King Fahd University of Petroleum & Minerals

Electrical Engineering Department

EE 360: Solution: Home Work #2

2.10

SOLUTION For the first four connections, the apparent power rating of each transformer is 1/3 of the total apparent power rating of the three-phase transformer. For the open-Δ and open-Y—open-Δ connections, the apparent power rating is a bit more complicated. The 500 kVA must be 86.6% of the total apparent power rating of the two transformers, so 250 kVA must be 86.6% of the apparent power rating of a single transformer. Therefore, the apparent power rating of each transformer must be 288 kVA.

The ratings for **each transformer** in the bank for each connection are given below:

Connection	Primary Voltage	Secondary Voltage	Apparent Power	Turns Ratio
Y-Y	19.9 kV	6.35 kV	167 kVA	2.50:1
Y-Δ	19.9 kV	11.0 kV	167 kVA	1.44:1
Δ-Y	34.5 kV	6.35 kV	167 kVA	4.33:1
Δ-Δ	34.5 kV	11.0 kV	167 kVA	2.50:1

2.12

SOLUTION *(a)* The equivalent of this three-phase transformer bank can be found just like the equivalent circuit of a single-phase transformer if we work on a per-phase bases. The open-circuit test data on the low-voltage side can be used to find the excitation branch impedances referred to the secondary side of the transformer bank. Since the low-voltage side of the transformer is Y-connected, the *per-phase* open-circuit measurements are:

$$V_{\phi,OC} = 277 \text{ V} \qquad I_{\phi,OC} = 4.10 \text{ A} \qquad P_{\phi,OC} = 315 \text{ W}$$

The excitation admittance is given by

$$|Y_{EX}| = \frac{I_{\phi,OC}}{V_{\phi,OC}} = \frac{4.10 \text{ A}}{277 \text{ V}} = 0.01480 \text{ S}$$

The admittance angle is

$$\theta = -\cos^{-1}\left(\frac{P_{\phi,OC}}{V_{\phi,OC}\, I_{\phi,OC}}\right) = -\cos^{-1}\left(\frac{315 \text{ W}}{(277 \text{ V})(4.10 \text{ A})}\right) = -73.9°$$

Therefore,

$$Y_{EX} = G_C - jB_M = 0.01483\angle -73.9° = 0.00410 - j0.01422$$

$$R_C = 1/G_C = 244\ \Omega$$

$$X_M = 1/B_M = 70.3\ \Omega$$

(b) If this transformer is operating at rated load and 0.90 PF lagging, then current flow will be at an angle of $-\cos^{-1}(0.9)$, or –25.8°. The per-unit voltage at the primary side of the transformer will be

$$\mathbf{V}_P = \mathbf{V}_S + \mathbf{I}_S Z_{EQ} = 1.0\angle 0° + (1.0\angle -25.8°)(0.0125 + j0.0588) = 1.038\angle 2.62°$$

The voltage regulation of this transformer bank is

$$\text{VR} = \frac{1.038 - 1.0}{1.0} \times 100\% = 3.8\%$$

(c) The output power of this transformer bank is

$$P_{OUT} = V_S I_S \cos\theta = (1.0)(1.0)(0.9) = 0.9 \text{ pu}$$

The copper losses are

$$P_{CU} = I_S^2 R_{EQ} = (1.0)^2 (0.0122) = 0.0122 \text{ pu}$$

The core losses are

$$P_{core} = \frac{V_P^2}{R_C} = \frac{(1.038)^2}{63.6} = 0.0169 \text{ pu}$$

Therefore, the total input power to the transformer bank is

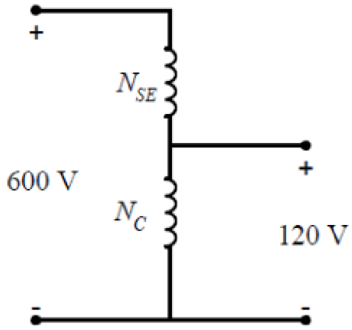
$$P_{IN} = P_{OUT} + P_{CU} + P_{core} = 0.9 + 0.0122 + 0.0169 = 0.929$$

and the efficiency of the transformer bank is

$$\eta = \frac{P_{OUT}}{P_{IN}} \times 100\% = \frac{0.9}{0.929} \times 100\% = 96.9\%$$

2.17

SOLUTION *(a)* For this configuration, the common winding must be the *smaller* of the two windings, and $N_{SE} = 4N_C$. The transformer connection is shown below:



(b) The kVA rating of the autotransformer can be found from the equation

$$S_{IO} = \frac{N_{SE} + N_C}{N_{SE}} S_W = \frac{4N_C + N_C}{4N_C} (10 \text{ kVA}) = 12.5 \text{ kVA}$$

(c) The maximum primary current for this configuration will be

$$I_P = \frac{S}{V_P} = \frac{12,500 \text{ VA}}{600 \text{ V}} = 20.83 \text{ A}$$

and the maximum secondary current is

$$I_S = \frac{S}{V_S} = \frac{12,500 \text{ VA}}{120 \text{ V}} = 104 \text{ A}$$

P1)

Primary resistance/phase $(R_1) = 2\ \Omega$

Secondary resistance/phase $(R_2) = 0.03\ \Omega$

Iron loss = 20 kW

Primary phase voltage = primary line voltage = 6,600 V

Secondary line voltage = 1,100 V

$$\text{Secondary phase voltage} = \frac{1,100}{\sqrt{3}} = 635.08\ \Omega$$

$$\text{Turns ratio } (a) = \frac{6,600}{635.08} \approx 10.4$$

$$\therefore R_{02} = R_2 + \frac{R_1}{a^2} = 0.03 + \frac{2}{10.4^2} = 0.0485\ \Omega$$

$$\text{Secondary phase current } (I_{Ph2}) = \text{secondary line current} = \frac{1,200 \times 10^3}{\sqrt{3} \times 1,100} = 629.84 \text{ A}$$

$$\text{Total full-load Cu loss } (P_{Cu}) = 3I_{Ph2}^2 R_{02} = 3 \times 629.84^2 \times 0.0485 = 57.72 \text{ kW}$$