current and primary power factor. Assume the voltage drop in the windings to be negligible.

Solution:

$I_0 = 3A$, $\cos\phi_0 = 0.2$ (lag), $N_1/N_2 = 1000/200=5$, $I_2 = 280A$, $\cos\phi_2 = 0.8$ (lag)

From the phasor diagram of ideal transformer on load (refer your course handout on transformer),

Load component of primary current $I_1' = I_2.N_2/N_1$ (from MMF balancing) = 280 x (1/5) = 56 A

Angle made by I_1' with $V_1 = \phi_1' = \phi_2 = \cos^{-1}(0.8) = 36.87^0$

No load power factor angle = $\phi_0 = \cos^{-1}(0.2) = 78.46^0$

Therefore, $I_1 = I_0 + I_1' = 3\angle 78.46^0 + 56\angle 36.87^0$

After phasor addition, we get, $I_1 =$ **$58.27\angle 38.83^0$ A**

Primary power factor = $\cos(38.83^0)$ = 0.**779 (lag)**

11. The primary of an ideal transformer draws 1A at a power factor of 0.4 lagging when connected across a 230V, 50 Hz supply and the secondary is on open circuit. The number of turns in the primary is twice that on secondary. A load taking 50A at a lagging power factor of 0.8 is now connected across the secondary. Calculate the primary current and primary power factor.

Solution:

I_0 = 1A, $\cos\phi_0$ = 0.4 (lag), V_1 = 230V, f = 50 Hz, N_1/N_2 = 2, I_2 = 50A, $\cos\phi_2$ = 0.8 (lag)

From the phasor diagram of ideal transformer on load (refer your course handout on transformer),

Load component of primary current $I_1' = I_2.N_2/N_1$ (from MMF balancing) = 50 x (1/2) = 25 A

Angle made by I_1' with $V_1 = \phi_1' = \phi_2 = \cos^{-1}(0.8) = 36.87^0$

No load power factor angle = $\phi_0 = \cos^{-1}(0.4) = 66.42^0$

Therefore, $I_1 = I_0 + I_1' = 1\angle 66.42^0 + 25\angle 36.87^0$

After phasor addition, we get, I_1 = **$25.87\angle 52.03^0$ A**

Primary power factor = $\cos(52.03^0)$ = **0.615 (lag)**

12. A 200 kVA, single-phase transformer with a voltage ratio of 6350/660V has the following winding resistances and reactance: R_1 = 1.56 ohm, R_2 = 0.016 ohm, X_1 = 4.67 ohm, X_2 = 0.048 ohm. Calculate the equivalent resistance and reactance of the transformer referred to the high voltage winding.

Solution:

Given transformer rating indicates that the high voltage winding is the primary winding. Therefore equivalent resistance and reactance need to be referred to the primary side.

Since, turns ratio = voltage ratio

$N_1/N_2 = V_1/V_2$ =6350/660 = 9.62

Equivalent resistance referred to primary:

$R_{e1} = R_1 + R_2' = R_1+R_2.(N_1/N_2)^2 = 1.56 + 0.016 \text{ x } (9.62)^2$ = **3.04 ohm**

Equivalent reactance referred to primary:

$X_{e1} = X_1 + X_2' = X_1+X_2.(N_1/N_2)^2 = 4.67 + 0.048 \text{ x } (9.62)^2$ = **9.11 ohm**

13. A single-phase transformer has 180 and 90 turns respectively in its secondary and primary windings. The winding resistances are 0.233 ohm for secondary and 0.067 ohm for primary. Calculate the resistance of (a) the primary in terms of the secondary winding, (b) the secondary in terms of the primary winding, (c) the total resistance of the transformer in terms of the primary.

Solution:

N_1 = 90, N_2 = 180, R_1 = 0.067 ohm, R_2 = 0.233 ohm

(a) Let R_1' be the resistance of the primary referred to secondary.

$R_1' = R_1.(N_2/N_1)^2 = 0.067 \text{ x } (180/90)^2$ = **0.268 ohm**

(b) Let R_2' be the resistance of the secondary referred to primary.

$R_2' = R_2.(N_1/N_2)^2 = 0.233 \times (90/180)^2 =$ **0.058 ohm**

(c) Let R_{e1} be the total or equivalent resistance in terms of the primary.

$R_{e1} = R_1 + R_2' = 0.067 + 0.058 =$ **0.125 ohm**

14. A 100 kVA transformer has 400 turns on the primary and 80 turns on the secondary. The primary and secondary resistances are 0.3 ohm and 0.01 ohm respectively. The corresponding leakage reactances are 1.1 ohm and 0.035 ohm respectively. The supply voltage is 2200V. Calculate the equivalent resistance, reactance and impedance referred to the primary circuit.

Solution:

[Note that all data might not need to be used always. There is no problem with that.]

$N_1 = 400$, $N_2 = 80$, $R_1 = 0.3$ ohm, $R_2 = 0.01$ ohm, $X_1 = 1.1$ ohm, $X_2 = 0.035$ ohm

Let R_2' be the resistance of the secondary referred to primary and X_2' be the leakage reactance of the secondary referred to primary.

Let R_{e1} be the equivalent resistance, X_{e1} leakage reactance and Z_{e1} equivalent impedance all referred to primary.

$R_{e1} = R_1 + R_2' = R_1 + R_2.(N_1/N_2)^2 = 0.3 + 0.01 \times (400/80)^2 =$ **0.55 ohm**

$X_{e1} = X_1 + X_2' = X_1 + X_2.(N_1/N_2)^2 = 1.1 + 0.035 \times (400/80)^2 =$ **1.975 ohm**

$Z_{e1} = \sqrt{(R_{e1}^2+X_{e1}^2)} =$ **2.05 ohm**