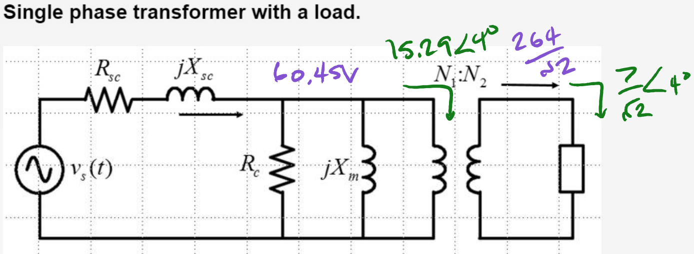
Assignment 6 - 3 Phase Transformers

Wednesday, March 16, 2016 10:51 AM

(10 pts)
The secondary winding of a transformer has a terminal voltage of $v_{sec}(t) = 264\,sin(377t)$ V. The turns ratio of the transformer is 68:210. If the secondary current of the transformer $i_{sec}(t) = 7\,sin(377t + [4°])$, (a) What is the RMS value of the primary current of this transformer? (b) What are its voltage regulation and (c) efficiency? The impedances of this transformer referred to the primary side are $R_{sc} = 0.2\,\Omega,\ X_{sc} = 0.75\,\Omega$ and $R_c = 300\,\Omega,\ X_m = 70\,\Omega$.

Single phase transformer with a load.



(a) RMS of primary current: 15.29 A

(b) Voltage regulation: 6.1 %

(c) Efficiency: 91.9 %

$$\%\ reg = \frac{V_{no\ load} - V_{load}}{V_{load}}$$

Vs = 64.2 < 11.44 rad

When load is OC, v1=0

$$V_t - I_t(R_{sc} + jX_s) = V_1$$

$$I_t = I_1 + I_{Rc} + I_{Xm}$$

(10 pts)
A 36 KVA $20k/480\,V$ $60\,Hz$ distribution transformer is tested with the following results. Open circuit test, measured from the LV, V_{oc}=$480V$, I_{oc} =$1.6A$, P_{oc}=115.2 W. Short circuit test, measured from the HV, V_{sc}=$1130V$, I_{sc}=$1A$, P_{sc}=282.5 W.

(a) Find the equivalent circuit of this transformer with all of the impedances referred to the HV side.

R_c = 3.4722 $M\Omega$ X_m = 0.52679 $M\Omega$

R_{sc} = 282.5 Ohms X_{sc} = 1094.1 Ohms

(b) Find the equivalent circuit of this transformer in per unit with respect to its own rated powr.

R_c = 312.5 pu X_m = 47.411 pu

R_{sc} = 0.025425 pu X_{sc} = 0.098469 pu

(c) The transformer feeds its rated load at a power factor of 0.6 inductive. If the primary voltage is 18000 V, what is the voltage right at the terminals of the secondary of this transformer? (There are two answers. Use the bigger one)

V = V

OC TEST (LV)

$V_{oc} = 480$
$I_{oc} = 1.6$
$P_{oc} = 115.2$

SC TEST (HV)

$V_{sc} = 1130$
$I_{sc} = 1$
$P_{sc} = 282.5$

in radians

$PF_{oc} = \frac{P_{oc}}{V_{oc} I_{oc}}$ $PF_{sc} = \frac{P_{sc}}{V_{sc} I_{sc}}$

$Y_e = \frac{I_{oc}}{V_{oc}} \angle -a\cos(PF_{oc})$ $Z_{sc} = \frac{V_{sc}}{I_{sc}} \angle a\cos(PF_{sc})$

$R_c = \frac{1}{Re\{Y_e\}}$ $R_{sc} = Re\{Z_{sc}\}$

$X_m = \frac{-1}{Im\{Y_e\}}$ $X_{sc} = Im\{Z_{sc}\}$

$\hookrightarrow R_{sc}^{hv} = \boxed{282.5\,\Omega}$
$\hookrightarrow X_{sc}^{hv} = \boxed{1094\,\Omega}$

$\hookrightarrow R_c^{lv} = 2k\,\Omega$
$\hookrightarrow X_m^{lv} = 303.4\,\Omega$

$Z_2 = Z_1 \frac{N_2^2}{N_1^2} \rightarrow R_c^{hv} = R_c^{lv} \frac{20k^2}{480^2} = \boxed{3.472\,M\Omega}$
$\rightarrow X_m^{hv} = X_m^{lv} \frac{20k^2}{480^2} = \boxed{526.8\,k\Omega}$

$Z_b = \frac{V_b^2}{S_b} \rightarrow Z_b^{lv} = \frac{480^2}{36k} = 6.4\,\Omega$

$$Z_b^{hv} = \frac{20k^2}{36k} = 11.11k\,\Omega$$

$$R_{c_{pu}} = \frac{R_c^{lv}}{Z_b^{lv}} = \boxed{0.3125} \qquad R_{sc_{pu}}^{hv} = \boxed{0.02543}$$

$$X_m^{pu} = \frac{X_m^{lv}}{Z_b^{lv}} = \boxed{47.41} \qquad X_{sc_{pu}}^{hv} = \boxed{0.09847}$$

(10 pts)

A 250-MVA 230/115-kV $\Delta - \Delta$ three-phase power transformer has a per-unit resistance of $R_{sc} = 0.07\ pu$ and a per-unit reactance of $X_{sc} = 0.25\ pu$. The excitation branch elements are $R_c = 110\ pu$ and $X_m = 24.44\ pu$. (a) If this transformer supplies a load of 200 MVA at 0.4 lagging, What is the voltage regulation of the transformer bank under these conditions (that is, what percent would the voltage at the load rise if we disconnect the load)? (b) Calculate all of the transformer impedances referred to the low-voltage side, in ohms.

Three Phase Transformer in a Substation

$$V_Y = \sqrt{3} V_\Delta$$

- (a) Regulation .... :* 21.7 %
- (b.1) R_{sc} .... :* 11 Ω
- (b.2) X_{sc} .... :* 39.29 Ω
- (b.3) R_c .... :* 17.3 $k\Omega$
- (b.4) X_m .... :* 3.9 $k\Omega$

$$V_Y = \sqrt{3} V_\Delta$$

$$Z_b = \frac{V_b^2}{S_b}$$

$$Z_b^{lv} = \frac{(V_b^{lv})^2}{S_b} = \frac{(\sqrt{3}\,115k)^2}{250M} = 158.7$$

$$R_{sc}^{lv} = R_{sc}^{pu} Z_b^{lv} = 0.07(158.7) = \boxed{11.11\,\Omega}$$

$$X_{sc}^{lv} = 0.25(158.7) = \boxed{39.68\,\Omega}$$

$$R_c^{lv} = 110(158.7) = \boxed{1746\,\Omega}$$

$$X_m^{lv} = 24.44(158.7) = \boxed{3879\,\Omega}$$

REGULATION

$$\%\ reg = \frac{|V_{nl}| - |V_{fl}|}{|V_{fl}|} 100\% \qquad \%\ reg = (|V_s| - 1)\ 100\%$$

$$I_{sc}^{pu} = \frac{S_{supply}}{S_b} \angle -acos\,PF$$

$$V_s = 1 + (R_{sc}^{pu} + jX_{sc}^{pu}) I_{sc}^{pu}$$

(-)ive b/c lagging

$$\hookrightarrow I_{sc}^{pu} = \frac{200M}{250M} \angle -acos\,0.4$$

$$\hookrightarrow V_s = 1 + (0.07 + j0.25) I_{sc}^{pu} \angle -acos\,0.4$$

↳ $I_{sc}^{pu} = \frac{200M}{250M} \angle -acos0.4$

↳ $V_s = 1 + (0.07 + j0.25)\, I_{sc}^{pu} \angle -acos0.4$

↳ $\boxed{\%\ reg = 20.6}$ (in rad)

(10 pts)
Three 26000 kVA 24000/277 V distribution transformers are connected in Δ/Y (Normally referred to as Dy). The open circuit test was performed on the low voltage side of the three phase transformer bank, and the following data were recorded: $V_{oc}^{line} = 480\,V$, $I_{oc}^{line} = 4.10\,A$, $P_{oc}^{3\phi}$ = 310 W. the short circuit test was performed on the high voltage side of the three phase transformer bank: V_{sc}^{line} = 1600 V, I_{sc}^{line} = 2.0 A, $P_{sc}^{3\phi} = 350$ W.

Three phase bank of single phase transformer on a utility pole.

(a) Find the single phase equivalent circuit referred to the low voltage side.

(b) Find the transformer regulation at the rated load and voltage and a power factor of 0.4 lagging (Neglect the core impedance).

(c) What is the transformer bank's efficiency under these conditions of load?

(a) R_c = 743.2258 Ω X_m = 67.8735 Ω

R_s = 3.885294 $m\Omega$ X_s = 61.4043 $m\Omega$

(b) V_r = 460.9584

(c) Efficiency (percent) = 460.9584

$V_{oc}^{line} = 480V$ $V_{sc}^{line} = 1600V$ $S_b = 26MVA$

$I_{oc}^{line} = 4.10A$ $I_{sc}^{line} = 2A$ $V_b^{hv} = 24kV$

$P_{oc}^{3\phi} = 310W$ $P_{sc}^{line} = 350W$ $V_b^{lv} = 277V$

oc test on LV side, Y

$V_{oc} = \frac{480}{\sqrt{3}}$ $I_{oc} = 4.1$ $P_{oc} = 310/3$ $\rightarrow$ $\boxed{R_c = 743.2\Omega \quad X_m = 67.87\Omega}$

SC test on HV side, Δ

$V_{sc} = \frac{1600}{\sqrt{3}}$ $I_{sc} = 2$ $P_{sc} = 350/3$

$\hookrightarrow R_{sc}^{hv} = 29.17\Omega$ $\hookrightarrow X_{sc}^{hv} = 461.0\Omega$

$z_{lv} = z_{hv} \frac{(N_{lv})^2}{(N_{hv})^2}$ $R_{sc}^{lv} = 29.17 \frac{277^2}{(24k)^2} = \boxed{3.88 m\Omega}$

$X_{sc}^{lv} = 461 \frac{277^2}{(24k)^2} = \boxed{61.4 m\Omega}$

$Z_b^{lv} = \frac{277^2}{26M} = 0.002951$ $R_{sc}^{pu} = 1.315 pu$

$X_{sc}^{pu} = 20.81 pu$

$I_{rated} = \frac{26MVA}{277V} =$

$\gamma = \operatorname{atan} \frac{X_{sc}}{R_{sc}}$ $\alpha = 180 - (\gamma - \theta_f)$

$|V_c| = I_{rated} Z_{sc}$