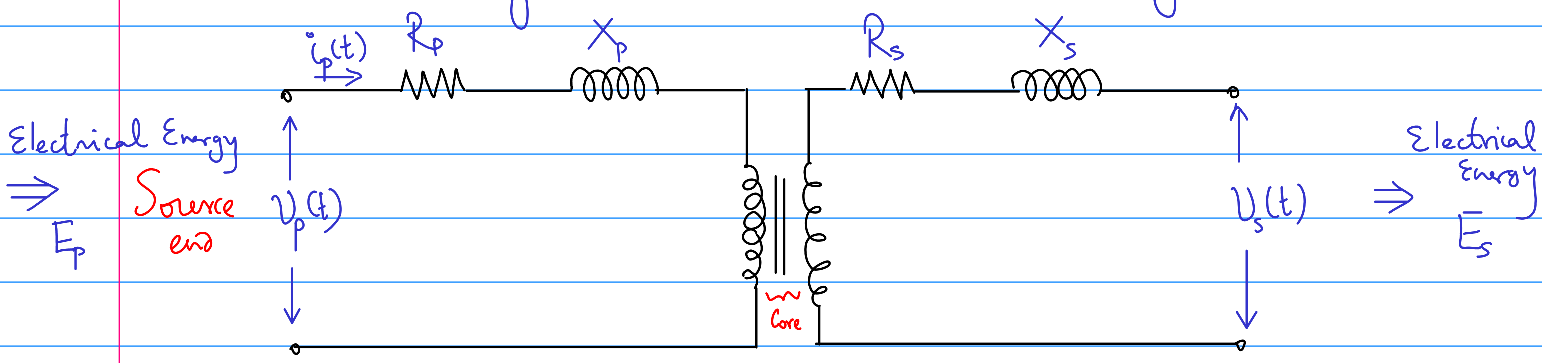
02.06.2022

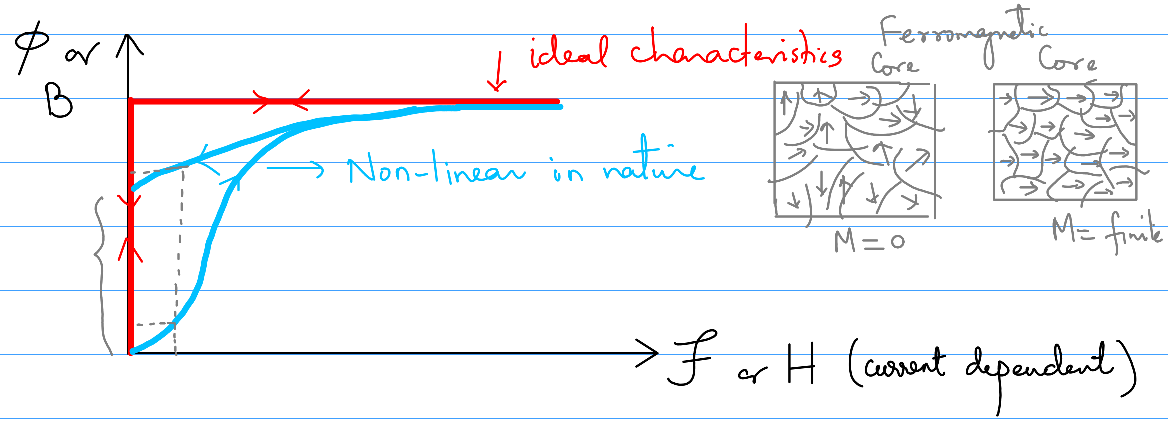
Equivalent ckt. model of a Real Transformer

1) Winding losses : a) Resistive heating b) Flux leakage.



2) Core-losses : Losses associated with magnetization of the core and the resistive heating of the core.

– Magnetization of the core of the transformer is non-linear in nature.



The primary current $i_p(t)$ due to primary voltage $V_p(t)$ is responsible for the excitation of the magnetic core in the transformer.

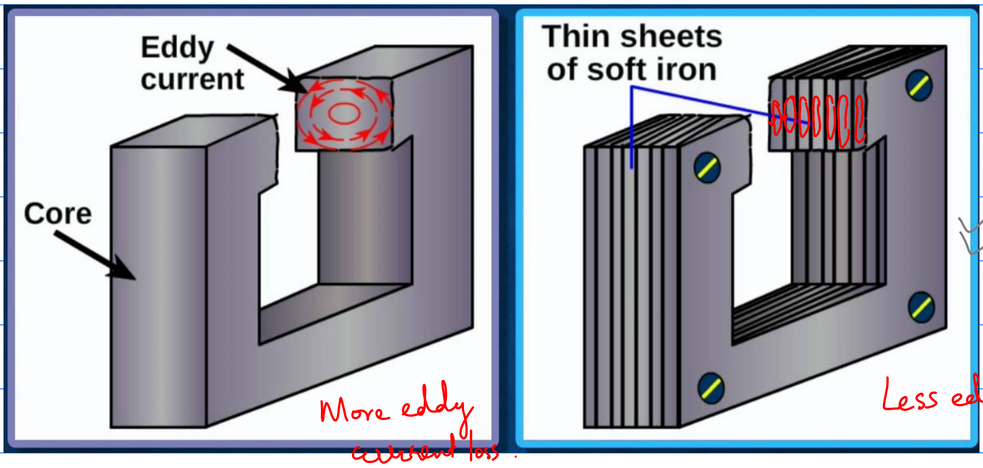
$$i_p(t) = \text{Excitation current in the core.}$$

$$\underbrace{i_p(t)}_{} = \underbrace{i_m(t)}_{\text{}} + \underbrace{i_{h+e}(t)}_{}$$

Magnetization current which is the current required to produce the flux in the transformer core

Core-loss current which the current required to make up for hysteresis and eddy current losses.

- Hysteresis: This is basically associated with the rearrangement of the magnetic domains in the core of the transformer
- Eddy current: This is resistive heating losses in the core of the transformer



More eddy current loss.

Less eddy current loss

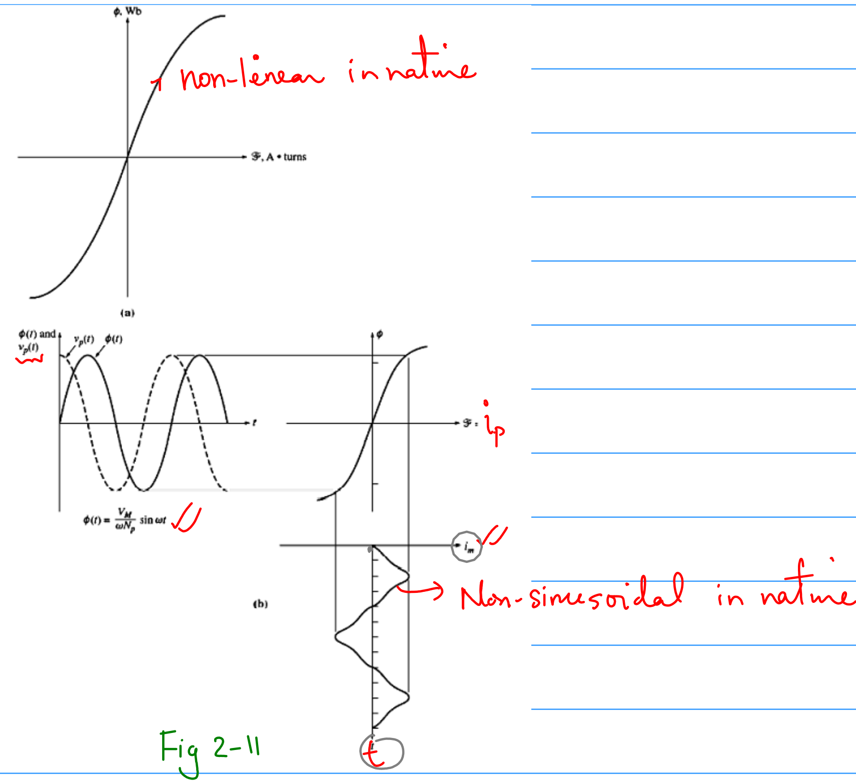


Fig 2-11

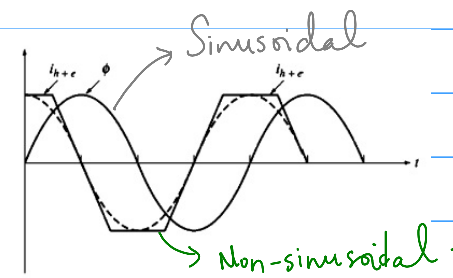


FIGURE 2–12
The core-loss current in a transformer.

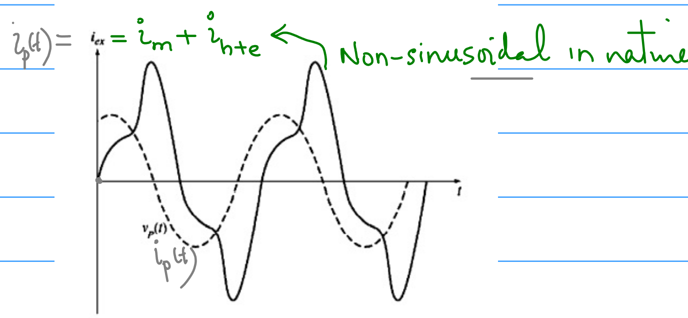


Fig 2-12

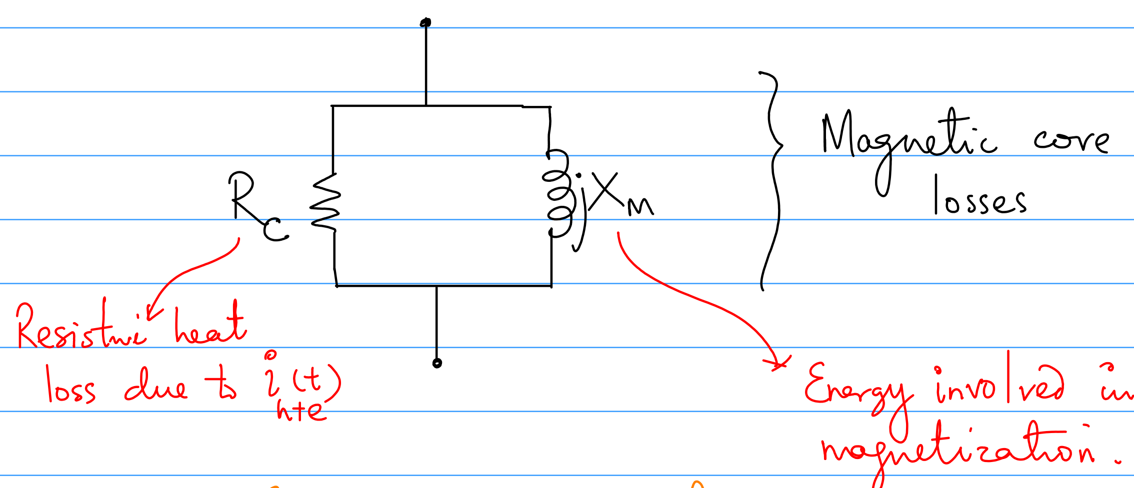
1.) Magnetization current $i_m(t)$ is typically proportional to the voltage applied to primary $v_p(t)$, however, it lags behind the $v_p(t)$ by $90°$.

Therefore, we can safely model this loss of electrical energy in magnetization of the core as a reactance X_m connected across the primary voltage source.

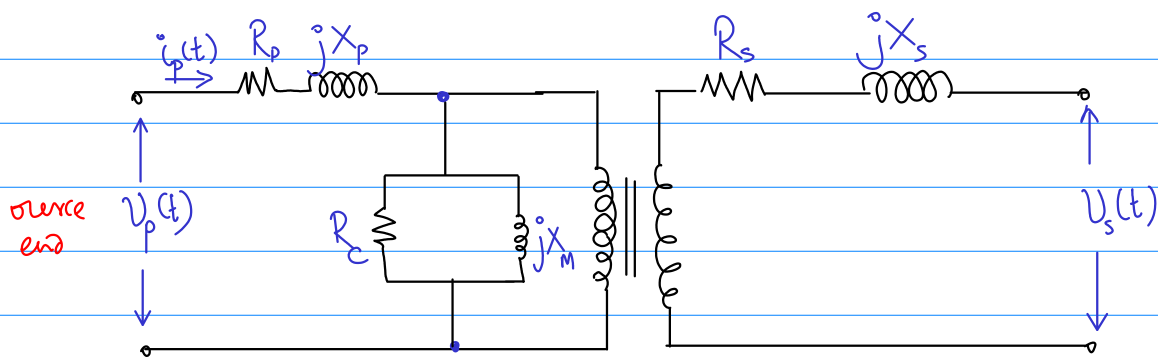
where in $\quad X_m = \omega \underbrace{L_m}_{\text{Inductance}}$

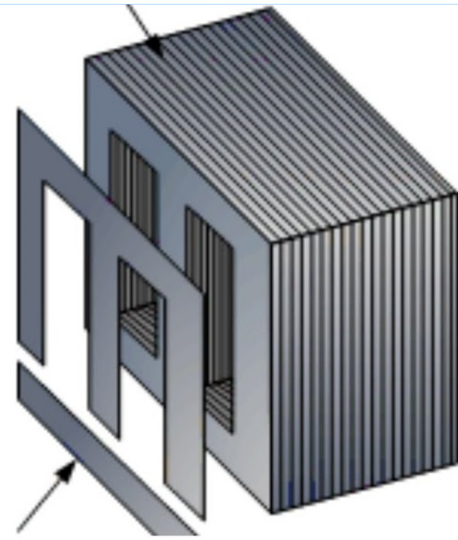
2) The core loss current $i_{hte}(t)$ is a current proportional to the $v_p(t)$ and it is in phase with the $v_p(t)$. Therefore, this core loss current is model as a resistance (core resistance).

Finally, we have ckt. elements corresponding to core losses as excitation branch.



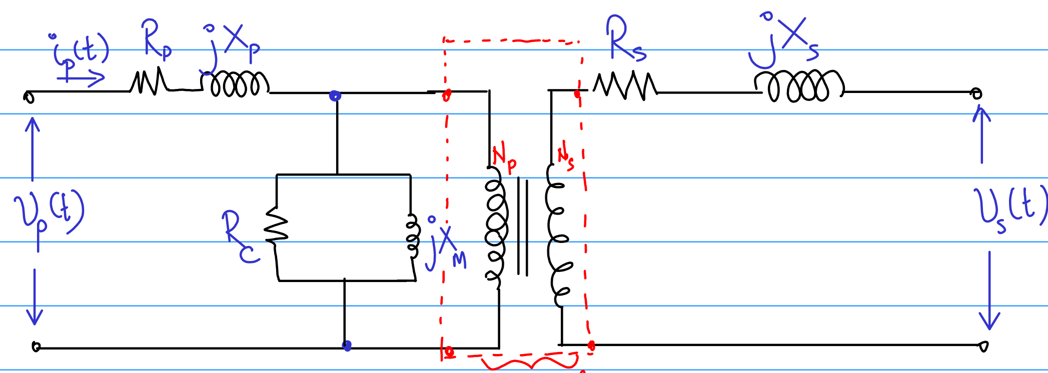
Exact circuit model of a real transformer.





Real Transformer

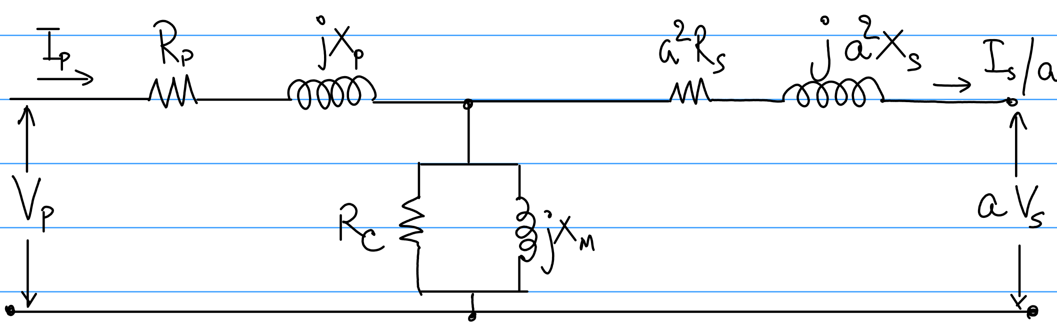
equivalent ckt. model.



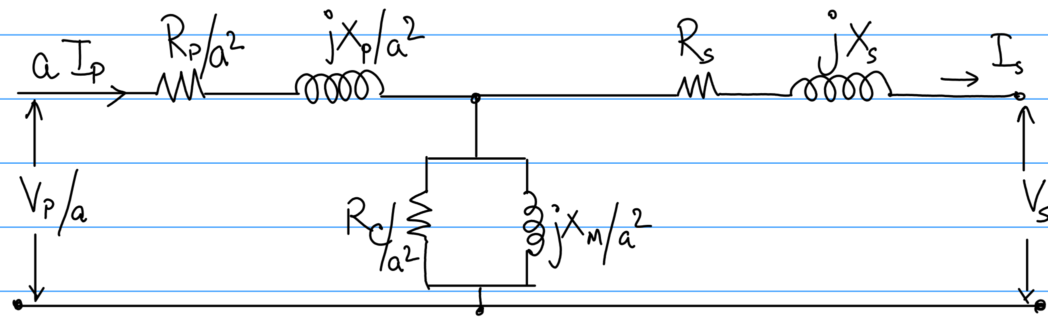
For analysis of the equivalent ckt. model of a real tranformer, we follow the steps below :

(i) Refer to the primary voltage level.

$$\frac{V_p}{V_s} = a \quad ; \quad \frac{I_p}{I_s} = \frac{1}{a} \quad ; \quad Z_p = a^2 Z_s$$

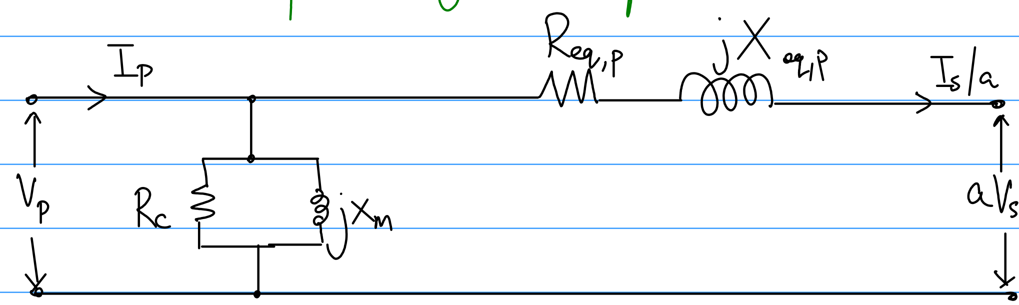


(ii) Refer to the secondary voltage level.



Approximate equivalent ckt. model of a real transformer

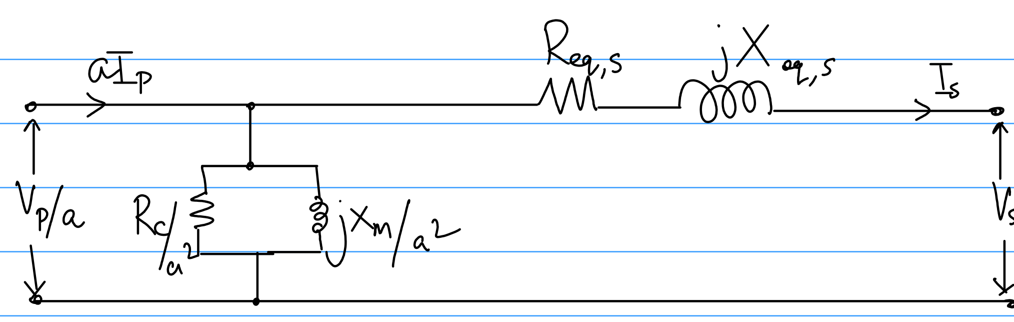
(i) Refer to the primary voltage level.



where $R_{eq,p} = R_p + a^2 R_s$

$$X_{eq,p} = X_p + a^2 X_s$$

(ii) Refer to the secondary voltage level.



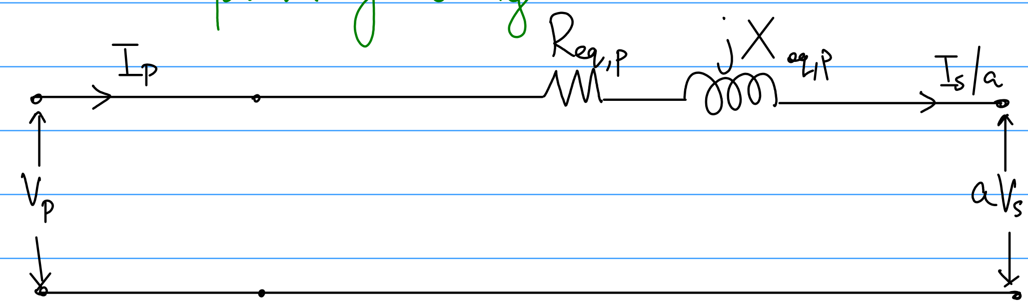
where, $$R_{eq,s} = \frac{R_p}{a^2} + R_s$$

$$X_{eq,s} = \frac{X_p}{a^2} + X_s$$

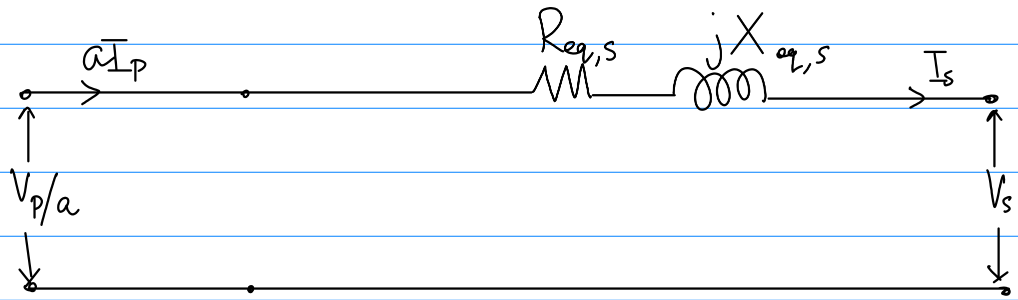
In designing the transformer, if the core is designed such that the hysteresis & eddy currents are minimum.

$\Rightarrow$ We may neglect the excitation branch assuming the i_{exc} to be very small as compared to primary/secondary current.

i) Refer to the primary voltage level.



(ii) Refer to the secondary voltage level.



Since we have modeled the real transformer with corresponding circuit elements, how do we determine the values of these circuit elements?

Is there any experimental test to determine $R_p, R_s, X_p, X_s, R_c, X_m$?