Quiz-3

Q1: A single-phase transformer has 500 turns on primary and 1000 turns on secondary. The voltage per turn in the primary winding is 0.2 volts. Determine

i) Voltage induced in the primary winding.
ii) Voltage induced in the secondary winding.
iii) The maximum value of the flux density if the cross-sectional area of the core is 200 cm^2.
iv) kVA rating of the transformer if the current in primary at full load is 10 A, the frequency is 50 Hz.

Solution:
The data given is,

$$N_1 = 500, \quad N_2 = 1000, \quad f = 50 \text{ Hz}, \quad A = 200 \times 10^{-4} \text{ m}^2$$

$$\frac{\text{Volt}}{\text{Turn}} = \left(\frac{E_1}{N_1}\right) = 0.2 \text{ volts}$$

i) Voltage induced in the primary

$$E_1 = \frac{\text{Volt}}{\text{Turn}} \times N_1 = 0.2 \times 500 = 100 \text{ volts}$$

ii) Voltage induced in the secondary

$$E_2 = \frac{N_2}{N_1} \times E_1 = \frac{1000}{500} \times 100 = 200 \text{ volts}$$

iii) The maximum value of the flux in the core

$$\phi_m = \frac{E_1}{4.44 \times f \times N_1} = \frac{100}{4.44 \times 50 \times 500} = 9.009 \times 10^{-4} \text{ Wb}$$

The maximum value of flux density B_m can be calculated as

$$B_m = \frac{\phi_m}{A} = \frac{9.009 \times 10^{-4}}{200 \times 10^{-4}} = 0.045 \text{ Wb/m}^2 \text{ or tesla}$$

iv) kVA rating of the transformer

$$V_1 \times I_1 \times 10^{-3} = V_2 \times I_2 \times 10^{-3} = 100 \times 10 \times 10^{-3} = 1 \text{ kVA}$$

Q2: A single phase 100 kVA, 3.3 kV/230 V, 50 Hz transformer has 89.5% efficiency at 0.85 lagging p.f. both at full load and at half load. Determine the efficiency of the transformer at 75% load and 0.9 leading p.f.

Solution:

The efficiency is given by,

$$\%\eta = \frac{n\text{kVA}\cos\phi}{n\text{kVA}\cos\phi + P_i + P_{cu}}$$

Where, n = Fraction of load, P_i = Iron loss, P_{cu} = Full load copper loss.

As given in the question, for $n = 1$ and $n = 0.5$ with cos φ = 0.85 the efficiency is 89.5 %.

Therefore,

$$0.895 = \frac{1 \times 100 \times 10^3 \times 0.85}{1 \times 100 \times 10^3 \times 0.85 + P_i + P_{cu}}$$

$$\Rightarrow \qquad P_i + P_{cu} = 9972.067 \qquad (1)$$

And for half load, copper loss = $\frac{P_{cu}}{4}$, therefore,

$$0.895 = \frac{0.5 \times 100 \times 10^3 \times 0.85}{0.5 \times 100 \times 10^3 \times 0.85 + P_i + \frac{P_{cu}}{4}}$$

$$\Rightarrow \qquad P_i + \frac{P_{cu}}{4} = 4986.033 \qquad (2)$$

After solving equations (2) and (1), we get

$$P_{cu} = 6648.044W$$

$$P_i = 3324.022W$$

Now for 75% load, n = 0.75, and copper loss = $0.75^2\, P_{cu} = 0.75^2 \times 6648.04 = 3739.52$ W.

Then efficiency at cos φ = 0.9 leading.

$$\frac{0.75 \times 100 \times 10^3 \times 0.9}{0.75 \times 100 \times 10^3 \times 0.9 + 3324.022 + 3739.52} \times 100 = 90.5268\ \%$$

Q3: A 200 kVA, 11000/400 V, delta-star distribution transformer gave the following test results:

Open circuit test: 400 V, 9 A, 1.50 kW.
Short circuit test: 350 V, rated current, 2.1 kW.
Determine the equivalent circuit parameters referred to the h.v. side.

Solution:

Problems relating to 3-phase balanced system are solved by reducing all the quantities to per phase values and so is done here.

Open-circuit test. This circuit is performed on the l.v. side, since the applied voltage for this test is equal to the rated voltage on the l.v. side, which is star connected.

Per phase applied voltage, $V_1 = \frac{400}{\sqrt{3}} = 231V.$

Per phase exciting current, $I_e = 9A.$

Per phase core loss, $P_c = \frac{1500}{3} = 500W.$

Since, $V_1 I_e \cos\theta_0 = P_c$

Core loss current, $I_e \cos\theta_0 = I_c = \frac{P_c}{V_1} = \frac{500}{231} = 2.165A.$

Magnetizing current, $I_m = \sqrt{I_t^2 - I_c^2} = \sqrt{9^2 - (2.165)^2} = 8.73A.$

l.v. side parameters,

$$R_{cL} = \frac{V_1}{I_c} = \frac{231}{2.165} = 106.8\Omega.$$

$$X_{m_L} = \frac{V_1}{I_m} = \frac{231}{8.73} = 26.47\Omega.$$

l.v. side parameters referred to h.v. side,

$$R_{cH} = R_{cL}\left(\frac{\text{Per phase voltage on h.v. side}}{\text{Per phase voltage on l.v. side}}\right)^2 = 106.8 \times \left(\frac{11000}{231}\right)^2 = 242.2\ k\Omega$$

$$X_{mH} = X_{cL}\left(\frac{11{,}000}{231}\right)^2 = (26.47) \times \left(\frac{11{,}000}{231}\right)^2 = 60.02\text{k}\Omega.$$

Short-circuit test: This test is performed on h.v. side, since 350 V is a fraction of the rated voltage on h.v. side, which is in delta.

Applied voltage/phase, $V_{sc} = 350$ V

Current/phase, $I_{sc} = \text{Rated current} = \frac{200{,}000}{3 \times 11{,}000} = 6.06A$

Ohmic loss per phase, $P_{sc} = \frac{2100}{3} = 700W$

HV side parameters,

$$z_{eH} = \frac{V_{sc}}{I_{sc}} = \frac{350}{6.06} = 57.8\Omega$$

$$r_{eH} = \frac{P_{sc}}{I_{sc}^2} = \frac{700}{(6.06)^2} = 19.06\Omega$$

$$x_{eH} = \sqrt{(57.8)^2 - (19.06)^2} = 54.6\Omega$$

Q4: A 3-phase balanced load which has a power factor of 0.707 is connected to a balanced supply. The power consumed by the load is 10kW. The power is measured by the two-wattmeter method. Calculate the reading of both wattmeters.

Solution:

As per given data

3-phase balanced pf=0.707

$\phi = 45°$

Power consumed by load=10kW

As per two-watt meter method,

$$P_T = \sqrt{3}V_L I_L cos\phi = 10000\ W$$

$$V_L I_L = \frac{10000}{\sqrt{3}\ \times 0.707} = 8166.19$$

$$W_1 = 8166.19\cos(30 - 45) = 7887.93\ W or\ 7.88\ kW$$

$$W_2 = 8166.19\cos(30 + 45) = 2113.56\ W\ or\ 2.11\ kW$$

Q5: A three-phase balanced system with a line voltage of 202 V rms feeds a delta-connected load with per phase impedance $Z_P = 25\angle 60^0$.

(a) Find the line current.

(b) Determine the total power supplied to the load.

Solution:

We are given a balanced 3-phase system with

Line voltage $V_{LL} = 202\ V\ rms$

Δ-connected load with per phase impedance $Z_\Delta = 25\angle 60°\ \Omega$

(a) <u>Line Current:</u>

Each Δ-branch sees full line to line voltage so:

$$I_{phase} = \frac{V_{LL}}{Z_\Delta} = \frac{202}{25\angle 60°} = 8.08\angle -60°\ A$$

We know line current in Δ-connection

$$I_L = \sqrt{3} I_{phase}$$

$$|\ I_L\ | = \sqrt{3} \times 8.08 = 13.99\ A$$

Phase angle

$$\angle I_L = \angle I_{pha} \quad - 30° = -60° - 30° = -90°$$

$$I_L = 13.99\angle -90°\ A\ (rms)$$

(b) Total Power Supplied to Load:

$$P_T = \sqrt{3} V_L I_L cos\theta = \sqrt{3} \times 202 \times 13.99 \times \cos(60°) = 2447.37\ W$$

Q6: A 100kW DC shunt motor is loaded to draw rated armature current at any given speed. When driven

i) At half the rated peed by armature voltage control and
ii) At 1.5 times the rated speed by field control, the respective output power delivered by the motor are approximately.

Solution:

Since data is not given, for simplicity neglect all losses including armature losses. This means we assume $R_a = 0$

Problem specifies that at any speed, armature current has the same value which is equal to the rated value.

Let V_{rated} and I_{rated} be the rated values. Then rated input= rated output =$V_{rated} I_{rated} = 100kW$.

(i) To obtain half the speed by armature voltage control (field current is assumed to remain unchanged), armature voltage must be made $\frac{V_{rated}}{2}$. This result is proved as follow. For the shunt motor $E = K\phi\omega_r = V - I_a R_a = V$ Since R_a is neglected.

Let field excitation be kept constant. Then neglecting armature reaction, $K\phi$ is constant, say K_1 and $V = K_1\omega_r$. At rated operation $V_{rated} = K_1 \omega_{r_{rated}}$.

To get $\omega_r = \frac{1}{2}\omega_{r_{rated}}$; V must be $\frac{V_{rated}}{2}$

Power=$\frac{V_{rated}}{2} \times I_{rated}$

Power = 50 kW

(ii) With V kept at V_{rated} ; ω_r is to be changed to $\frac{3}{2}\omega_{r_{rated}}$ by field control but the current is still I_{rated} for the given data.

Hence power=$V_{rated}I_{rated} = 100\ kW$