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Courses » Electrical Machines - I

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Unit 3 - Week 2

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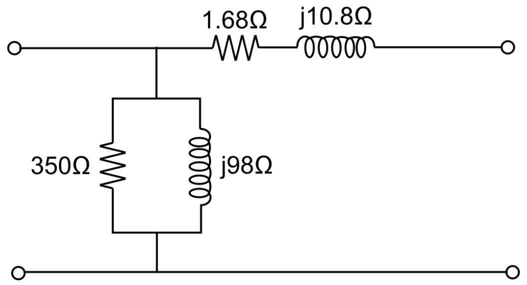
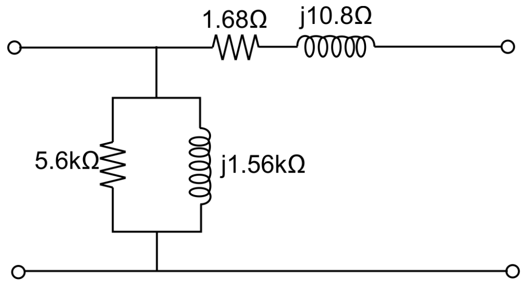
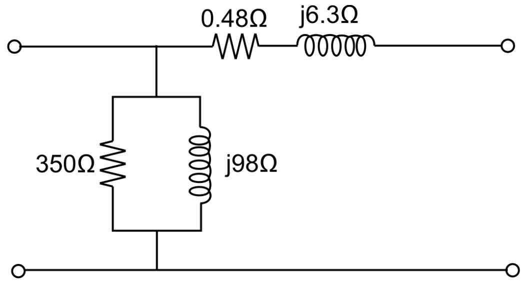
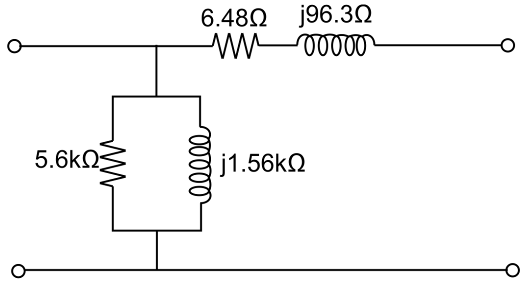
Week 2: Assignment

1) A 50 Hz, single phase transformer has primary to secondary turns ratio (N1/N2) equal to 4. The leakage impedance of the high voltage and low voltage windings are (0.4 + j6)Ω and (0.08 + j0.3)Ω respectively. The resistance accounting for core loss, Rc and magnetizing reactance, Xm referred to primary side are 350Ω and 98Ω respectively. Find the approximate equivalent circuit referred to primary side. ***10 points***

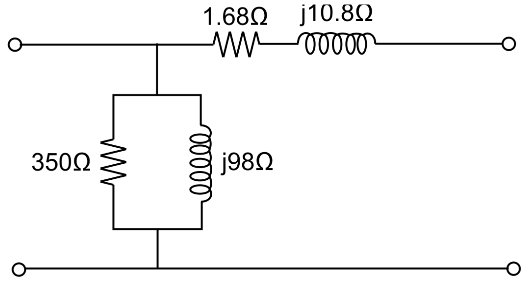








Accepted Answers:

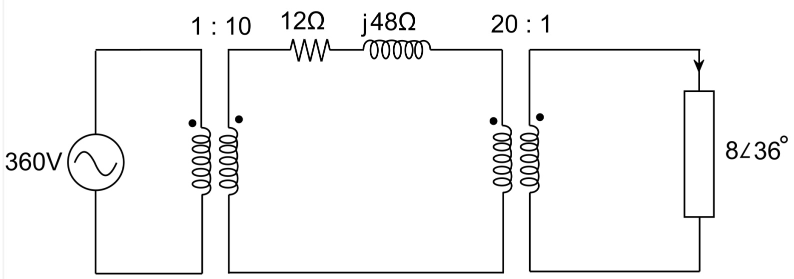


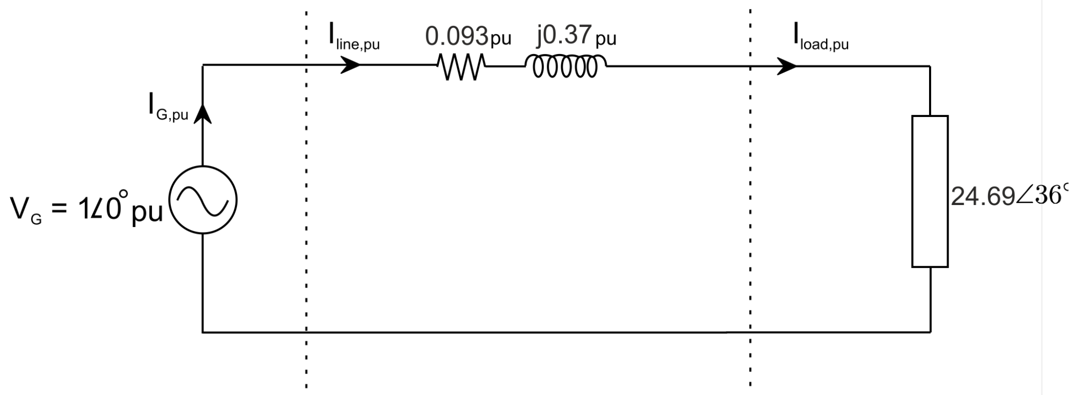
2) A 50 Hz, single phase transformer has primary to secondary turns ratio (N1/N2) equal to 8. The resistances are 0.2Ω and 0.02Ω and the reactances are 4Ω and 0.1Ω for high voltage and low voltage windings respectively. Find the voltage to be applied at the high voltage side to obtain a current of 160A in the low-voltage winding on short circuit? ***10 points***

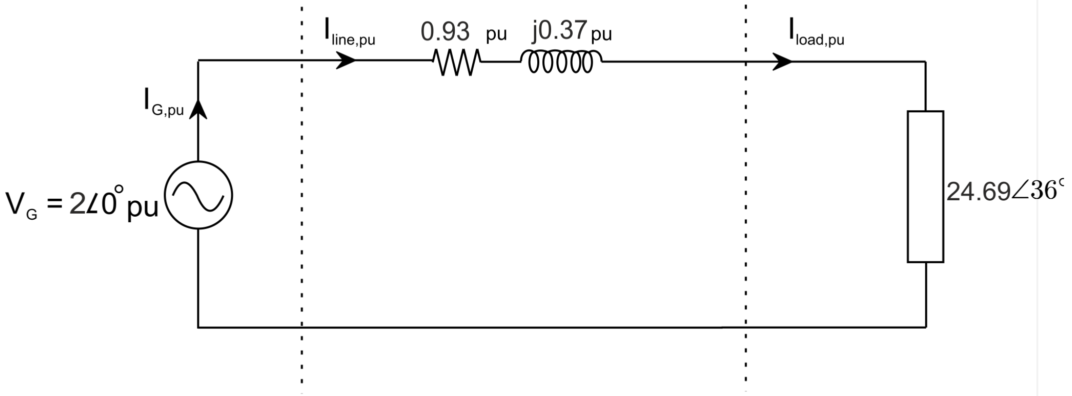
- 1640.2 V
- 1680.64 V
- 210.8 V
- 13.12 kV

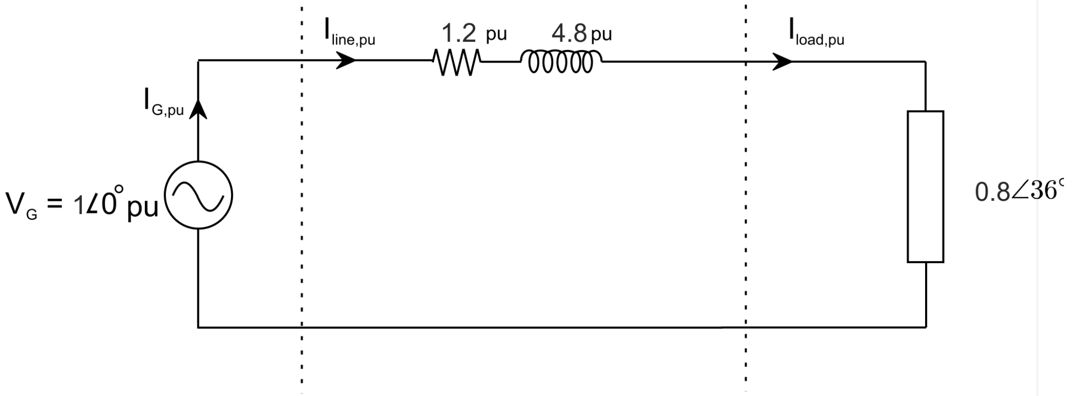
Accepted Answers:
210.8 V

3) A simple power system is shown in figure. This system contains a 360V generator connected to an ideal 1:10 step-up transformer, a transmission line, an ideal 20:1 step-down transformer and a load. The impedance of the transmission line is 12+j48Ω, and the impedance of the load is 8∠36°Ω. Convert this system to its per unit equivalent circuit if base values for this system is chosen as 360V and 10kVA at the generator side. ***10 points***



- 





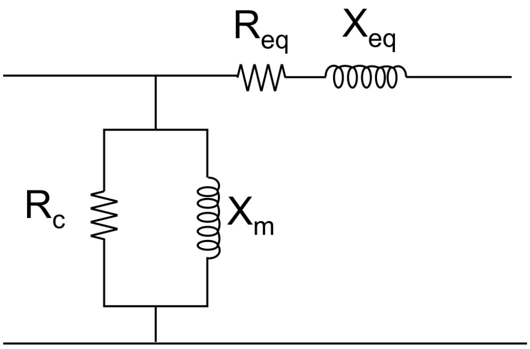
Accepted Answers:

4) The open-circuit test and the short circuit test were performed on the primary side of a 10 kVA, 2000/240 V, 50 Hz transformer, and the following data were obtained: ***10 points***

OC Test: Voc : 240V; Ioc = 0.6A; Poc = 80W

SC Test: Vsc : 112V; Isc = 5A, Psc = 160W

Find the approximate equivalent circuit referred to the primary side?

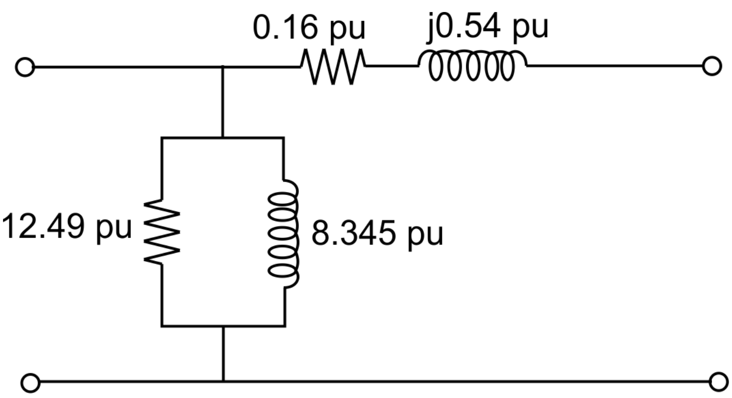


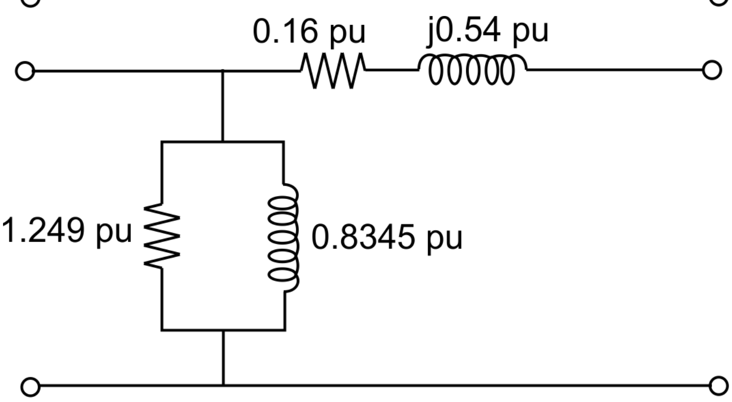
Approximate equivalent circuit
referred to primary side

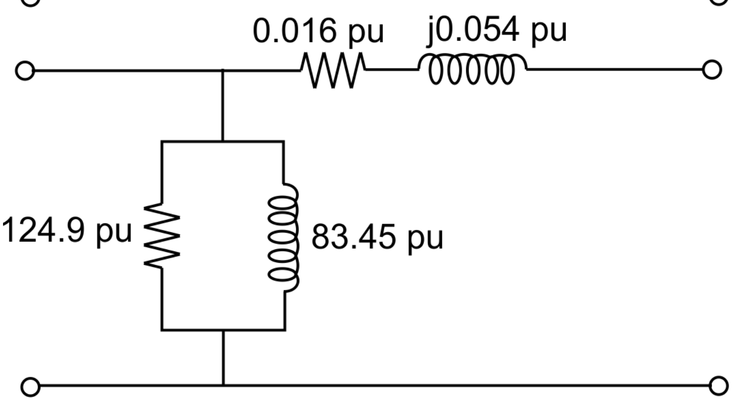
- Req = 6.4Ω ; Xeq = j21.46Ω ; Rc = 49.96kΩ ; Xm = j33.34 kΩ
- Req = 6.4Ω ; Xeq = j21.46Ω ; Rc = 720Ω ; Xm = j480Ω
- Req = 0.092Ω ; Xeq = j0.31Ω ; Rc = 720Ω ; Xm = j480Ω
- Req = 0.092Ω ; Xeq = j0.31Ω ; Rc = 49.96kΩ ; Xm = j33.34 kΩ

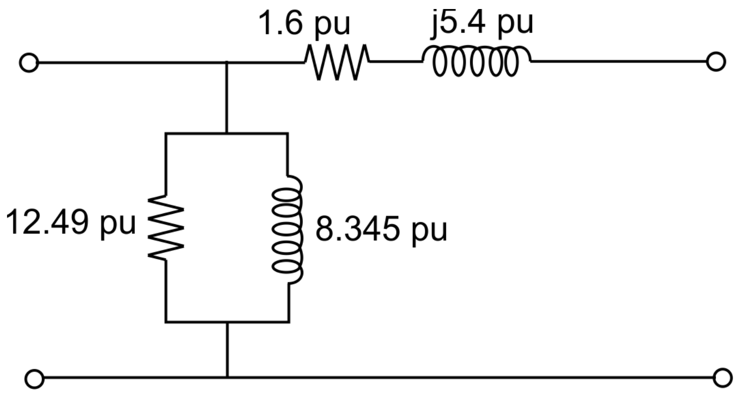
Accepted Answers:
Req = 6.4Ω ; Xeq = j21.46Ω ; Rc = 49.96kΩ ; Xm = j33.34 kΩ

5) Find the approximate per-unit equivalent circuit for the transformer in problem-4,using transformer's ratings as the system base. ***10 points***

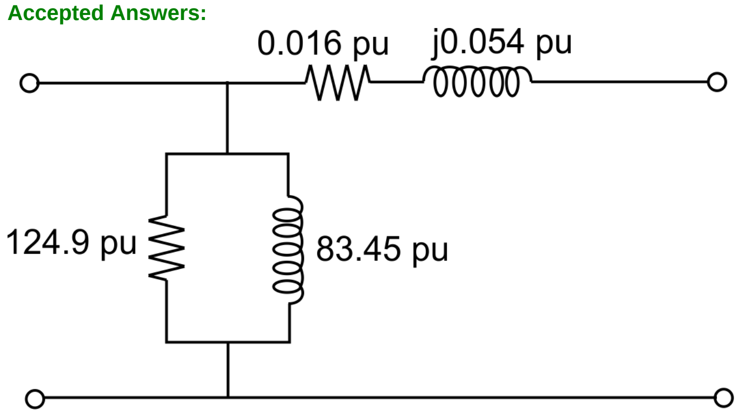








Accepted Answers:



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Assignment - 2 : Solution

Q1. Solution

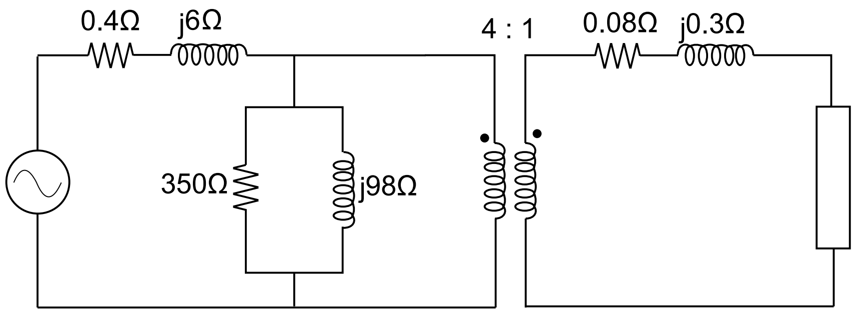

Figure 1:

Approximate equivalent circuit parameters referred to primary side :

$$R_{eq}^{'} = R_1 + \left(\frac{N1}{N2}\right)^2 \times R_2 = 0.4 + 4^2 \times 0.08\Omega = 1.68\Omega$$

$$X_{eq}^{'} = X_1 + \left(\frac{N1}{N2}\right)^2 \times X_2 = 6 + 4^2 \times 0.3\Omega = 10.8\Omega$$

$$R_c^{'} = 350\Omega$$

$$X_m^{'} = 98\Omega$$

Q2.Solution

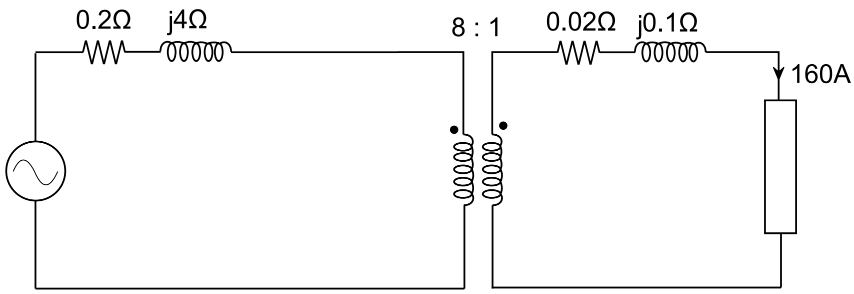

Figure 2:

Parameters referred to high voltage side:

$$R_{eq} = 0.2 + 8^2 \times 0.02\Omega = 1.48\Omega$$

$$X_{eq} = 4 + 8^2 \times 0.1\Omega = 10.4\Omega$$

$$Z_{eq} = 1.48 + 10.4j = 10.504\angle 81.9^\circ$$

High-voltage side current, $I = \dfrac{160}{8} = 20A$

$\therefore$ The voltage required on short circuit

$$Z_{eq}I = 10.54 \times 20 = 210.8V$$

Q3.Solution

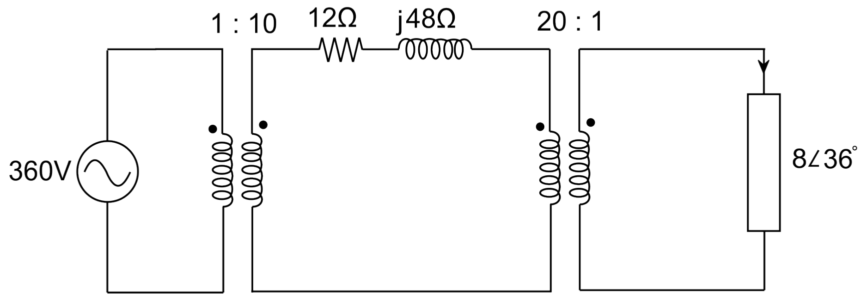

Figure 3:

Base quantities in the generator region, $\quad V_{base1} = 360V; \quad S_{base1} = 10kVA$

$$I_{base1} = \frac{S_{base1}}{V_{base1}} = \frac{10,000}{360} = 27.78A$$

$$Z_{base1} = \frac{V_{base1}}{I_{base1}} = \frac{360}{27.78} = 12.95\Omega$$

The turns ratio of transformer-I is $(\dfrac{N1}{N2})$ = 1/10 = 0.1, so the base voltage in the transmission line region is:

$$V_{base2} = \frac{V_{base1}}{(N1/N2)} = \frac{360}{0.1} = 3600V$$

$$S_{base2} = 10kVA$$

$$I_{base2} = \frac{10,000}{3600} = 2.78A$$

$$Z_{base2} = \frac{3600}{2.78} = 1294.96\Omega$$

The turns ratio of transformer-II is $(\frac{N1}{N2})$ = 20/1 = 20, so the base voltage in the transmission line region is:

$$V_{base3} = \frac{V_{base2}}{(N1/N2)} = \frac{3600}{20} = 180V$$

$$S_{base3} = 10kVA$$

$$I_{base3} = \frac{10000}{180} = 55.55A$$

$$Z_{base3} = \frac{180}{55.55} = 3.24\Omega$$

The power system can be converted to a per-unit system by divided each component by its base value in its region of the system.

$$\text{Generator per unit voltage, } V_{G,pu} = \frac{360\angle 0^\circ}{360} = 1\angle 0^\circ pu$$

$$\text{Transmission line per-unit impedance, } Z_{line,pu} = \frac{12 + j48}{1294.96} = 0.0093 + j0.037 \ \ pu$$

$$\text{Load per-unit impedance,} Z_{load,pu} = \frac{8\angle 36^\circ}{3.24} = 2.469\angle 36^\circ$$

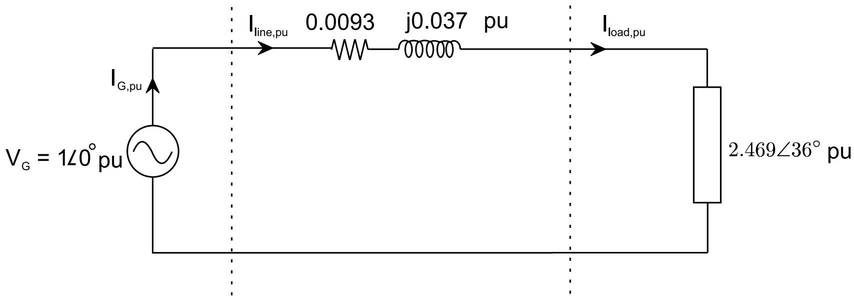

Figure 4:

Q4.Solution

Open circuit test must be conducted at the rated terminal voltage. From the data, it can be seen that, it is performed on the low-voltage side. Thus, the equivalent core-loss resistance as referred to the low-voltage side is:

$$R_c = \frac{240^2}{80} = 720$$

The apparent power under no load:$S_{oc} = V_{oc}I_{oc} = 240 \times 0.6 = 144\ VA$

Thus, the reactive power is

$$Q_{oc} = \sqrt{144^2 - 80^2} = 119.73\ VAR$$

The magnetizing reactance as referred to the low-voltage side is

$$X_m = \frac{240^2}{119.73} = 481.082\ \Omega$$

The core-loss resistance and the magnetizing reactance as referred to the high voltage side are obtained as follows:

$$\frac{N1}{N2} = \frac{2000}{240} = 8.33$$

$$R_{cHV} = 8.33^2 \times 720 = 49.96\ k\Omega$$

$$X_{mHV} = 8.33^2 \times 481.082 = 33.378\ k\Omega$$

Since, the short-circuit current is 5A, the short -circuit test is performed on the high-voltage side. Thus,

$$R_{eqHV} = \frac{P_{sc}}{I_{sc}^2} = \frac{160}{5^2} = 6.4\ \Omega$$

$$Z_{eqHV} = \frac{V_{sc}}{I_{sc}} = \frac{112}{5} = 22.4\Omega$$

$$X_{eqHV} = \sqrt{22.4^2 - 6.4^2} = 21.46\ \Omega$$

The approximate equivalent circuit referred to primary (High Voltage) side is given below:

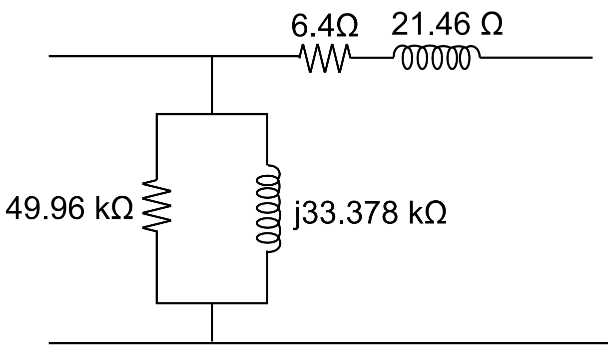

Figure 5:

Q5.Solution

The transformer in problem-4, is rated at 10 kVA, 2000/240-V.The approximate equivalent circuit developed was referred to the high-voltage side of the transformer. So to convert it to per-unit, the primary circuit- base impedance must be found.

$$V_{base1} = 2000V$$

$$S_{base1} = 10kVA$$

$$Z_{base1} = \frac{V_{base1}^2}{S_{base1}} = \frac{2000^2}{10,000} = 400\Omega$$

Therefore,

$$R_{eq\_pu} = \frac{6.4}{400} = 0.016\,pu$$

$$X_{eq\_pu} = \frac{21.46}{400} = 0.054\,pu$$

$$R_{c\_pu} = \frac{49960}{400} = 124.9\,pu$$

$$X_{m\_pu} = \frac{33378}{400} = 83.45\,pu$$

Q6.Solution

Since the open circiut test is conducted at the rated voltage and short circuit test is conducted at ratd current the Core loss corresponds to rated voltage and copper loss corresponds to full load

$$\text{Efficiency of converter } = \frac{\text{Output Power}}{\text{Input Power}}$$

Input Power = Output Power + Losses

Input Power = (10kVA x 0.8) + 60W + 280W = 8340W

$$\text{Efficiency} = \frac{8000}{8340} \times 100$$

$$= 95.92\%$$

Q7.Solution

From the data it is evident that the Open Circuit (OC) test was conducted on the LV side and the Short Circuit (SC) test was conducted on the HV side.

$$\text{The full load current on the HV side is } = \frac{9600}{2400} = 4$$

From the test data Ohmic loss at 3A short circuit current is 47W

$$\text{Therefore, ohmic loss at full load current} = 47 \times \left(\frac{4}{3}\right)^2 = 83.55W$$

From open circuit test, the no load losses comes to 50W

$$\text{Therefore, Efficiency} = \frac{OutputPower}{Inputpower} \times 100$$

$$OutputPower = 9600 \times 0.8 = 7680W$$

$$InputPower = OutputPower + Losses$$

$$= 768 + 50 + 83.55 = 7813.55W$$

$$\therefore Efficiency = \frac{7680}{7813.55} \times 100 = 98.29\%$$

Q8.Solution

$$\text{Losses in the transformer at maximum efficiency} = 12000(1-0.983) = 204W$$

$$\text{At maximum efficiency, Core loss and Copper loss are same and is equal to half the losses}$$

$$\therefore \text{Core loss} = \text{Copper loss} = 204/2 = 104W$$

$$\text{For first 10 hours:-}$$

$$\text{Load kVA} = \frac{3000}{0.8} = 3.75kVA$$

$$\therefore \text{Copper loss} = 10 \times \left(\frac{3.75}{12}\right)^2 \times 104 = 101.56Whr$$

$$= 0.10156kWhr$$

$$\text{Next 6 hours:-}$$

$$\text{Load kVA} = \frac{10000}{0.9} = 11.11kVA$$

$$\therefore \text{Copper loss} = 6 \times \left(\frac{11.11}{12}\right)^2 \times 104 = 534.9Whr$$

$$= 0.535kWhr$$

$$\text{Next 6 hours:-}$$

$$\text{Load kVA} = \frac{15000}{0.9} = 16.67kVA$$

$$\therefore \text{Copper loss} = 6 \times \left(\frac{16.67}{12}\right)^2 \times 104 = 1204.2Whr$$

$$= 1.204kWhr$$

$$\therefore \text{Total copper loss} = 0.1015 + 0.535 + 1.204$$

$$= 1.84kWhr$$

$$\therefore \text{Total Iron loss} = 104 \times 24$$

$$= 2.496kWhr$$

$$\text{Total real power consumed for 24 hours} = 3000 \times 10 + 10000 \times 6 + 15000 \times 6$$

$$= 180kWhr$$

$$\text{Total real power consumed + Copper loss + Iron loss} = 180 + 2.496 + 1.84$$

$$= 184.336kWhr$$

$$\therefore \text{All day efficiency} = \frac{\text{Total real power consumed for 24 hours}}{\text{Total real power consumed + Copper loss + Iron loss}} = \frac{180}{184.336} = 0.9765$$

$$= 97.65\%$$

Q9.Solution

The 4kW reading on the wattmeter gives the core loss of the two transformers

$$\therefore \text{The core loss of each transformer} = \frac{4000}{2} = 2kW$$

The 6kW reading of second wattmeter gives the full load copper losses of the two transforemrs

$$\therefore \text{Full load copper loss of each transformer} = \frac{6000}{2} = 3kW$$

$$\therefore \text{Efficiency of transformer} = \left(\frac{200k}{200k + 2k + 3k}\right) \times 100$$

$$= 97.56\%$$

Q10.Solution

Maximum efficiancy of a transformer always exists for UPF laods

Hence Power Factor=1

For maximum efficiency, Copper loss is equal to iron loss

Let the fraction of load at which maximum efficiency ocuurs be 'x'

$$\therefore x^2\text{(350)=300}$$

$$\implies x = \sqrt{\frac{300}{350}} = 0.9258$$

$$\therefore \text{Efficiency} = \frac{20000 \times 0.9258}{(20000 \times 0.9258) + 600} \times 100$$

$$= \frac{18516.4}{19116.4} \times 100$$

$$= 96.86\%$$