IIT(BHU) VARANASI

STUDENTS' NOTES

TOPIC-ELECTRICAL-II

www.MINEPORTAL.in

$-V_3)2 + 6 + (V_1 - V_3)\times 4 - (V_3 - $

$= 0$

$+6 + 4V_1 - 4V_3 - 5V_3 = 0$

$V_2 - 11V_3 = -6 \quad — (3)$

$V_2 = \frac{-326}{439}, \quad V_3 = \frac{254}{439}$

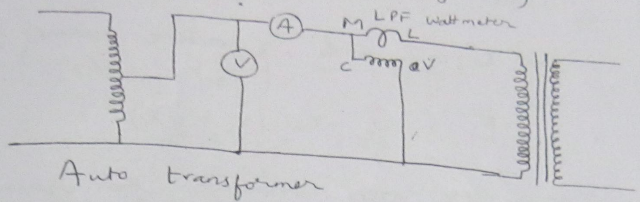
4/02/2013

Teacher – II

Determination of Eqt. Ckt. parameters

Open Circuit test

(Conducted from low voltage side)



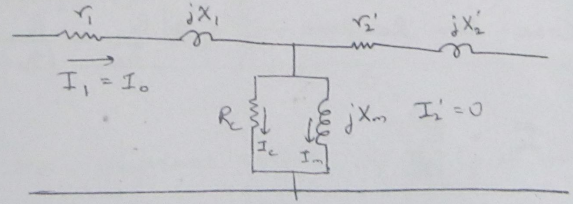
Auto transformer

$V = V_{\text{rated voltage}}$

I = around 5% of full load current.

W_0 = ~~to~~ no load power, W_0.

Equivalent circuit



Core loss, $P_0 = W_0 - I_0^2 r_1$

No load power factor, $\cos\phi_0 = \frac{P_0}{V_0 I_0}$

No load current has two components, I_c and I_m.

$\bar{I}_0 = \bar{I}_c + \bar{I}_m$

I_c is active current &

$I_c = I_0 \cos\phi_0$ (active current)

and $I_m = I_0 \sin\phi_0$ (reactive current).

$$\bar{E}_1 = \bar{V}_0 - I_0 (r_1 + j X_1)$$

If r_1 & X_1 are unknown, then ignore $I_0^2 r_1$ & $I_0(r_1 + j X_1)$

$$\bar{E}_1 \cong V_0$$

$$\& \; P_0 = W_0$$

~~to~~ Core loss $= I_c^2 R_c = P_0$

Core loss Resistance — $R_c = \frac{P_0}{I_c^2} = \frac{P_0}{(I_0 \cos\phi_0)^2}$

$$\bar{I}_m = \frac{\bar{E}_1}{j X_m}$$

Magnetizing Reactance, $X_m = \frac{E_1}{I_m} = \frac{E_1}{I_0 \sin\phi_0}$

Q. In 110V/220V 50Hz, 1.5KVA two winding transformer, the open circuit test gives, $V_0 = 110V$, $I_0 = 0.8$ Amp., $W_0 = 18W$

$R_c = ?$
$X_m = ?$
$\cos\phi_0 =$

$I_c =$
$I_m =$

$$\cos\phi_0 = \frac{18}{110 \times 0.8} = 0.2045$$

$$\sin\phi_0 = 0.958$$

$$I_c = I_0 \cos\phi_0 = 0.8 \times 0.2045 = 0.1$$

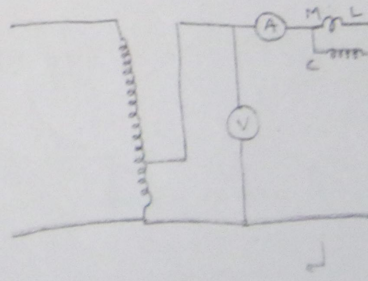
$$I_m = I_0 \sin\phi_0 = 0.8 \times 0.95 = 0.$$

$$R_c = \frac{P_0}{I_c^2} = \frac{18}{(0.16)^2} = 703 \,\Omega$$

$$X_m = \frac{E_1}{I_m} = \frac{110}{0.76} = 144$$

Short Circuit Test

(performed from high voltage side).



I_{sc} = Rated current

V_{sc} = (low voltage)

W_{sc} = (Rated copper loss).

current α

$I_0 \cos\phi_0$ (active current)

$I_0 \sin\phi_0$ (reactive current).

$E_1 = V_1 - I_0 (r_1 + jX_1)$

unknown, then ignore $(r_1 + jX_1)$

$I_c^2 R_c = P_0$

$R_c = \frac{P_0}{I_c^2} = \frac{P_0}{(I_0 \cos\phi_0)^2}$

$X_m = \frac{E_1}{I_m} = \frac{E_1}{I_0 \sin\phi_0}$

5 KVA true

open circuit

$I_0 = 0.8$ Amp., $W_0 = 18$ W.

$X_m = ?$

$\cos\phi_0 =$

$I_m =$

wattmeter → ... voltmeter → ...

$\cos\phi_0 = \frac{18}{110 \times 0.8} = 0.2045$

$\sin\phi_0 = 0.958$

$I_c = I_0 \cos\phi_0 = 0.8 \times 0.2045 = 0.16$ Amp.

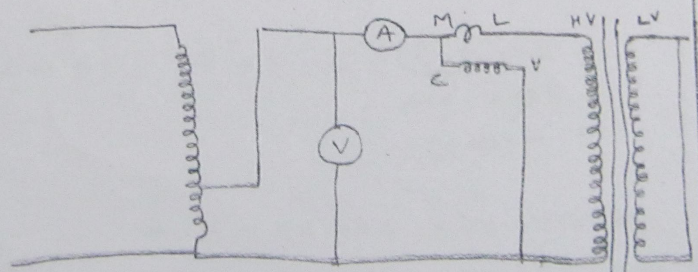
$I_m = I_0 \sin\phi_0 = 0.8 \times 0.95 = 0.76$ Amp

$R_c = \frac{P_0}{I_c^2} = \frac{18}{(0.16)^2} = 703\ \Omega.$

$X_m = \frac{E_1}{I_m} = \frac{110}{0.76} = 144.7\ \Omega.$

Short Circuit Test

(performed from high voltage side).

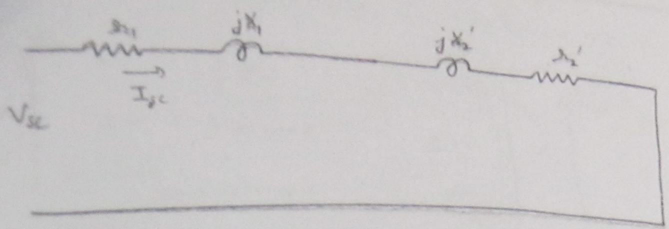


I_{sc} = Rated current

V_{sc} = (low voltage)

W_{sc} = (Rated copper loss).

Core loss are assumed to be zero.



Short ckt power factor, $\cos\phi_{sc} = \frac{W_{sc}}{V_{sc} \cdot I_{sc}}$

Copper loss is active loss, $W_{sc} = (r_1 + r_2') I_{sc}^2$

$$r_1 + r_2' = \left(\frac{W_{sc}}{I_{sc}^2}\right)$$

If r_1 is known
r_2' is known else $(r_1 + r_2')$.

$$\overline{I_{sc}} = I_{sc} \cos\phi_{sc} + j\, I_{sc} \sin\phi_{sc}$$

Impedance of circuit, $Z = \frac{V_{sc}}{I_{sc}} = (r_1 + r_2') + j(X_1 + X_2')$

$$= \sqrt{(r_1 + r_2')^2 + (X_1 + X_2')^2}$$

$$(X_1 + X_2') = \left(\frac{V_{sc}}{I_{sc}}\right)^2 - \left(\frac{W_{sc}}{I_{sc}^2}\right)$$

$$X_1 \approx X_2'$$

Q. In a short ckt test, $I_{sc} = 6$ & $V_{sc} = 25\,V$, $W_{sc} = 150\,W$. Calcul

$r_1 + r_2'$, $X_1 + X_2'$.

$$\cos\phi_{sc} = \frac{\cancel{150}\,150}{25 \times 6.8} = \cancel{0.88}\ 0.$$

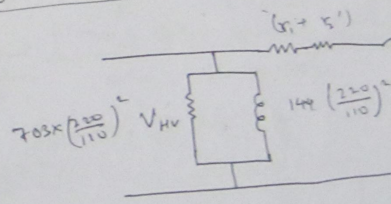
$$(X_1 + X_2') = \left(\frac{25}{6.8}\right)^2 - \left(\frac{150}{(6.8)^2}\right)$$

$$= 13.51 - 3.24$$

$$= 10.26$$

$$Z = \frac{25}{6.8} = 3.676 = \sqrt{(r_1 + r_2')^2}$$

Equivalent ckt. ref. to high



Q. Find the referred values o

R_c ref. to (HV) R_c

X_m ref. to HV $X_m|_{HV}$

Q. In a short ckt test, $I_{sc} = 6.8$ Amp. & $V_{sc} = 25\,V$, $W_{sc} = 150\,W$. Calculate, $r_1 + r_2'$, $X_1 + X_2'$.

$$\cos\phi_{sc} = \frac{\cancel{15}\,150}{25 \times 6.8} = \cancel{0.88}\ 0.88$$

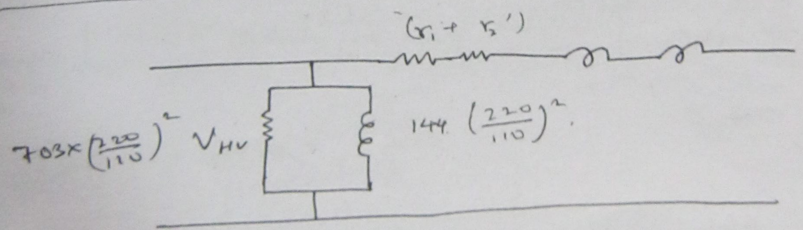
$$(X_1 + X_2') = \left(\frac{25}{6.8}\right)^2 - \left(\frac{150}{(6.8)^2}\right)$$

$$= 13.51 - 3.24$$

$$= 10.26$$

$$z = \frac{25}{6.8} = 3.676 = \sqrt{(r_1 + r_2')^2 + (X_1 + X_2')^2}$$

Equivalent ckt. ref. to high voltage side



Q. Find the referred values of R_c from HV side.

R_c ref. to (HV) $\quad R_c|_{HV} = R_c|_{LV} \cdot a^2$

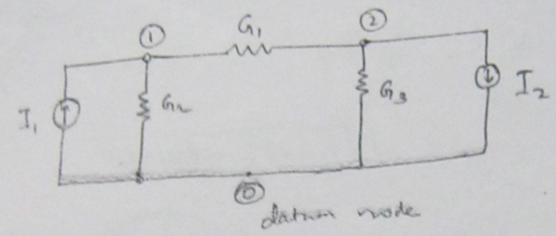
$$= 703 \times \left(\frac{220}{110}\right)^2$$

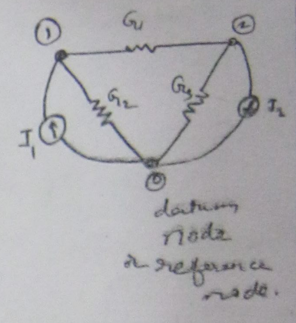
X_m ref. to HV $\quad X_m|_{HV} = X_m|_{LV} \cdot a^2 = 144 \times \left(\frac{220}{110}\right)^2$

(Any book dealing with transformer)
(Electrical Machines)
(Nagrath Kothari).

05/02/2013

Teacher - I





KCL at node 1 } Current source entering node 1 = Sum of currents leaving node 1

$$I_1 = V_1 G_2 + (V_1 - V_2) G_1$$

KCL at node 2 } Current source entering node 2 = sum of currents leaving node 2

$$-I_2 = V_2 G_3 + (V_2 - V_1) G_1$$

$$\begin{bmatrix} I_1 \\ -I_2 \end{bmatrix} = \underbrace{\begin{bmatrix} G_1 + G_2 & -G_1 \\ -G_1 & G_1 + G_3 \end{bmatrix}}_{A} \begin{bmatrix} V_1 \\ V_2 \end{bmatrix}$$

$$\begin{bmatrix} a_{11} & a_{12} \end{bmatrix}$$

Based on second ckt of (01/02/2013)

$$\underbrace{\begin{bmatrix} 7+4-6=5 \\ -7 \\ 6 \end{bmatrix}}_{I} = \underbrace{\begin{bmatrix} 4+3+4=11 & -3 & -4 \\ -3 & 3+1+2=6 & -2 \\ -4 & -2 & 2+2+5=11 \end{bmatrix}}_{G} \underbrace{\begin{bmatrix} V_1 \\ V_2 \\ V_3 \end{bmatrix}}_{V}$$

G ← node admittance matrix.

$$G^{-1} I = G^{-1} G V$$

$$G^{-1} I = V$$

Cramer's rule

$$V_1 = \left(\frac{\begin{vmatrix} 5 & -3 & -4 \\ -7 & 6 & -2 \\ 6 & -2 & 11 \end{vmatrix}}{|G|} \right)$$

$$x = \frac{\Delta x}{\Delta} \qquad V_1 = \frac{5(62) + 3(-77+12) - 4(14-36)}{11(66-4) + 3(-33-8) - 4(6+24)}$$

$$\Delta x = [\;]$$

$$\begin{vmatrix} a_1 & a_2 & a_3 \\ b_1 & b_2 & b_3 \\ c_1 & c_2 & c_3 \end{vmatrix} = \Delta$$

$$= \frac{350 - 195 + 88}{770 - 123 - 120} = \frac{203}{527} = 0.4624$$

$v_2 = \frac{-326}{439} = -0.743V$

$$v_3 = \frac{\begin{vmatrix} 11 & -3 & 5 \\ -3 & 6 & -7 \\ -4 & -2 & 6 \end{vmatrix}}{439} = \frac{254}{439} = 0.579$$

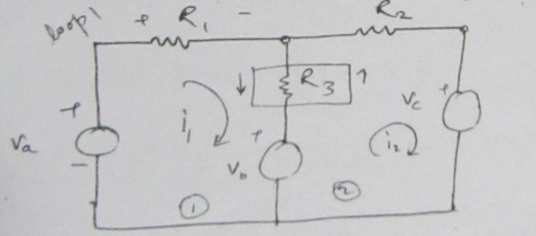
$G = \frac{1}{R}$ conductance

$Y = \frac{1}{\boxed{R+jX}}$ impedance

admittance.

08/02/2013

KVL



KVL ① : $V_a - R_1 i_1 - R_3(i_1 - i_2) - V_b = 0$

KVL ② : $V_b - R_3(i_2 - i_1) - R_2 i_2 - V_c = 0$

$$-R_1 i_1 - R_3(i_1 - i_2) = V_b - V_a$$

$$R_3(i_2 - i_1) + R_2 i_2 = V_b - V_c \quad \text{—— (2)}$$

$$+R_1 i_1 + R_3(i_1 - i_2) = V_a - V_b \quad \text{—— (1)}$$

$$\begin{bmatrix} R_1 + R_3 & -R_3 \\ -R_3 & R_3 + R_2 \end{bmatrix} \begin{bmatrix} i_1 \\ i_2 \end{bmatrix} = \begin{bmatrix} V_a - V_b \\ V_b - V_c \end{bmatrix}$$

~~node~~ loop impedance matrix

$$\begin{bmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{bmatrix}$$

<u>08/02/2013</u>

<u>Class Test - I</u> of <u>Electrical</u>

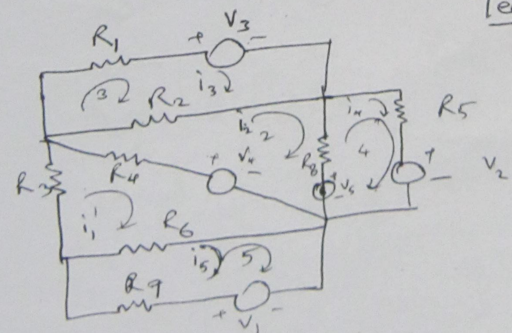
Date : 19-02-2013 Tuesday

Time : 08:00 am to 09:00 am.

Venue :- Survey Hall.

<u>Teacher-I</u>

<u>08/02/2013</u>



$$V_{n\times 1} = Z_{n\times n} I_{n\times 1}$$

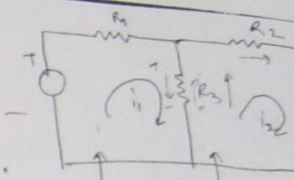
$$
\begin{bmatrix} -V_4 \\ V_4 - V_5 \\ -V_3 \\ V_5 - V_2 \\ V_1 \end{bmatrix}
=
\begin{bmatrix} R_3 + R_4 + R_6 & & & & \\ & & & & \\ & & & & \\ & & & & \\ & & & & \end{bmatrix}
\begin{bmatrix} i_1 \\ i_2 \\ i_3 \\ i_4 \\ i_5 \end{bmatrix}
$$

$$
\begin{bmatrix}
a_{11} & a_{12} & a_{13} & a_{14} & a_{15} \\
a_{21} & a_{22} & a_{23} & a_{24} & a_{25} \\
a_{31} & a_{32} & a_{33} & a_{34} & a_{35} \\
a_{41} & a_{42} & a_{43} & a_{44} & a_{45} \\
a_{51} & a_{52} & a_{53} & a_{54} & \cancel{a_{55}}\, a_{55}
\end{bmatrix}
$$

$$
= \begin{bmatrix}
R_3 + R_4 + R_6 & -R_4 & 0 & 0 & -R_6 \\
-R_4 & R_2 + R_4 + R_8 & -R_2 & -R_8 & 0 \\
0 & -R_2 & R_1 + R_2 & 0 & 0 \\
0 & -R_8 & 0 & R_5 + R_8 & 0 \\
-R_6 & 0 & 0 & 0 & R_6 + R_7
\end{bmatrix}
$$

12/02/2013

Q.



Loop eq.

$i_1 \downarrow \uparrow i_2$

$(i_1 - i_2)$

$-(i_2 - i_1)R_3 -$

$(i_1 - i_2)R_3 -$

$V_1 = i_1 R_1$

$V_2 = -(i$

$V_1 = i_1(R$

$V_2 = +$

$-V_2 =$

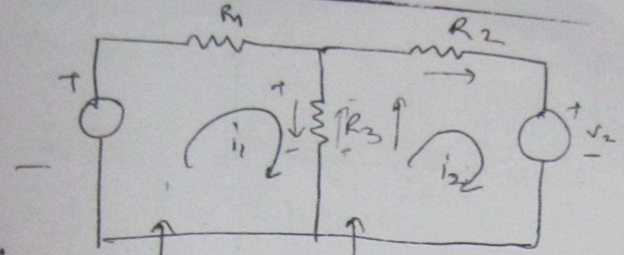
Sum of all the voltage sources along

$$\begin{bmatrix} V_1 \\ -V_2 \end{bmatrix} =$$

similarly for i_2

12/02/2013

Q.



$V_1 - i_1R_1 + (i_2 - i_1)R_3 = 0$

Loop eq. : KVL : - - - $V_1 - i_1R_1 - (i_1 - i_2)R_3 = 0$

$i_1 \downarrow \uparrow i_2$

$(i_1 - i_2)\downarrow$ $\uparrow(i_2 - i_1)$

$-(i_2 - i_1)R_3 - i_2R_2 - V_2 = 0.$

$(i_1 - i_2)R_3 - i_2R_2 - V_2 = 0.$

$V_1 = i_1R_1 + (i_1 - i_2)R_3$

$V_2 = -(i_2 - i_1)R_3 - i_2R_2$

$V_1 = i_1(R_1 + R_3) - R_3 i_2$

$V_2 = +R_3 i_1 - i_2(R_2 + R_3)$

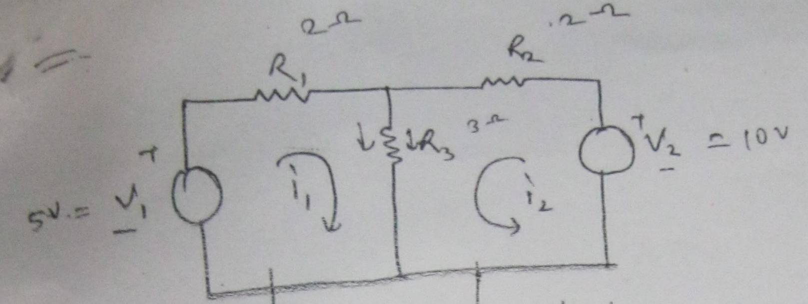
$-V_2 = -i_1R_3 + i_2(R_2 + R_3).$

Sum of all the voltage sources along the dir of i_1 with proper polarity

$$\begin{bmatrix} V_1 \\ -V_2 \end{bmatrix} = \underbrace{\begin{bmatrix} R_1 + R_3 & -R_3 \\ -R_3 & R_2 + R_3 \end{bmatrix}}_{Z} \underbrace{\begin{bmatrix} i_1 \\ i_2 \end{bmatrix}}_{I}$$

similarly for i_2

$[V] = [Z][I]$



Loop eq:

$KVL: V_2 - i_2R_2 - (i_2+i_1)R_3 = 0$

Loop eq:

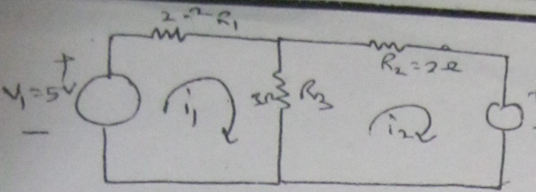
$KVL: V_1 - i_1R_1 - (i_1+i_2)R_3 = 0$

$V_1 = i_1R_1 + (i_1+i_2)R_3 = i_1(R_1+R_3)+i_2R_3$

$V_2 = i_2R_2 + (i_1+i_2)R_3 = i_1R_3 + i_2(R_2+R_3)$

$5 - i_1 2 - (i_1+i_2)3 = 0$

$10 - i_2 2 - (i_1+i_2)3 = 0$



$$5 - i_1 2 - (i_1 - i_2)3 = 0$$

$$-(i_2 - i_1)3 - i_2 2 - 10 = 0$$

$$\begin{bmatrix} 5 \\ -10 \end{bmatrix} = \begin{bmatrix} 5 & -3 \\ -3 & 5 \end{bmatrix} \begin{bmatrix} i_1 \\ i_2 \end{bmatrix}$$

$$i_1 = \frac{\begin{vmatrix} 5 & -3 \\ -10 & 5 \end{vmatrix}}{\begin{vmatrix} 5 & -3 \\ -3 & 5 \end{vmatrix}} = -\frac{5}{16}$$

$$i_2 = \frac{\begin{vmatrix} 5 & 5 \\ -3 & -10 \end{vmatrix}}{16} = -\frac{35}{16}.$$

$$\begin{bmatrix} 5 \\ 10 \end{bmatrix} = \begin{bmatrix} 5 & 3 \\ 3 & 5 \end{bmatrix} \begin{bmatrix} i_1 \\ i_2 \end{bmatrix}$$

$$i_1 = \frac{\begin{vmatrix} 5 & 3 \\ 10 & 5 \end{vmatrix}}{\begin{vmatrix} 5 & 3 \\ 3 & 5 \end{vmatrix}} = -\frac{5}{16}$$

$$i_2 = \frac{\begin{vmatrix} 5 & 5 \\ 3 & 10 \end{vmatrix}}{\begin{vmatrix} 5 & 3 \\ 3 & 5 \end{vmatrix}} = \frac{35}{16}.$$