ECE 330
POWER CIRCUITS AND ELECTROMECHANICS

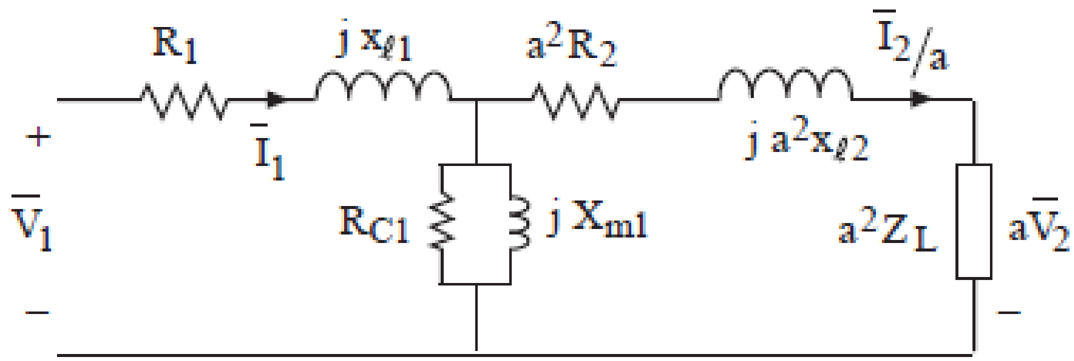
LECTURE 13
TRANSFORMERS (3)

Acknowledgment-These handouts and lecture notes given in class are based on material from Prof. Peter Sauer's ECE 330 lecture notes. Some slides are taken from Ali Bazi's presentations

Disclaimer- These handouts only provide highlights and should not be used to replace the course textbook.

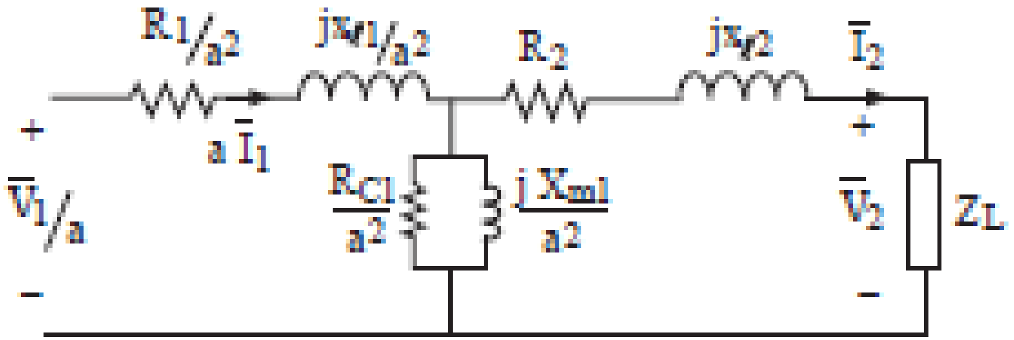
SINUSOIDAL EXCITATION

- When a transformer is excited with sinusoidal sources, the equivalent circuit becomes:



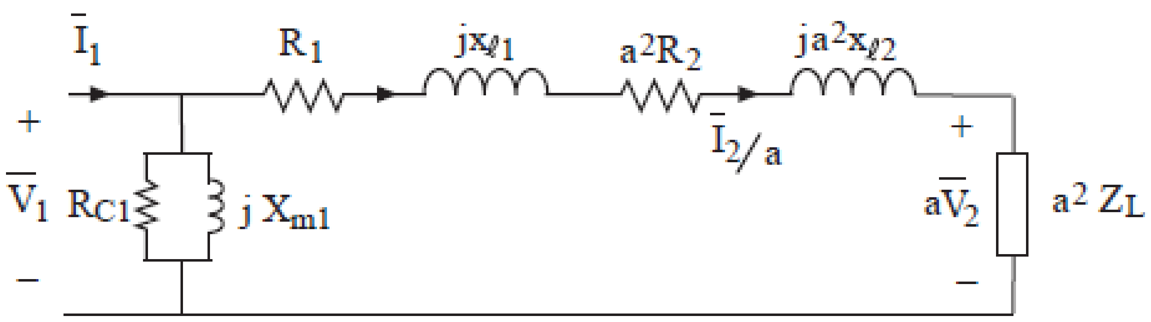
APPROXIMATE CIRCUIT

- If we desire a similar equivalent circuit with all quantities referred to winding 2, it can be easily deduced. The impedances are divided by a^2 , voltage is divided by a and the current is multiplied by a.



APPROXIMATE CIRCUIT

- An approximate circuit can be drawn with reasonable assumptions.
- Since R_c and X_m >> other impedances, they can be moved to the front, next to V_1 or V_1/a.



ECE ILLINOIS

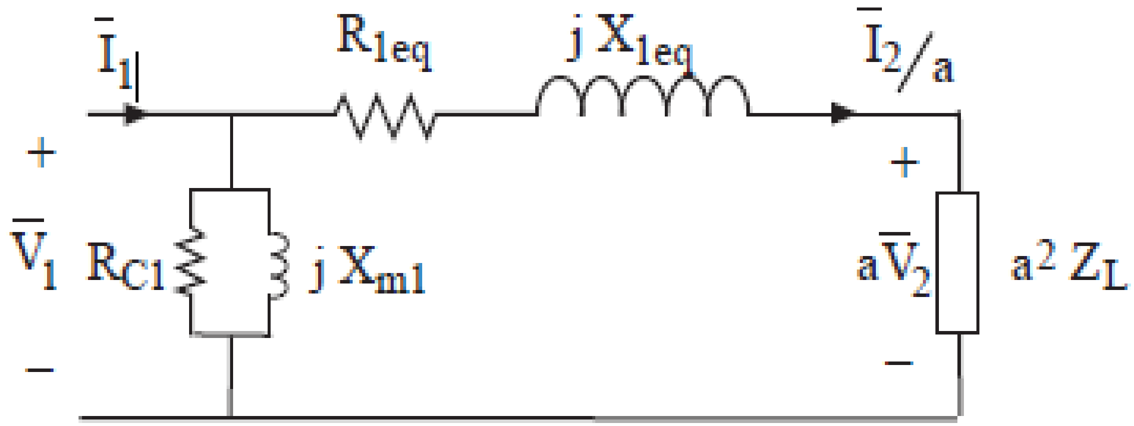
ILLINOIS

APPROXIMATE CIRCUIT

- Series resistances and reactances can then be lumped together.

$$R_{1eq} = R_1 + a^2 R_2$$

$$X_{1eq} = X_{\ell 1} + a^2 X_{\ell 2}$$

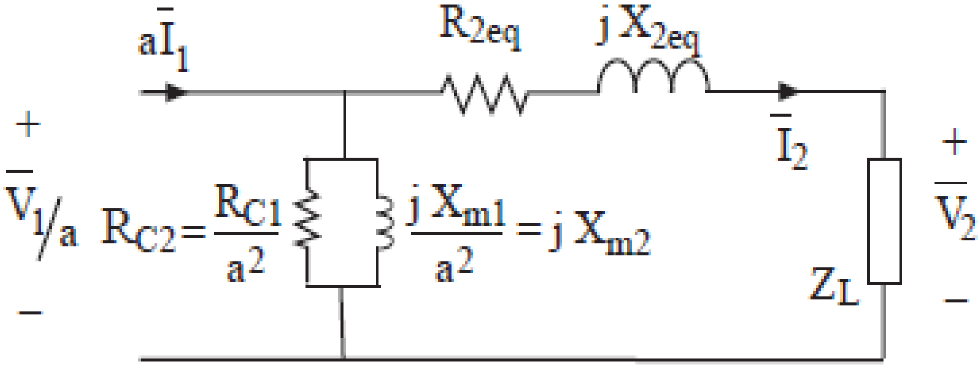


APPROXIMATE CIRCUIT

- The equivalent impedances referred to secondary side:

$$R_{2,eq} = \frac{R_1}{a^2} + R_2 = \frac{R_{1,eq}}{a^2}$$

$$X_{2,eq} = \frac{X_{l1}}{a^2} + X_{l2} = \frac{X_{1,eq}}{a^2}$$

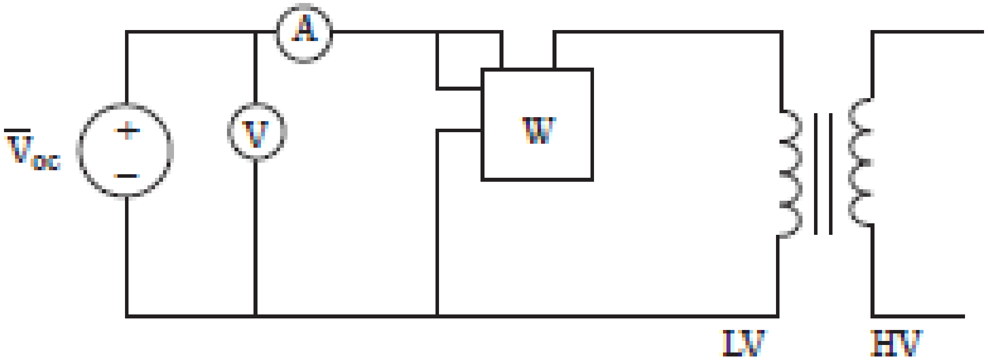


TRANSFORMER TESTING

Source: fivestarhv.com

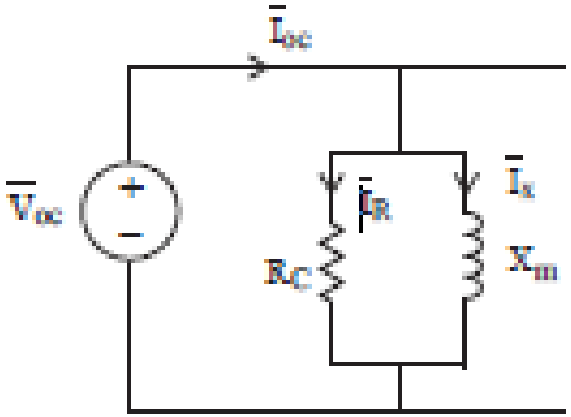
OPEN-CIRCUIT TEST

- The open circuit test measures the magnetizing reactance X_m and R_c. Because of the ready availability of a low-voltage source, this test is performed with all instrumentation on the LV side with the HV side being open-circuited



OPEN-CIRCUIT TEST

Rated voltage is applied to the LV side. The wattmeter has a current coil in series and a voltage coil in parallel to the source. From the approximate equivalent circuit, the equivalent circuit for the open circuit test reduces to that shown in Figure



OPEN-CIRCUIT TEST

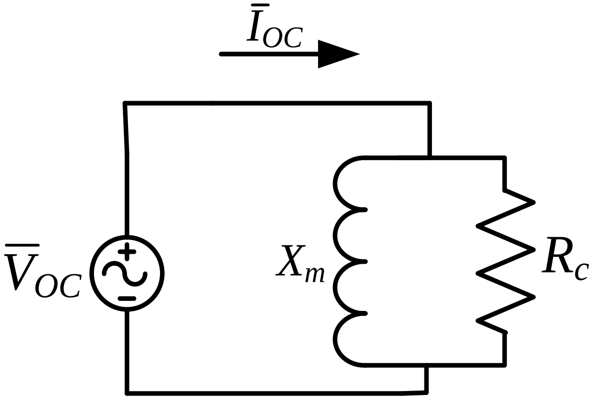
- The open circuit test is used to find R_c // X_m and thus R_c and X_m. These values are found with respect to the low-voltage side.

$$R_c = \frac{V_{OC}^2}{P_{OC}}$$

$$X_m = \frac{V_{OC}^2}{Q_{OC}}$$

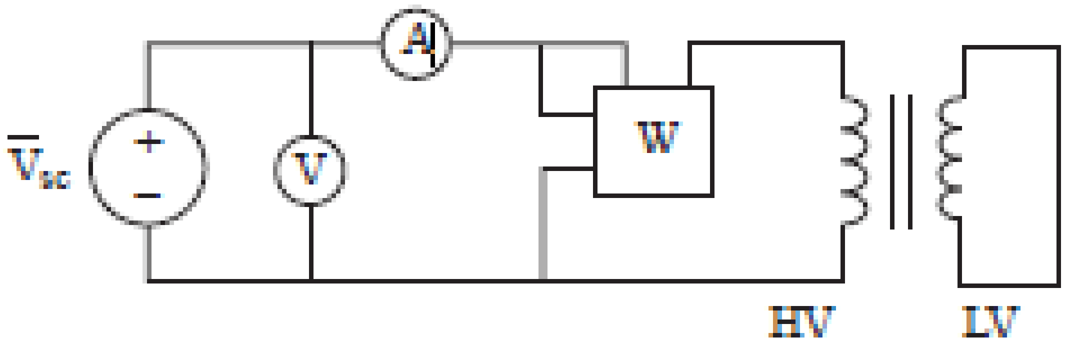
$$or, I_{Rc} = \frac{V_{OC}}{R_c}, \qquad I_{Xm} = \sqrt{I_{OC}^2 - I_{Rc}^2}$$

$$X_m = \frac{V_{OC}}{I_{Xm}}$$



SHORT-CIRCUIT TEST

In the short-circuit test, one of the windings is short-circuited and *rated current* is made to flow in the windings by applying an appropriate voltage. Since current on the HV side is smaller, all the instrumentation is on the HV side



SHORT-CIRCUIT TEST

- Short one side and apply rated current. The high-voltage side is used to apply the rated current as it is lower and safer.

- The applied voltage should be around 5-10% of the rated voltage due to the short circuit.

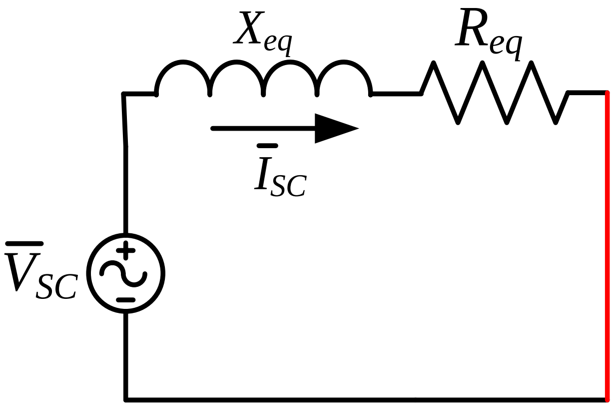
- R_c and X_m are ignored as they are very large in parallel with R_{eq} and X_{eq}.

SHORT-CIRCUIT TEST

- The short circuit test is used to find $R_{eq} + jX_{eq}$ and thus R_{eq} and X_{eq}. These values are found with respect to the high-voltage side.

$$R_{eq} = \frac{P_{SC}}{I_{SC}^2}$$

$$Z_{eq} = \frac{V_{SC}}{I_{SC}}, \qquad X_{eq} = \sqrt{Z_{eq}^2 - R_{eq}^2}$$



DC TEST AND EXAMPLE

- Apply low DC voltage and current to either transformer side to find R_1 and/or R_2.

- Example 3.9 in the book.

READING MATERIAL

- Reading material: Sections 3.4.5-3.4.7.

- Next time: Section 3.5.