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IIT(BHU) VARANASI

STUDENTS' NOTES

TOPIC-ELECTRICAL-IV

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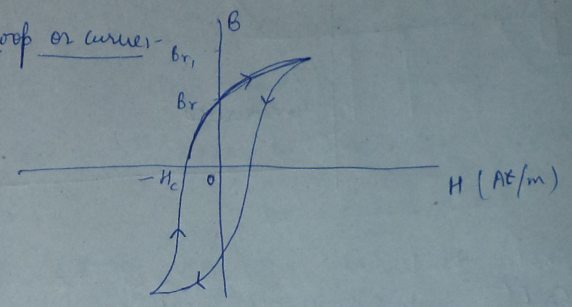
Electrical

Rotary Converters :-

Role of frequency in minimizing the size of transformer and size of machinaries.

Hysteris loop or curves-



Ferrite

Area of loop represents loss of electrical energy density per cycle.

losses in ferromagnetic material

① Eddy current loss

$$P_e = K t^2 f^2 B_{max}^2 \quad W/m^3$$

$t \rightarrow$ thickness

$f \rightarrow$ frequency

$B_{max} \rightarrow$ Maximum flux density T or wb/m^2

② Hysterisis loss

$$P_h = \eta f B_{max}^x$$

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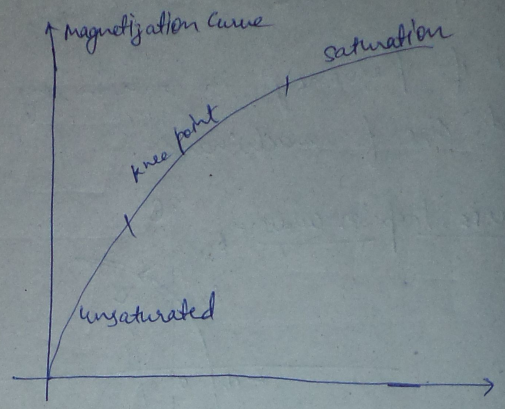
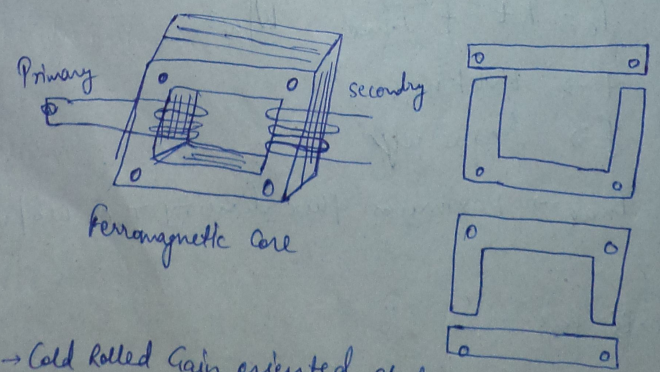
x is 1.2 to 1.8 ← material dependent quantity



$$E = \frac{1}{2}\epsilon_0 E^2 = \frac{1}{2} 8.85 \times 10^{-12} \times (10^3)^2$$

$$\Rightarrow \frac{\frac{1}{2} \times 8.85 \times 10^{-12} \times (10^3)^2}{\frac{1}{2} \times 4\pi \times 10^{-7} \times (10^3)^2}$$

Transformer :-



C.R.G.O.S → Cold Rolled Gain oriented steel Sheet

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The ferromagnetic core of transformer made by using C.R.G.O.S. material. For preparing the core of transformer care is taken that continuous air gap is not there

several no. of turns of Cu wire are put in one of the limb of transformer. This coil is connected to A.C. supply and is referd as primary winding. Similar Coiling is done on another limb of transformer.

A coil of several no. of turns is inserted to which a load is connected. This is secondry winding. The copper wire which is used in winding is known as S.W.G. wire or (standard wire gauge) or It is ~~made~~ used in strip conductors. These conductors are having insulations on its surface so that when copper wires are placed side by side for making a coil the electrical short circuit can be avoided. In S.W.G. wire the electrical insulation is in form of coating or varnish. These conductors are having circular cross-section. when rectangular wires are used then insulation is provided using paper tape, wrapped along the length of conductor.

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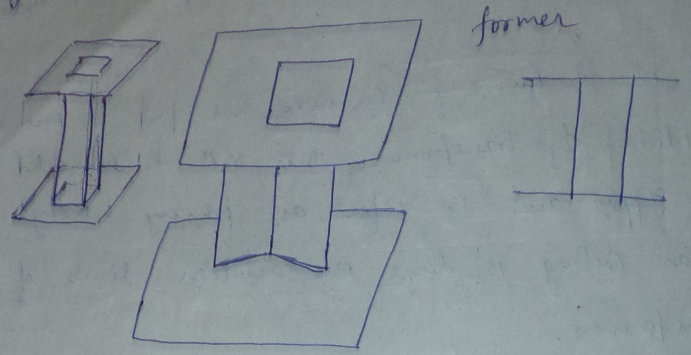
The sheet metal stampings are having holes at different place so that when core is prepared, the core is tightened using insulated nuts and bolts, when



ferromagnetic material is subjected to alternate magnetization. The core is having or each and every steel metal stamping has a tendency to change microscopically (change in dimension).

The phenomena of microscopic changes in ferromagnetic material subjected to alternating magnetization is called magneto restriction.

The core is prepared using insulated stampings of C.R.G.O.S.

The humming noise coming out from electrical machinary or transformer referred as magneto restriction. This noise is reduced by tighting the core.

The sheet metal is used for preparation of core of electrical machine to reduce eddy current losses.

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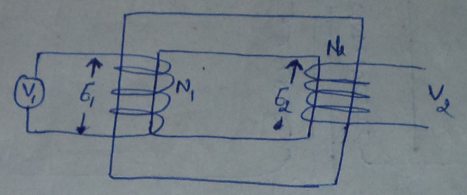

$$e_1 = -N_1 \frac{d\phi}{dt}$$

acc^n to faraday law

(EMF) eq^n)

$$E_1 = 4.44 f \cdot \phi_{max} \cdot N_1$$

$$E_2 = 4.44 f \phi_{max} N_2$$

$$V_1 = E_1 + I_1 (r_1 + jX_1)$$

$$V_1 \cong E_1$$

$$V_2 = E_2 - I_2 (r_2 + jX_2)$$

terminal voltages are V_1 & V_2

EMF's are E_1, E_2

X_1 :- leakage reactance of primary coil.

r_1 :- resistance of primary coil

X_2 :- for secondary

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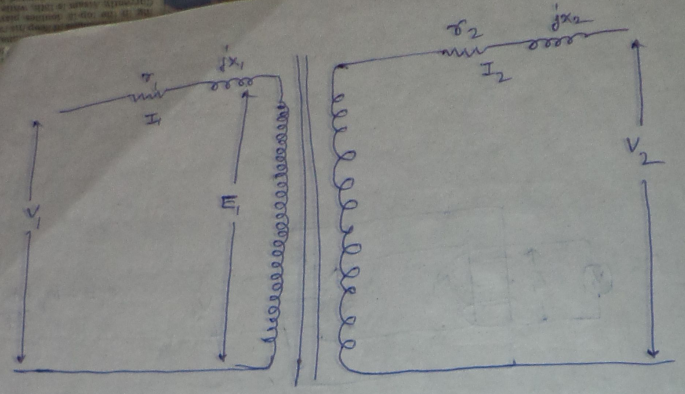

$$\bar{V}_1 = \bar{E}_1 + I_1 (r_1 + jx_1)$$

If $I_1 \to 0$

$$\bar{V}_1 \simeq \bar{E}_1$$

$$\bar{V}_2 = \bar{E}_2 - \bar{I}_2 (r_2 + jx_2)$$

If $I_2 \to 0$

$$\bar{V}_2 = \bar{E}_2$$

$$\bar{V}_1 \simeq E_1 = 4.44 \cdot f \cdot \phi_{max} \cdot N_1$$

$$\bar{V}_2 \simeq E_2 = 4.44 f \phi_{max} N_2$$

$$\frac{V_1}{V_2} = \frac{E_1}{E_2} = \frac{N_1}{N_2}$$

The rating of transformer is given in terms of VA (voltage Ampere) or kVA (kilo voltage Ampere)

Transformer is transferring electrical energy from high voltage to low voltage or vice-versa.

If I_1 secondary be zero

Q. In 1.5 determi

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If I_1 is primary current and I_2 is secondary current and assuming losses to be zero.

then $V_1 I_1 = V_2 I_2$

(Input power = Output power)

$$\frac{V_1}{V_2} = \frac{I_2}{I_1}$$

$$\therefore \frac{V_1}{V_2} = \frac{E_1}{E_2} = \frac{N_1}{N_2} = \frac{I_2}{I_1}$$

Q. In 1.5 kVA 50 Hz transformer 220 V | 100 V determine the rated current I_1 & I_2 ?

$$\frac{I_2}{I_1} = \frac{V_1}{V_2} = \frac{220}{100} = \frac{22}{10} = 2.2$$

$$V_1 I_1 = 1.5 \times 10^3$$

$$220 \times I_1 = 1.5 \times 10^3$$

$$I_1 = \frac{1.5 \times 1000}{220} = 6.82\ A$$

$$V_2 I_2 = 1.5 \times 10^3$$

$$100 \times I_2 = 1.5 \times 10^3$$

$$I_2 = 15\ A$$

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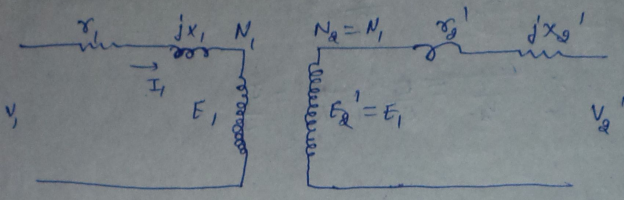
Referred Values :-

The circuit shown here are at different voltages, if I can make $N_2 = N_1$ such that $E_2 = E_1$ then the magnetic coupling part of ideal transformer can be avoided.



The dashed quantities r_2', x_2', I_2', N_2' refers to the secondary quantities referred to primary side. In this process the losses should not change.

$$I_2^2 r_2 = I_2'^2 r_2'$$

But $I_2' \simeq I_1$

The referred value of secondary resistance ref. to primary

$$r_2' = \left(\frac{I_2}{I_1}\right)^2 r_2 = a^2 r_2$$

Similarly, we can write $I_2^2 x_2 = I_2'^2 x_2'$

$$x_2' = \left(\frac{I_2}{I_1}\right)^2 x_2 \qquad (I_2' \cong I_1)$$

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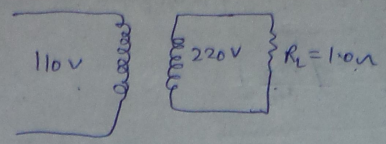
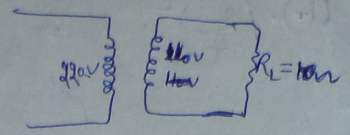
In an ideal transformer of rating 220 V/110 V when obtained the referred values from primary side. when load resistance of 1 Ω is connected on 110 V/220 V side

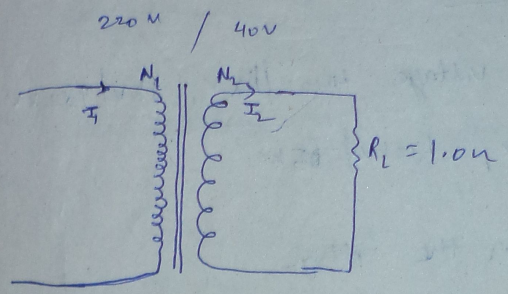


R_L' referred to 110 V side $= 1.0\left(\frac{110}{220}\right)^2$



R_L'' referred to 220 V side $= 1.0 \times \left(\frac{220\,V}{110}\right)^2$

Referred values :-



Ideal transformer (no loss)

Let referred value of $R_L = 1.0\,\Omega$ referred from primary side. losses should remain same, or

$$I_1^2 R_L' = I_2^2 R_L$$

$$\frac{V_1}{V_2} = \frac{N_1}{N_2} = \frac{I_2}{I_1} = \text{a transformation Ratio}$$

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Referred values $R_L' = R_L \left(\frac{N_2}{N_1}\right)^2$

$$R_L' = a^2 R_L$$

If $V_1/V_2 = 220V/40V$

$$a = \left(\frac{220}{40}\right)$$

$$R_L' = (100) \cdot \left(\frac{220}{40}\right)^2$$

Assign

Role of mining in the growth of the society:-

Use of transformer:-

① Stepping up the voltage 440V/11kV, 11kV/132kV, 132kV/400kV, 400kV/765kV

② Stepping down the voltage

765kV/400kV, 400kV/132kV, 132kV/11kV, 11kV/440V.

③ Maximum power transfered

In a DC circuit when internal resistance of circuit match with load resistance, then max. power transfer ~~takes the~~ place. In AC circuit load impedance is complex conjugate of internal impedance then

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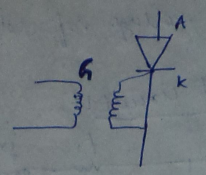
max. power transfer takes place.

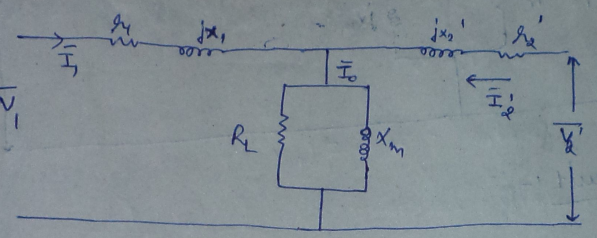
Input output transformer - Impedance matching.

4) SCR → Semiconductor controlled Rectifier

Pulse transformer



Equivalent Circuit :-



This is the exact equivalent circuit of two winding transformer.

r_1 :- primary winding a.c. resistance

r_2 :- secondry —"— .

$\bar{V}_1$: primary input voltage

$\bar{I}_1$:- primary input current

r_1 :- primary winding AC resistance

X_1 :- —"— leakage rectance

R_c :- core loss resistance

X_m :- magnetizing reactance

X_2' :- secondry winding leakage rectance refered to primary side.

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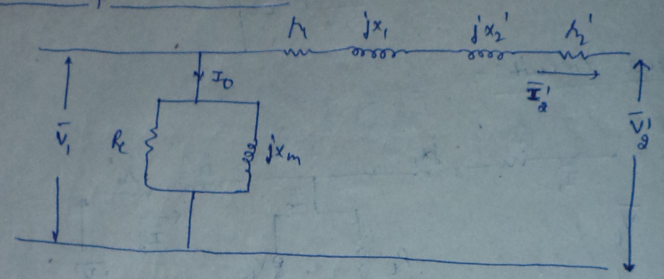
$\bar{I}_1$:- primary input current

$\bar{I}_0$:- no load current

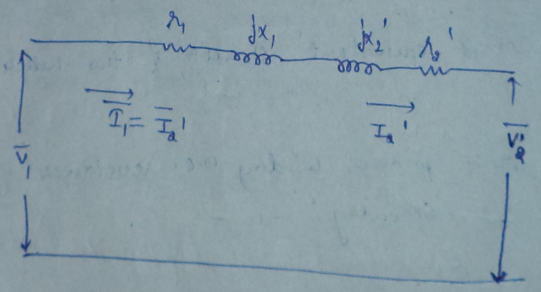
I_2' :- Secondry winding current referred to primary side.

V_2' :- Secondry voltage referred to primary side.

Approximate equivalent circuit :-



Caffs circuit :-



Determination of equivalent circuit parameters :-

1) open circuit test (conducted from low voltage side)

2) Short circuit test (— " — high — " —)

1.0 kVA

220V | 40V

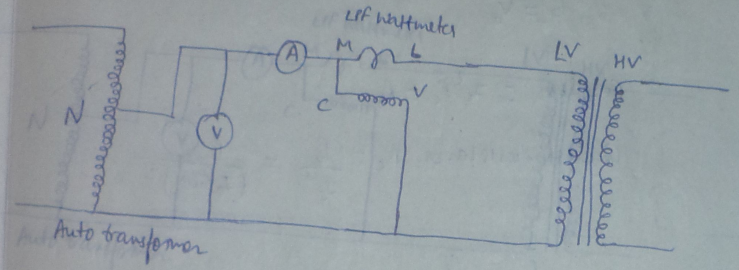
$\frac{1000}{220} < \frac{1000}{40}$

The short circuit test is normal conducted from high voltage side.

because high voltage rated current is less. Instruments to measure high current and power at higher current are not required.

(1) Open circuit Test :-

(Conducted from low voltage side)

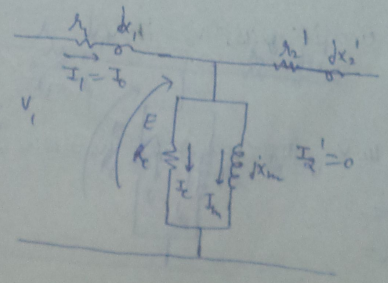


V_0 = V_{rated} voltage

I_0 = around 5 % of full load current

W_0 = no load power, W

Equivalent circuit :



Core loss $P_0 = W_0 - I_0^2 r_1 \simeq W_0$

No load power factor : $\cos\phi = \frac{P_0}{V_0 I_0}$

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220V | 40V

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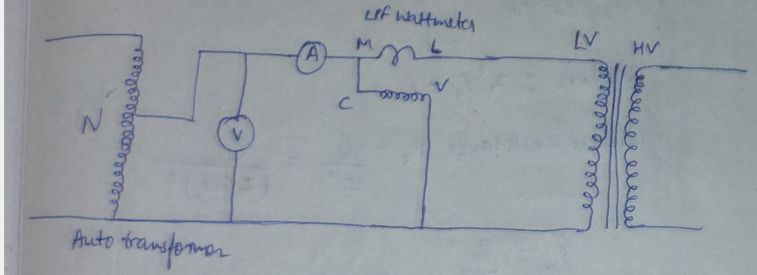

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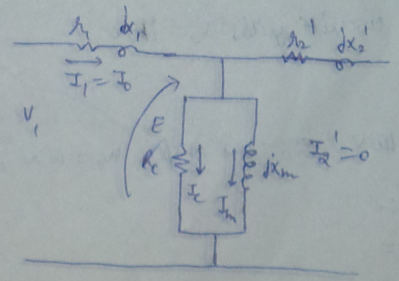

Core loss $P_0 = W_0 - I_0^2 r_1 \simeq W_0$

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

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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 or

$$I_c = I_0 \cos\phi_0 \quad \text{(active current)}$$

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

$$\bar{E}_1 = \bar{V}_0 - I_0(r_1 + jx_1)$$

if r_1 & x_1 are unknown, then ignore $I_0^2 r_1$ & $I_0(r_1+jx_1)$

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

Coreloss $= I_c^2 R_c = P_0$

Coreloss resistance $R_c = \dfrac{P_0}{I_c^2} = \dfrac{P_0}{(I_0\cos\phi_0)^2}$

$$\bar{I}_m = \frac{\bar{E}_1}{jX_m}$$ Magnetizing Reactance

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

In a 100V/200V, 50hz. 1.5kV The open circuit yields $V_0 = 110V$

Q/ $V_0 = 110V$, $I_0 = 0.8$ Amp, $W_0 = 18W$, $R_c = ?$, $X_m = ?$, $\cos\phi_0 =$

$I_c =$

$I_m =$

Sol: $R_c = \dfrac{18}{(0.16)^2} = 703\,\Omega$ $\quad X_m = \left(110/0.76\right) = 144.7\,\Omega$

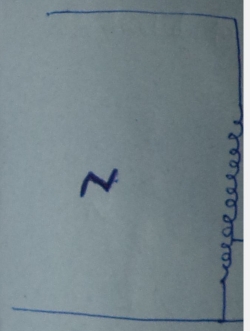
$\cos\phi_0 = 0.20$

$\sin\phi_0 = 0.9$

$I_c = 0.16$

$I_m = 0$

(2) Short Circuit



$I_{sc} =$

$Y_{sc} =$

$W_{sc} =$

Core loss

Short circuit

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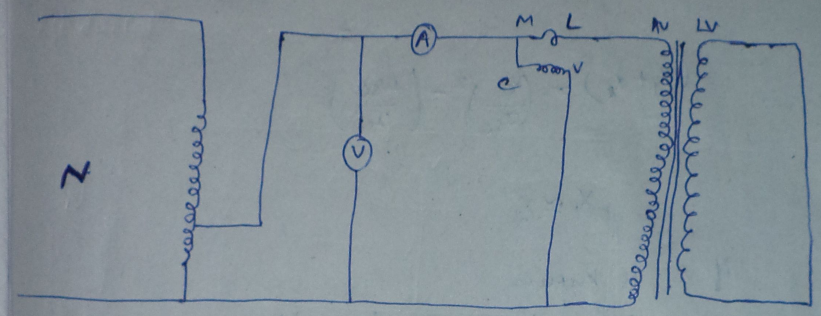
$\cos\phi_0 = 0.2045$

$\sin\phi_0 = 0.95$ Amp.

$I_c = 0.16$ Amp $= 0.8 \times 0.2045$

$I_m = 0.76$ Amp $= 0.8 \times 0.95$

(2) Short Circuit test:-

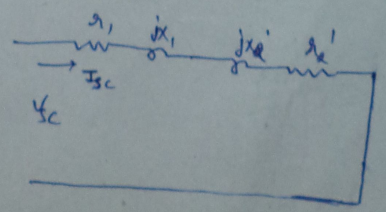


I_{sc} = Rated current

V_{sc} = low voltage

W_{sc} = (Rated Copper loss)

Core loss are assumed to be zero.



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

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Copper loss is active loss

$$W_{sc} = (r_1 + r_2')I_{sc}^2$$

$$\bar{I}_{sc} = I_{sc}\cos\phi_{sc} + jI_{sc}\sin\phi_{sc}$$

Impedence of circuit $z = \frac{V_{sc}}{I_{sc}} = (r_1 + r_2') + j(x_1 + x_2')$

$$= \sqrt{(r_1 + r_2')^2 + (x_1 + x_2')^2}$$

$$=$$

$$(x_1 + x_2') = \left(\frac{V_{sc}}{I_{sc}}\right)^2 - \left(\frac{W_{sc}}{I_{sc}^2}\right)$$

$$x_1 \simeq x_2'$$

If r_1 is known

r_2' is known else $(r_1 = r_2')$

Q: In a short circuit test I_{sc} is 6.8 Amp and V_{sc} is 25 V, $W_{sc} = 150$ W. Calculate $r_1 + r_2'$ & $x_1 + x_2'$

Sol:

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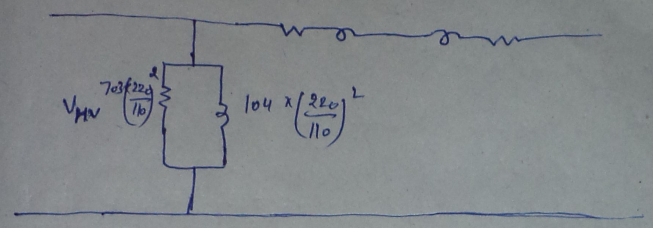
Equivalent circuit ref. to HV side.



Find the referred values of R_c from HV side

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

$= R_c\big|_{LV} \left(\frac{220}{110}\right)^2$

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

X_m refers to HV side $X_m\big|_{HV} = X_m\big|_{LV} a^2$

$= 104 \times \left(\frac{220}{110}\right)^2$

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