SokVAXfr

13,200 : 2,400
leakage reactance = 0.250Ω
4% reactance
1% resistance

core loss
@ rating = 1,800 W.

(a) Neglecting xfrn losses, unity power factor

\[
\frac{E_2}{E_1} = \frac{N_2}{N_1} = \frac{I_1}{I_2}
\]

in this case \[
\frac{E_2}{E_1} = \frac{13200}{2400} = 5.5,
\]

\[
R_{02} = R_2 + R_1 n^2
\]

\[
X_{02} = X_2 + X_1 n^2
\]

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

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

\[
I_2 = \frac{\text{kVA rated} \times 1000}{E_2} = \frac{500 \times 1000}{13200} = 37.9 \text{ amp}
\]

\[
R_{02} = 0.01 \left(\frac{13200 \text{ V}}{37.9 \text{ A}}\right) = 3.48 \Omega
\]

\[
X_{02} = 0.04 \left(\frac{13200 \text{ V}}{37.9 \text{ A}}\right) = 13.92 \Omega
\]
open circuit test \[ E = 2300 \quad I = 2.3A \quad P = 4000 \text{ watts} \]
short circuit test \( E = 600 \) \( P_{\text{sh}} = 6000 \text{ watts} \)
\( I_{\text{sh}} = 45.4A \)
(a) copper loss \[ 6000 \text{ watts} \]
(b) equivalent resistance referred to the primary \[ R_{01} = \frac{P_{\text{sh}}}{I_{\text{sh}}^2} = \frac{6000}{(45.4)^2} = 2.92 \Omega \]
(c) equivalent reactance referred to secondary \[ R_{02} = 2.92 \times \left( \frac{2300}{11000} \right)^2 = 0.129 \Omega \]
(d) equivalent impedance referred to the primary \[ Z_{01} = \frac{E I}{I} = \frac{600}{45.4} \Omega = 13.2 \Omega \]
(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 \[ E_1 = \sqrt{\left( \frac{11,000 \times 0.8 + 45.5 \times 2.92}{\text{pf}} \right)^2 + \left( \frac{11,000 \times 0.6 + 45.5 \times 12.8}{\text{reactance}} \right)^2} \]
\[ E_1 = 11,500 \]
Regulation = \[ \frac{11,500 - 11,000}{11,000} \times 100 = 4.567\% \]
(a) **open circuit test**

- **always** performed at rated arming voltage
- **transformers** with HV primary, LV secondary, usually measure secondary

In open circuit test, primary winding impedance can be neglected.

Primary V, I, P measurements determine \( G_c \) and \( L_c \) or \( X_c \)

\[
Y_{oc} = G_c - jB_c
\]

The **susceptance** \( B_c = \frac{1}{X_c} = \frac{1}{\omega L_c} \)

**open circuit power**

Real power \( P_{oc} = V_{oc}^2 G_c \) \[ G_c = \frac{P_{oc}}{V_{oc}^2} \]

Imaginary power \( Q_{oc} = V_{oc}^2 B_c \)

\[
Q_{oc} = \sqrt{S_{oc}^2 - P_{oc}^2} \quad B_c = \frac{V_{oc}^2}{V_{oc}^2}
\]

\[
\alpha_{pe} = \frac{V_{oc}}{V_{oc}} \quad I_2 = 0
\]

**open circuit test example**:

\[
S = (440)(1) = 440 \text{ VA}
\]

\[
Q^2 = (440)^2 - (100)^2 = (428.5)^2
\]

\[
G_c = \frac{100}{440^2} = 0.00052 \Omega
\]

\[
B_c = \frac{-428}{440^2} = -0.00221 \Omega
\]

\[
\alpha_{pe} = \frac{440}{1100} = 0.4
\]
**Short Circuit Test**

- Used to determine winding impedances.
- Always conducted at rated current of winding.
- Shorting secondary shorts out core effects leaving $Z_{pri} + \text{transformed } Z_{sec}$.

\[ Z_{s.c.} = R_1 + jX_1 + a_{ps}^2 (R_2 + jX_2) \]

- Measure primary $V_{sc}, I_{sc}, P_{sc}$

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

But $P_{sc} = I_{sc}^2 (R_1 + a_{ps}^2 R_2)$

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

Imaginary power:

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

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

\[ R_1 = a_{ps}^2 R_2 = \frac{P_{sc}}{2 I_{sc}^2}, \quad X_1 = a_{ps} X_2 = \frac{Q_{sc}}{2 I_{sc}^2} \]

\[ a_{ps} = \frac{I_2, sc}{I_1, sc} \]

**Example:**

- $13200 \text{ V @ 15 kVA}$

\[ P_{in} = 750 \text{ watts} \]

\[ I_{rated} = \frac{15 \text{ kVA}}{1.320 \text{ kV}} = 11.36 \text{ A}. \]

- Apparent power:

\[ S = (11.36 \text{ A})(100 \text{ V}) = 1136 \text{ VA} \]

\[ Q = \sqrt{(1136)^2 - 750^2} = 853 \text{ VAR} \]

\[ R_1 = a_{ps}^2 R_2 = \frac{750}{2(11.36)^2} = 2.9 \Omega \]

\[ X_1 = a_{ps}^2 X_2 = \frac{853}{2(11.36)^2} = 3.3 \Omega \]