

Exam 2  
ET 332b

## Questions (15 pts)

- 1.) In the \_\_\_\_\_, rated voltage is applied to the low voltage windings to find the core losses and magnetizing reactance.
- a.) open circuit test
  - b.) short circuit test
  - c.) loop back test
  - d.) efficiency test
- 2.) In the short circuit test, voltage is adjusted until rated \_\_\_\_\_ is read on the instruments.
- a.) power
  - b.) voltage
  - c.) current
- 3.) A three-phase transformer connection that can supply balanced three phase voltages from only 2 single-phase transformers is called the \_\_\_\_\_ connection.
- a.) delta-delta
  - b.) wye-delta
  - c.) open delta
  - d.) wye-wye
- 4.) When transformers operate in parallel, a circulating current can flow. This current is caused by \_\_\_\_\_.
- a.) unequal power ratings
  - b.) different transformer impedances
  - c.) unequal transformer ratios
  - d.) load unbalance
- 5.) Measurements from the two-watt meter method of three-phase power measurement can be used to find \_\_\_\_\_.
- a.) total load watts
  - b.) load power factor
  - c.) total load VARs
  - d.) all of the above

Problem 1 (30 pts)

The following data were taken from the short circuit and open circuit tests of a 50 kVA, - 7200-480 V 60 Hz single-phase transformer.

Open Circuit Test - Low voltage side

$V_{oc} = 480 \text{ V}$        $I_{oc} = 2.7 \text{ A}$        $P_{oc} = 270 \text{ W}$

Short Circuit Test - High voltage side

$V_{sc} = 392 \text{ V}$        $I_{sc} = 6.94 \text{ A}$        $P_{sc} = 1525 \text{ W}$

- a.) Compute the values of core loss resistance, magnetizing reactance and total winding impedance from the test results.
- b.) Draw the approximate equivalent circuit of the transformer in **low voltage terms** and label the components with the values from part a.

(+20)

a.) Find  $R_c$  and  $X_m$  from O.C. Test

$$R_c = \frac{V_{oc}^2}{P_{oc}} = \frac{(480\text{V})^2}{270\text{W}} = 853.3 \Omega$$

$$I_{fe} = \frac{P_{oc}}{V_{oc}} = \frac{270\text{W}}{480\text{V}} = 0.5625 \text{ A}$$

$$I_m = \sqrt{I_{oc}^2 - I_{fe}^2} = \sqrt{2.7^2 - 0.5625^2} = 2.641 \text{ A}$$

$$X_m = \frac{V_{oc}}{I_m} = \frac{480\text{V}}{2.641\text{A}} = 181.7 \Omega$$

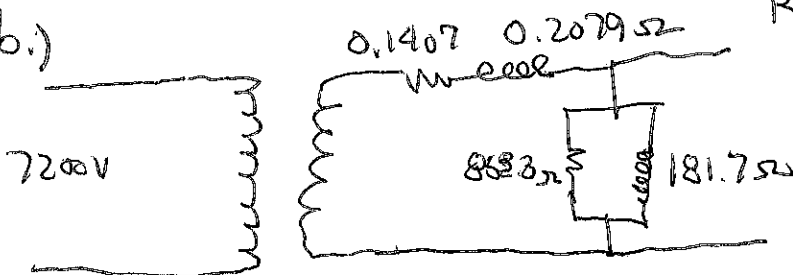
Find  $R_{eq}$  and  $X_{eq}$  from S.C. Test. Done on H.V. Side

$$Z_{eq} = \frac{V_{sc}}{I_{sc}} = \frac{392\text{V}}{6.94\text{A}} = 56.48 \Omega$$

$$R_{eq} = \frac{P_{sc}}{I_{sc}^2} = \frac{1525\text{W}}{6.94^2} = 31.66 \Omega$$

$$X_{eq} = \sqrt{Z_{eq}^2 - R_{eq}^2} = \sqrt{56.48^2 - 31.66^2} = \sqrt{3198 - 1002} = 46.78 \Omega$$

b.)



(+10)

Refer  $X_{eq}$  and  $R_{eq}$  to L.V. side  
divide by  $a^2$

$$a = \frac{7200}{480} = 15$$

$$\frac{31.66 \Omega}{15^2} = \frac{R_{eq}}{a^2} = 0.1407 \Omega$$

$$\frac{46.78}{15^2} = \frac{X_{eq}}{a^2} = 0.2079 \Omega$$

Problem 2 (25 pts)

A 50 kVA 7200-240 V single phase transformer has a **per unit** winding impedance of  
 0.0129+0.021j p.u.

This value is based on the power and voltage ratings of the transformer. The open circuit test shows that the transformer core losses at rated voltage are 430 Watts.

- a.) Find the efficiency of the transformer when a 35 kVA load operating at rated voltage and 95% lagging power factor is connected to its low voltage side.
- b.) Find the percent transformer regulation when the transformer operates with the load from part a.

a.) 
$$\eta = \frac{P_o}{P_o + P_c + I_L^2 R_{eq}} \times 100\%$$

$$F_p = \frac{P}{S} \Rightarrow F_p S_o = P_o \quad F_p = \frac{95\%}{100\%} = 0.95 \quad S_o = 35,000 \text{ VA}$$

$$P_o = 0.95(35,000) = 33250 \text{ W}$$

+14

find  $R_{eq}$  in ohms  $Z_{base} = \frac{V_{base}^2}{S_{base}}$   $V_{base} = 240 \text{ V}$   $S_{base} = 50,000 \text{ VA}$   
 $Z_{base} = \frac{(240)^2}{50,000} = 1.152 \Omega$   
 $I_L = S_o / V_R \quad I_L = \frac{35,000 \text{ VA}}{240 \text{ V}} = 145.83 \text{ A}$

Convert  $Z_{pu}$  to  $Z_{act}$   $Z_{base} [Z_{pu}] = Z_{act} \quad (1.152 \Omega)(0.0129 + 0.021j) = Z_{act}$

$I_L^2 R_{eq} = (145.83 \text{ A})^2 (0.0147 \Omega) = 312.6 \text{ W}$

$0.0147 + 0.03341j \Omega = Z_{act}$

$$\eta = \frac{33250 \text{ W}}{33250 + 430 + 312.6 \text{ W}} \times 100\% \quad \eta = \frac{33250}{33992.6} \times 100\% = \boxed{97.82\%}$$

$\theta = \cos^{-1}(F_p)$

b.)  $\%VR = \frac{|V_{NL}| - |V_R|}{|V_R|} \times 100\%$   $V_{NL} = \bar{V}_R + \bar{I}_L \bar{Z}_{eq}$   $\bar{V}_R = 240 \angle 0^\circ$   $\theta = \cos^{-1}(0.95)$   
 $Z_{eq} = Z_{act}$   $\bar{I}_L = 145.83 \angle -18.2^\circ$   $\theta = -18.2^\circ$   
 $Z_{eq} = 0.0147 + 0.03341j = 0.0365 \angle 66.3^\circ \Omega$

+13

$$\bar{V}_{NL} = 240 \angle 0^\circ + (145.83 \angle -18.2^\circ)(0.0365 \angle 66.3^\circ)$$

$$\bar{V}_{NL} = 240 \angle 0^\circ + 5.323 \angle 48.1^\circ$$

$$\bar{V}_{NL} = 243.6 \angle 0.932^\circ$$

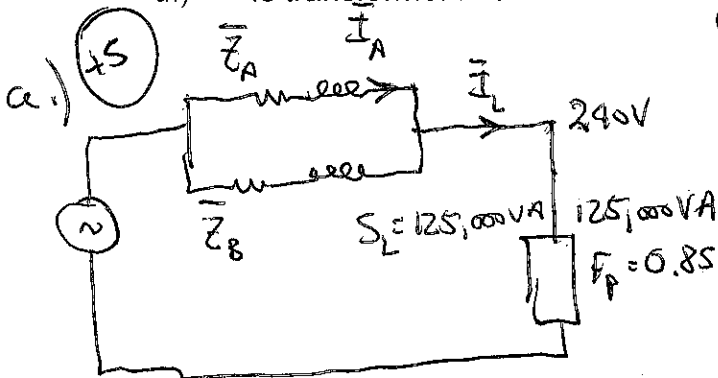
$$\%VR = \frac{243.6 - 240}{240} \times 100 = \boxed{1.5\%}$$

Problem 3 (30 pts)

Transformers A and B listed below are 7200-240 volt transformers that operate in parallel supplying a single load of 125 kVA at rated secondary voltage and a power factor of 85% lagging.

Transformer	% Impedance	Rated S
A	(1.19+2.10j)%	50 kVA
B	(1.20+2.93j)%	100 kVA

- Sketch the equivalent circuit using impedance values in ohms in terms of the secondary voltage.
- Determine the secondary current supplied by transformer A in amps
- Determine the apparent power loading of transformer A
- Is transformer A overloaded?



Convert % to pu, then add  $\Omega$   $V_{base} = 240 \text{ V}$

$$Z_{baseA} = \frac{V_{base}^2}{S_{baseA}} = \frac{240^2}{50,000 \text{ VA}}$$

$$S_{baseA} = 50,000 \text{ VA}$$

$$S_{baseB} = 100,000 \text{ VA}$$

$$Z_{baseA} = 1.152 \Omega$$

$$Z_{baseB} = \frac{V_{base}^2}{S_{baseB}} = \frac{240^2}{100,000 \text{ VA}} = 0.576 \Omega$$

(circled +5)

$$\bar{Z}_A = \left[ \frac{(1.19 + 2.10j)\%}{100\%} \right] Z_{baseA} = (0.0119 + 0.021j) 1.152 \Omega = 0.0137 + 0.0242j \Omega$$

$$\bar{Z}_B = \left[ \frac{(1.20 + 2.93j)\%}{100\%} \right] Z_{baseB} = (0.0120 + 0.0293j) (0.576 \Omega) = 0.006912 + 0.01687j \Omega = 0.01829 \angle 67.7^\circ \Omega$$

$$\bar{I}_L = \frac{S_L}{V_s} \angle -\cos^{-1}(F_p) = \frac{125,000 \text{ VA}}{240 \text{ V}} \angle -\cos^{-1}(0.85) = 520.8 \angle -31.8^\circ \text{ A}$$

$$\bar{I}_A = \bar{I}_L \left[ \frac{\bar{Z}_B}{\bar{Z}_A + \bar{Z}_B} \right] = 520.8 \angle -31.8^\circ \left[ \frac{0.01829 \angle 67.7^\circ \Omega}{0.0278 \angle 60.5^\circ + 0.01829 \angle 67.7^\circ} \right] = (0.3956 \angle 4.35^\circ) (520.8 \angle -31.8^\circ \text{ A})$$

$$\bar{I}_A = 206 \angle -27.5^\circ \text{ A} \quad \text{(circled +15)}$$

$$c.) |S_A| = |I_A| |V_s| = (206 \text{ A}) (240 \text{ V}) = 49,440 \text{ VA}$$

d.)  $49,440 < 50,000 \text{ VA}$  rated  
Not overloaded

(circled +2)

(circled +3)