ECE 330
POWER CIRCUITS AND ELECTROMECHANICS

LECTURE 10
TRANSFORMERS (4)

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.

EFFICIENCY

- Efficiency (η) is defined as the ratio of the output power (P_{out}) to the input power (P_{in}).

$$\eta = \frac{P_{out}}{P_{in}} \times 100 = \frac{P_{out}}{P_{out} + P_{loss}} \times 100 = \frac{P_{in} - P_{loss}}{P_{in}} \times 100$$

- Efficiency is usually expressed as a percentage: η% of the input power is seen at the output.

LOSSES

- Copper losses due to wire resistance are usually calculated as I^2R where I is the current and R is the resistance. $P_C = I^2R$
- I and R on both the primary and secondary sides are considered.
- Core losses are due to hysteresis and eddy currents in the transformer.

LOSSES

- Can be simply found as $P_i = \frac{V_m^2}{R_c}$ where V_m is the voltage across R_c.
- Core losses are usually nonlinear, so this equation is an approximation.
- Some empirical approximations.
  - Hysteresis Losses: $P_h = k_h f \; B^{1.6}$.
  - Eddy Current Losses: $P_e = k_e f^2 B^2$.

TRANSFORMER EFFECIENCHY

- In a transformer, efficiency can be calculated as follows:

$$P_c = I_1^2 R_1 + I_2^{'2} R_2^{'}$$

$$P_i = \frac{V_m^2}{R_c}$$

$$P_{in} = V_{in} I_{in} \cos(\theta_v - \theta_i)$$

$$P_{out} = I_2^2 R_L$$

$$\eta = \frac{P_{out}}{P_{in}} \times 100 = \frac{P_{out}}{P_{out} + P_c + P_i} \times 100 = \frac{P_{in} - P_c - P_i}{P_{in}} \times 100$$

ECE ILLINOIS

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VOLTAGE REGULATION

- Voltage regulation is used to determine how well a transformer regulates its load voltage when the load varies from a certain value to no load (open circuit).

$$\%VR = \frac{|V_{no\ load} - V_{load}|}{|V_{load}|} \times 100\%$$

- Notice that the output voltage depends on the currents as they affect the voltage drop.
- Good VR is close to zero.

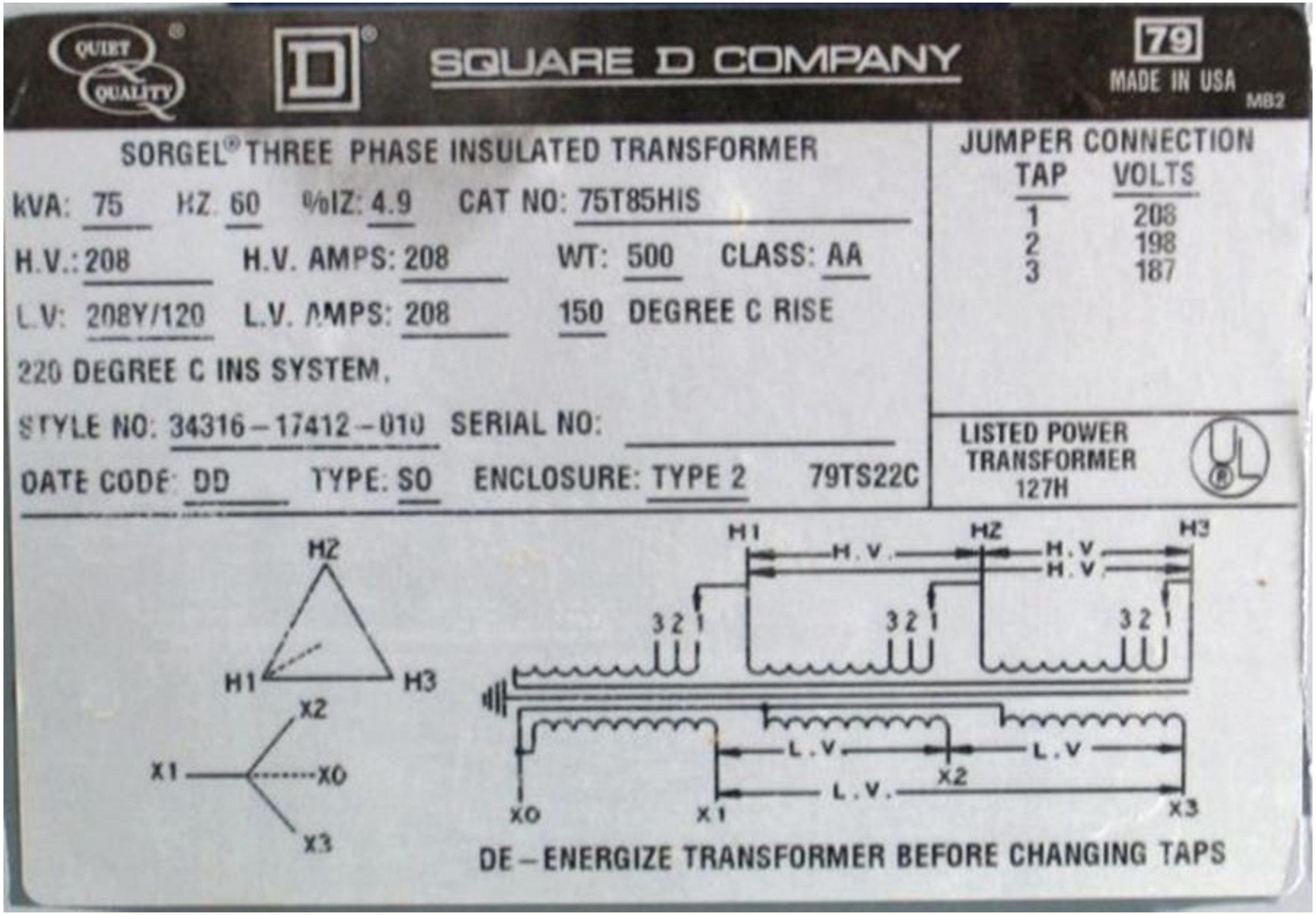
TRANSFORMER NAMEPLATE

- The "Nameplate" can be found on a transformer and shows basic information about its ratings.
  - Rated V_1/V_2.
  - Rated kVA.
  - %Z (% impedance)

$$\%Z = \frac{|Z_{eq}|}{Z_{rated}} \times 100 = \frac{\sqrt{R_{eq}^2 + X_{eq}^2}}{Z_{rated}} \times 100$$

$$Z_{rated} = \frac{|V_{rated}|}{|I_{rated}|} = \frac{V_{rated}^2}{S_{rated}}$$

TRANSFORMER NAMEPLATE



Source: emadrlc.blogspot.com

SHORT-CIRCUIT CURRENT

- The short-circuit current (I_{sc}) is a characteristic of the transformer:

$$I_{sc} = \frac{100}{\%Z} I_{rated}$$

- Example: Given $I_{1,rated}$=10 A, $V_{2,rated}$=120 V, a =2, find $\%Z$ and I_{sc} for $|Z_{eq}|$ seen from side 1 to be 0.12 Ω.

$$V_{1,rated} = aV_{2,rated} = 240\ V$$

$$Z_{1,rated} = \frac{240}{10} = 24\ \Omega$$

$$\%Z = \frac{0.12}{24} \times 100 = 0.5\%$$

$$I_{sc} = \frac{100}{0.5} \times I_{rated} = 2000\ A$$