Indian Institute of Technology Bombay
Department of Electrical Engineering
EE-114 : Power Engineering-1
Quiz-4: Solution

1. Given:
   50 MVA, 60 Hz single phase transformer with voltage rating of 8 kV:78 kV. The Open circuit (OC), and Short Circuit (SC) tests are conducted on the LV side.
   SC Test Data: 674 V, 6.25 kA, 187 W
   OC Test Data: 8 kV, 62.1 A, 206 kW

   (a) $|Z_{eqLV}| = \frac{V_{sc,LV}}{I_{sc,LV}} = 107.8 \text{ m}\Omega$
   $R_{eq,LV} = \frac{P_{sc,LV}}{I^2_{sc,LV}} = 4.78 \text{ m}\Omega$
   $X_{eq,LV} = \sqrt{|Z_{eq,LV}|^2 - R^2_{eq,LV}} = 107.7 \text{ m}\Omega$
   $Z_{eq,LV} = 4.8 + j108 \text{ m}\Omega$

   (b) N = 78/8 = 9.75
   $R_{eq,HV} = N^2 R_{eq,LV} = 0.455\ \Omega$
   $X_{eq,HV} = N^2 X_{eq,LV} = 10.24\ \Omega$
   $Z_{eq,LV} = 10.3 + j0.46\ \Omega$

   (c) N = 78/8 = 9.75
   $R_{c,LV} = \frac{V^2_{oc,LV}}{P_{oc,LV}} = 311\ \Omega$
   $S_{oc,LV} = V_{oc,LV} I_{oc,LV} = 497 \text{ kVA}$
   $Q_{oc,LV} = \sqrt{S^2_{oc,LV} - P^2_{oc,LV}} = 452.3 \text{ kVAR}$
   $X_{m,LV} = \frac{V^2_{oc,LV}}{Q_{oc,LV}} = 141.5\ \Omega$

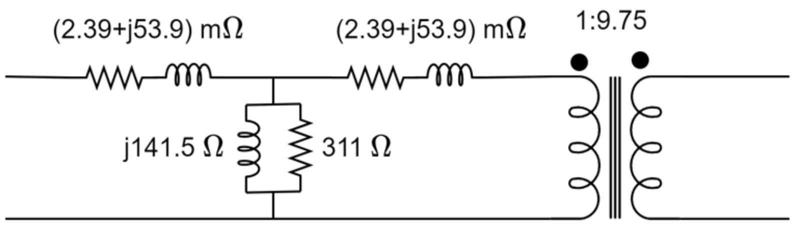
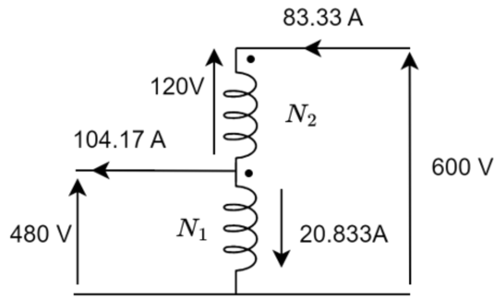


Figure 1: Equivalent Circuit referred to LV side

   (d) Assuming that the load is connected on the HV side. The rated low-voltage side current is $I_L = 50MVA/8kV = 6.25$ kVA.
   The low-voltage side terminal voltage is $V_L = |V_{load} + Z_{eq,L} I_L| = 8.341$ kV
   Voltage regulation = (8.341-8)/8 = 4.26 %
   Efficieny,$\eta = \frac{P_{load}}{P_{load}+P_{oc}+P_{sc}} = \frac{50\times0.9}{50\times0.9+0.393} = 99.13$ %



(a)

Figure 2: Connection diagram as an autotransformer.

2. Given: 120:480 V, 10 kVA single phase transformer

   (b) kVA rating of the autotransformer, $S_{auto} = S(1 + \frac{N_1}{N_2}) = 10(1 + \frac{480}{120}) = 50$ kVA

   (c) The autotransformer losses will not differ from the single phase transformer case. Core losses are same as both the winding are operated at rated voltage and the copper losses are same as the windings carry rated currents.

   (d) $P_{loss} = P(1 - \eta) = 210$ W.
   $P_{output} = 0.85 \times 50 = 42.5$ kW (as load pf is 0.85)
   Efficiency, $\eta_{auto} = \frac{P_{output}}{P_{output}+P_{loss}} = 0.995$

3. Three phase Y-△ transformer is rated at 225 kV:24 kV, 400 MVA
   Transformer series reactance referred to HV $Z_T = 11.7\ \Omega$
   Load = 325 MVA, 0.93 pf lagging at a voltage of 24 kV (L-L) on LV side
   Impedance of feeder connected on the Hv side, $Z_F = 0.11 + j2.2\ \Omega$

   (a) The equivalent circuit is shown below

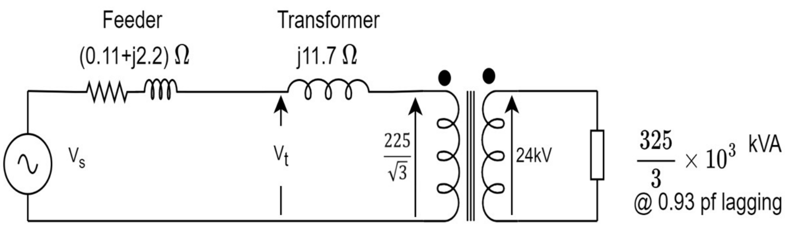


Figure 3: Per Phase Equivalent circuit of transformer referred to HV side.

   (b) Current on the HV side, $I_{HV} = \frac{325\times10^6}{\sqrt{3}225\times10^3}\angle(-cos^{-1}0.93) = 0.834\angle - 21.6°$ kA
   The line-to-line rms voltage at the HV terminals of the transformer is
   $V_t = \sqrt{3}|\frac{225}{\sqrt{3}} + I_{HV}Z_T| = 231.7$ kV

   (c) The line-to-line rms voltage at the sending is
   $V_s = \sqrt{3}|\frac{225}{\sqrt{3}} + I_{HV}(Z_T + Z_F)| = 233.3$ kV