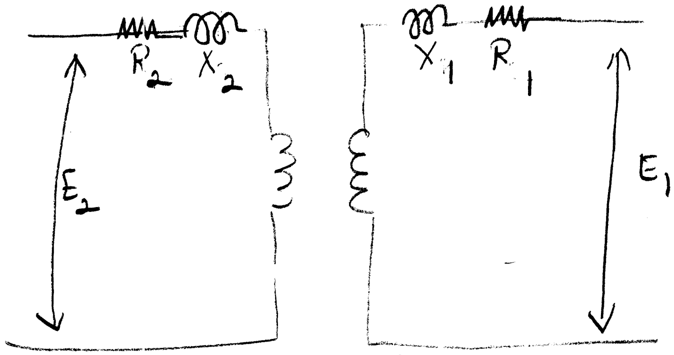


<u>500kVA xfmr</u>

13,200 : 2400
4% reactance
1% resistance

leakage reactance 0.250Ω
resistance = .055Ω

core loss
@ rating = 1800 w.

(a) Neglecting xfmr losses, unity power factor

$$\frac{E_2}{E_1} = \frac{N_2}{N_1} = \frac{I_1}{I_2}$$

in this case $\frac{E_2}{E_1} = \frac{132\cancel{00}}{24\cancel{00}} = 5.5$,

$$R_{02} = R_2 + R_1 n^2$$

$$X_{02} = X_2 + X_1 n^2$$

$$Z_{02} = \sqrt{R_{02}^2 + X_{02}^2}$$

$$\frac{Z_{01}}{Z_{02}} = n^2 = \left(\frac{N_1}{N_2}\right)^2$$

$$I_2 = \frac{\text{kva rated} \times 1000}{E_2} = \frac{500 \times 1000}{13200} = 37.9 \text{ amp.}$$

$$R_{02} = .01\left(\boxed{\frac{13200\text{ V}}{37.9\text{ A}}}\right) = 3.48\ \Omega$$

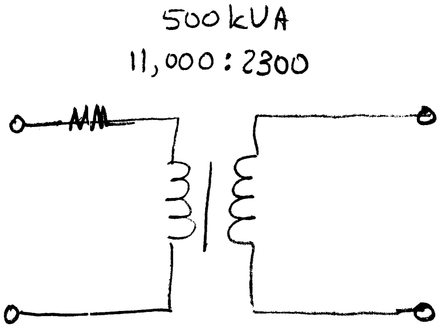
use load rating

$$X_{02} = .04\left(\frac{13200\text{ V}}{37.9\text{ A}}\right) = 13.92\ \Omega$$

use load rating

Transformers-1

See Constance p.255



open circuit test $E = 2300$ $I = 2.3A$, $P = 4000$ watts

short circuit test (secondary shorted) $E_{pri} = 600$ $I_{pri} = 45.4A$, $P_{pri} = 6000$ watts.

(a) copper loss

6000 watts.

(b) equivalent resistance referred to the primary

$$R_{01} = \frac{P_{short}}{I_{short}^2} = \frac{6000}{(45.4)^2} = 2.92\Omega$$

(c) equivalent resistance referred to secondary.

$$R_{02} = 2.92 \times \left(\frac{2300}{11000}\right)^2 = 0.129\Omega$$

(d) equivalent impedance referred to the primary

$$Z_{01} = \frac{E_1}{I_1} = \frac{600\ V}{45.4A} = 13.2\Omega.$$

(e) equivalent reactance referred to the secondary

$$X_{01} = \sqrt{Z_{01}^2 - R_{01}^2} = \sqrt{(13.2)^2 - (2.92)^2} = 12.8\Omega$$

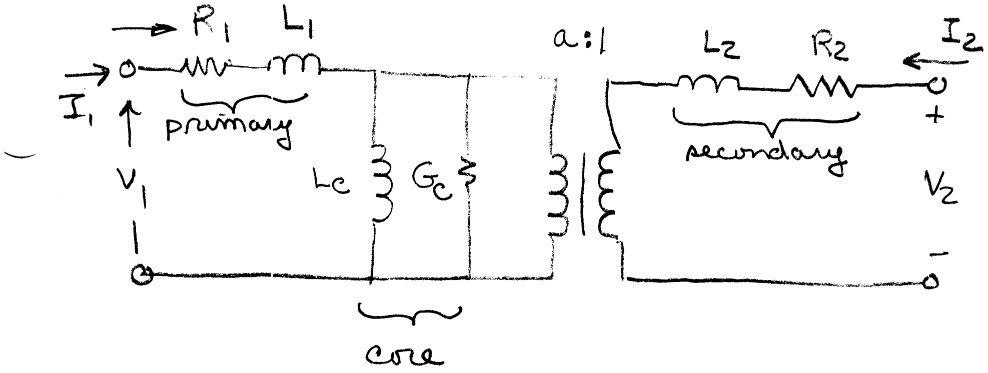
$$X_{02} = 12.8 \times \left(\frac{2300}{11000}\right)^2 = 0.563\Omega$$

(f) regulation at 0.8 power factor rating

$$E_1 = \sqrt{(\underset{v}{\underline{11,000}} \times \underbrace{0.8}_{pf} + \underset{i}{\underline{45.5}} \times \underbrace{2.92}_{resistance})^2 + (\underset{v}{\underline{11,000}} \times 0.6 + \underset{i}{\underline{45.5}} \times \underbrace{12.8}_{reactance})^2}$$

$$E_1 = 11,500$$

$$\text{Regulation} = \frac{11,500 - 11,000}{11,000} \times 100 = 4.56\%$$



(a) <u>open circuit test</u>

- always performed at rated winding voltage
- transformers with HV primary, LV secondary, usually measure secondary (in this case, put core impedances on secondary)

in open circuit test, primary winding impedance can be neglected

primary V, I, P measurements determine G_c and L_c or X_c

$$Y_{\text{open circuit}} = G_c - jB_c$$

The susceptance $B_c = \frac{1}{X_c} = \frac{1}{\omega L_c}$,

open circuit power

real power → $P_{oc} = V_{oc}^2 G_c \Rightarrow G_c = \frac{P_{oc}}{V_{1,oc}^2}$ $\quad S_{oc} = V_{1,oc}^2 Y_c = V_{1,oc}^2 (G_c - jB_c)$

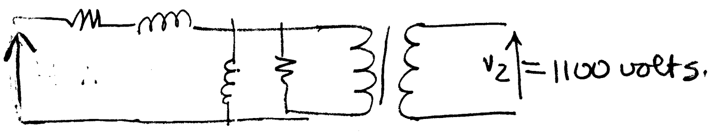
$Q_{oc}^2 = S_{oc}^2 - P_{oc}^2$ $\quad Q_{oc} = V_{1,oc}^2 B_c$

imaginary power → Q_{oc}; real power → P_{oc}

$$\Rightarrow B_c = \frac{\sqrt{S_{oc}^2 - P_{oc}}}{V_1^2}$$

$$a_{pe} = \frac{V_{1,oc}}{V_{2,oc}}\Big|_{I_2 = 0}$$

<u>open circuit test example</u>:



P = 100 watts

I = 1 amp

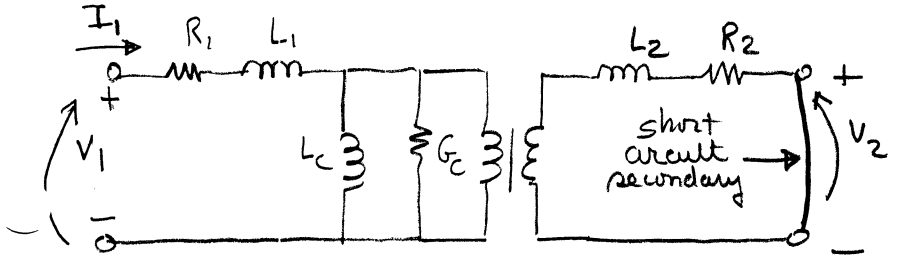
$$S = (440)(1) = 440 \text{ VA}$$

$$Q^2 = (440)^2 - (100)^2 = (428.5)^2$$

$$G_c = \frac{100}{440^2} = .00052\ \mho$$

$$B_c = -\frac{428}{440^2} = -.00221\ \mho$$

$$a_{pe} = \frac{440}{1100} = 0.4$$



Transformers - 3

SHORT CIRCUIT TEST

- used to determine winding impedances
- always conducted at rated current of winding
- shorting secondary shorts out core effects leaving Z_{pri} + transformed Z_{sec}.

$$Z_{s.c.} = R_1 + jX_1 + a_{pe}^2 (R_2 + jX_2)$$

- measure primary V_{sc}, I_{sc}, P_{sc}

$$V_{sc} I_{sc} = I_{sc}^2 Z = I_{sc}^2 (R_1 + a_{ps}^2 R_2) + j I_{sc}^2 (X_1 + a_{ps} X_2)$$

$$\text{but } \underset{\nwarrow \text{real}}{P_{sc}} = I_{sc}^2 (R_1 + a_{ps}^2 R_2)$$

$$\Rightarrow R_1 + a_{ps}^2 R_2 = \frac{P_{sc}}{I_{sc}^2}$$

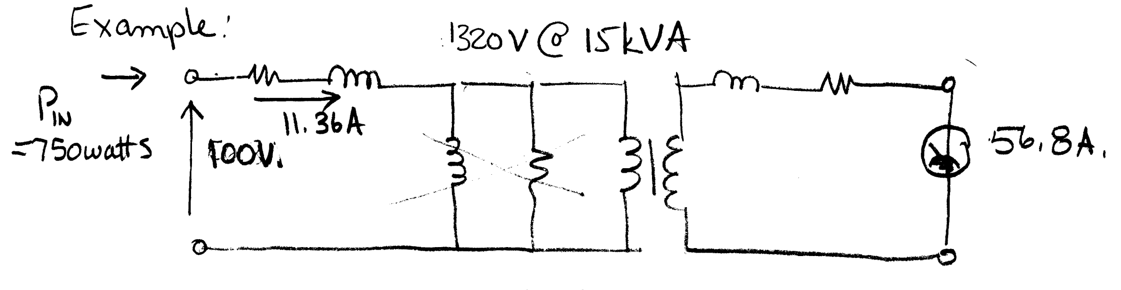
imaginary power,

$$Q_{sc}^2 = S_{sc}^2 - P_{sc}^2 = I_{sc}^2 (X_1 + a_{ps} X_2)$$

$$\Rightarrow X_1 + a_{ps}^2 X_2 = \frac{\sqrt{V_{sc}^2 I_{sc}^2 - P_{sc}^2}}{I_{sc}^2}$$

$$R_1 = a_{ps}^2 R_2 = \frac{P_{sc}}{2I_{sc}^2} \qquad X_1 = a_{ps}^2 X_2 = \frac{Q_{sc}}{2I_{sc}^2} \qquad a_{ps} = \frac{I_{2,sc}}{I_{1,sc}}$$

Example:



$$I_{rated} = \frac{15\,KVA}{1.320\,kV} = 11.36\,A.$$

apparent power $S = (11.36A)(100V) = 1136$ VA

$$Q = \sqrt{(1136)^2 - (750)^2} = 853\,VAR$$

$$R_1 = a_{ps}^2 R_2 = \frac{750}{2(11.36)^2} = 2.9\,\Omega.$$

$$X_1 = a_{ps}^2 X_2 = \frac{853}{2\cdot(11.36)^2} = 3.3\,\Omega.$$

$$a_{ps} = \frac{I_{2,sc}}{I_{1,sc}} = \frac{56.8}{11.36}$$

$$a_{ps} = 5$$