Lecture 14
TRANSFORMER TESTS AND THREE PHASE TRANSFORMER BASICS

Agenda

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How to get the parameters for the transformer model?

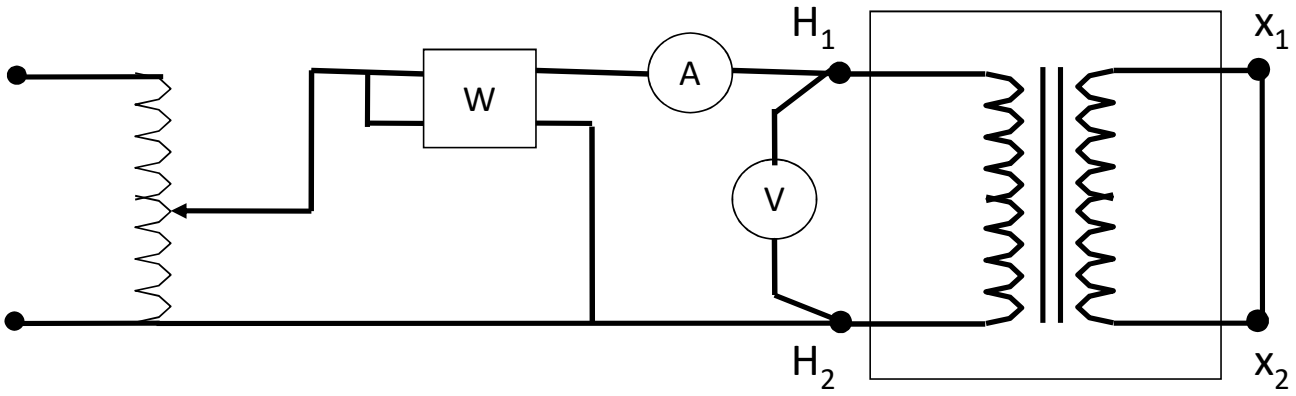
Lecture Outcomes

at the end of the lecture, the student must be able to …

- Apply the open and short circuit tests to derive transformer parameters
- Explain how a three-phase Transformer works.

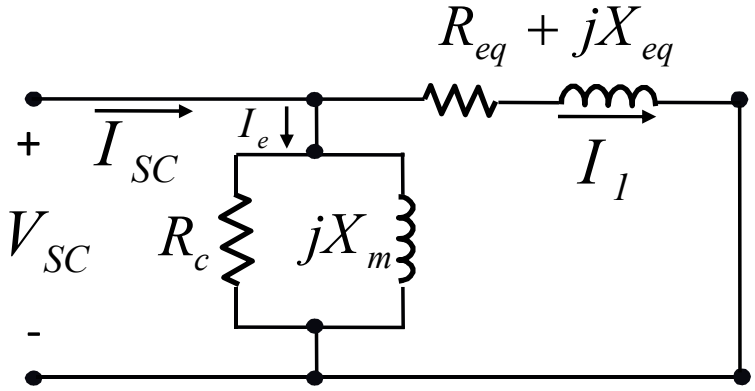
Transformer Tests:
Short-Circuit Test

Conducted to determine series impedance
With the secondary (Low-voltage side) short-circuited, apply a primary voltage (usually 2 to 12% of rated value) so that full load current flows.



Short-Circuit Test

Short-Circuit Test



$$I_e \approx 0$$

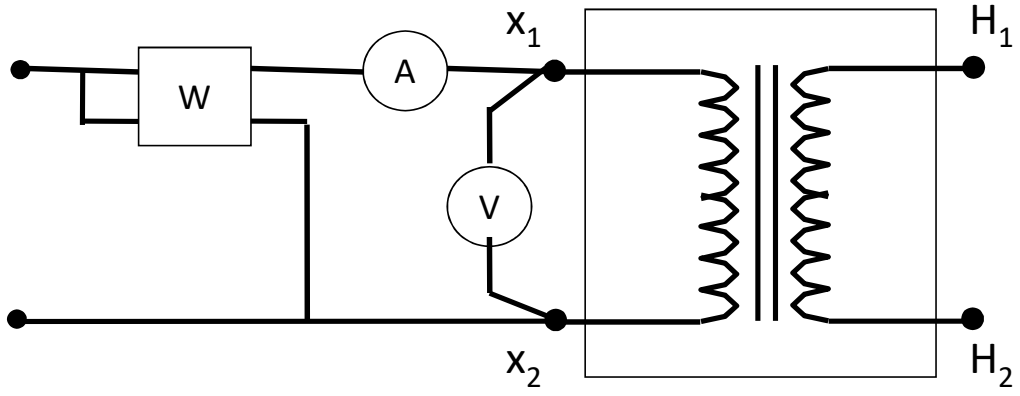
$$I_{sc} = I_1$$

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

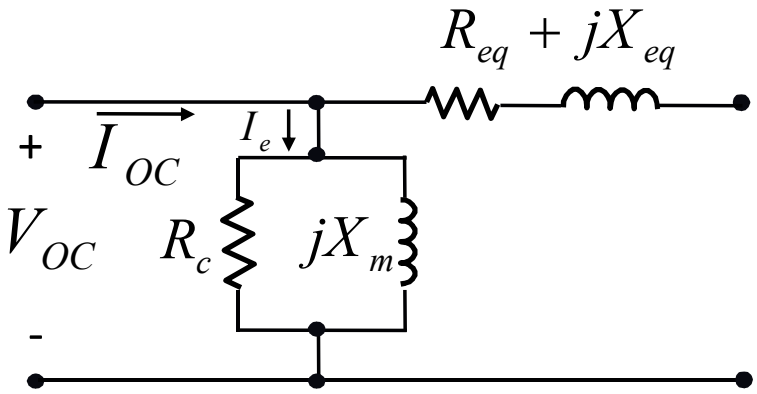
Transformer Tests:
Open-Circuit Test

Conducted to determine shunt impedance

With the secondary (High-voltage side) open-circuited, apply rated voltage to the primary.



Open-Circuit Test



$$I_{OC} = I_e$$

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

$$\frac{1}{X_m} = \sqrt{\left[\frac{I_{OC}}{V_{OC}}\right]^2 - \frac{1}{R_c^2}}$$

Short-Circuit and Open-Circuit Tests

Example:
50 kVA, 2400/240V, single-phase transformer

Short-Circuit Test: HV side energized

$$V_{SC} = 48\ volts \qquad I_{SC} = 20.8\ amps \qquad P_{SC} = 617\ watts$$

Open-Circuit Test: LV side energized

$$V_{OC} = 240\ volts \qquad I_{OC} = 5.41\ amps \qquad P_{OC} = 186\ watts$$

Determine the Series and Shunt Impedance of the transformer.
What is %Z and X/R of the transformer?

Short-Circuit and Open-Circuit Tests

Solution:

From the short-circuit test

$$Z_{eq,H} = \frac{48}{20.8} = 2.31 \ \ ohm$$

$$R_{eq,H} = \frac{617}{(20.8)^2} = 1.42 \ \ ohm$$

$$X_{eq,H} = \sqrt{2.31^2 - 1.42}^2 = 1.82 \ \ ohm$$

From the open-circuit test

$$R_{cq,L} = \frac{(240)^2}{186} = 310 \ \ ohm$$

$$\frac{1}{X_m} = \sqrt{\left[\frac{5.41}{240}\right]^2 - \left[\frac{1}{310}\right]^2}$$

$$X_{m,L} = 45 \ \ ohm$$

Short-Circuit and Open-Circuit Tests

Referred to the HV side

$$R_{c,H} = a^2 R_{c,L} = 30{,}968 \ \ ohm$$

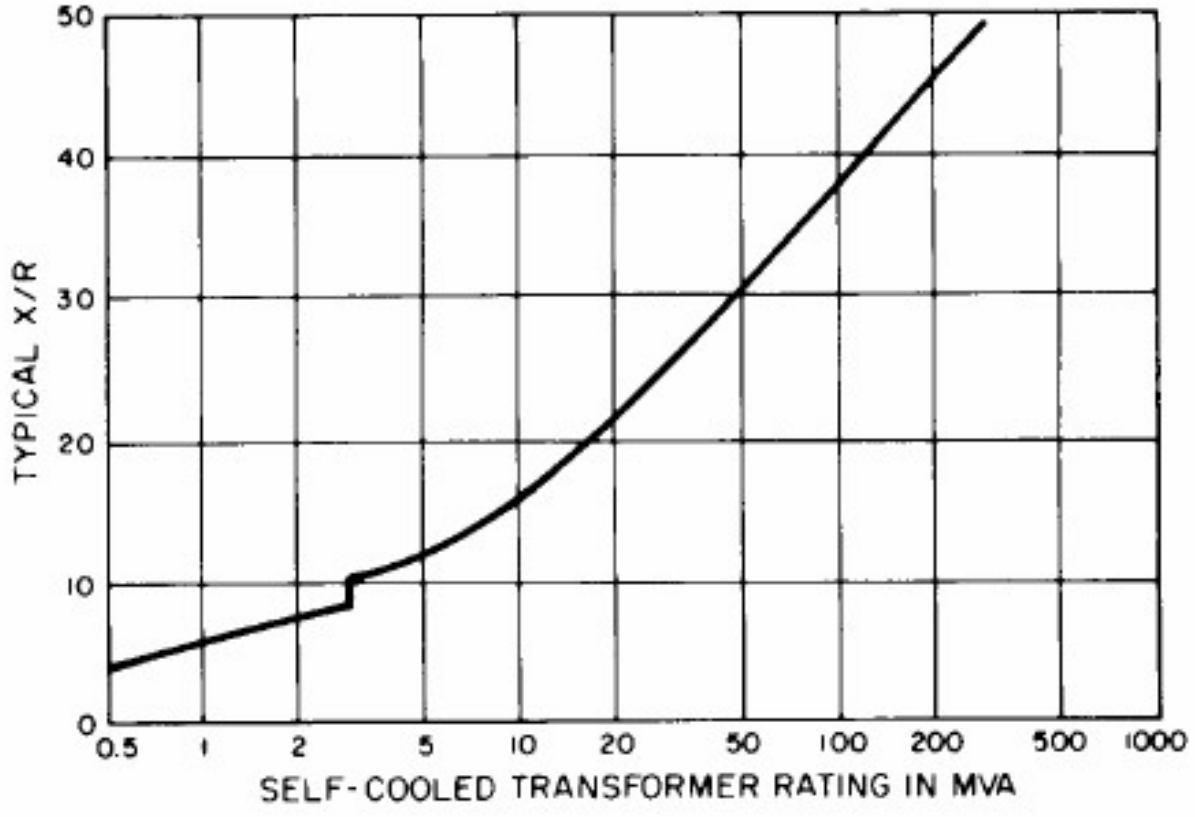
$$X_{m,H} = a^2 X_{m,L} = 4{,}482 \ \ ohm$$

%Z and X/R

$$Z_{BASE} = \frac{[2.4]^2}{50/1000} = 115.2 \ \ ohm$$

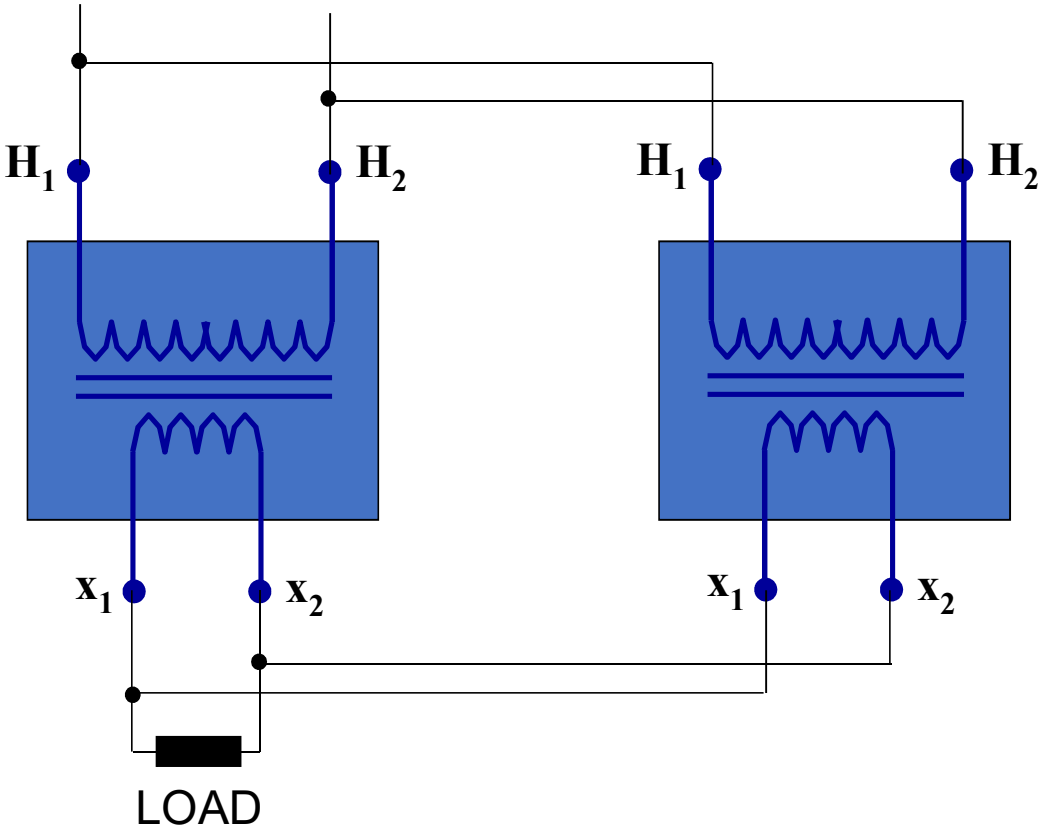
$$\%Z = \left(\frac{2.31}{115.2}\right) x100 = 2\% \qquad X/R = \frac{1.82}{1.42} = 1.28$$

X/R Ratios of Transformers



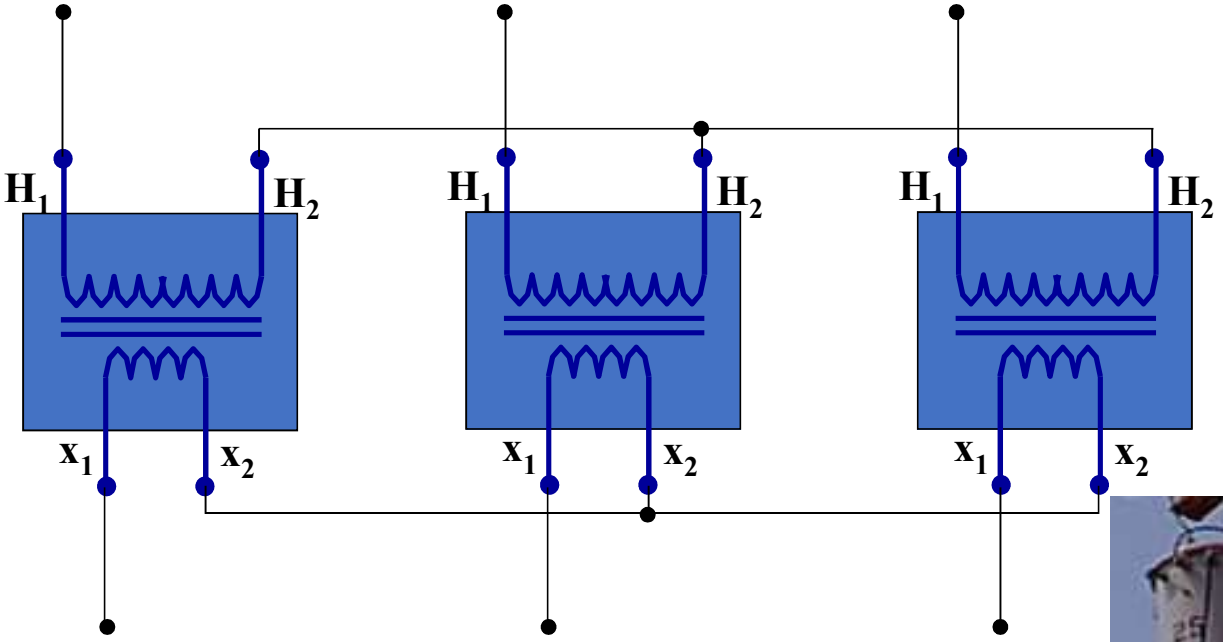
Source: Based on IEEE Std C37.010-1979.

Transformers in Parallel



- Same turns ratio
- Connected to the same primary phase
- Identical frequency ratings
- Identical voltage ratings
- Identical tap settings
- Per unit impedances within 0.925 to 1.075 of each other

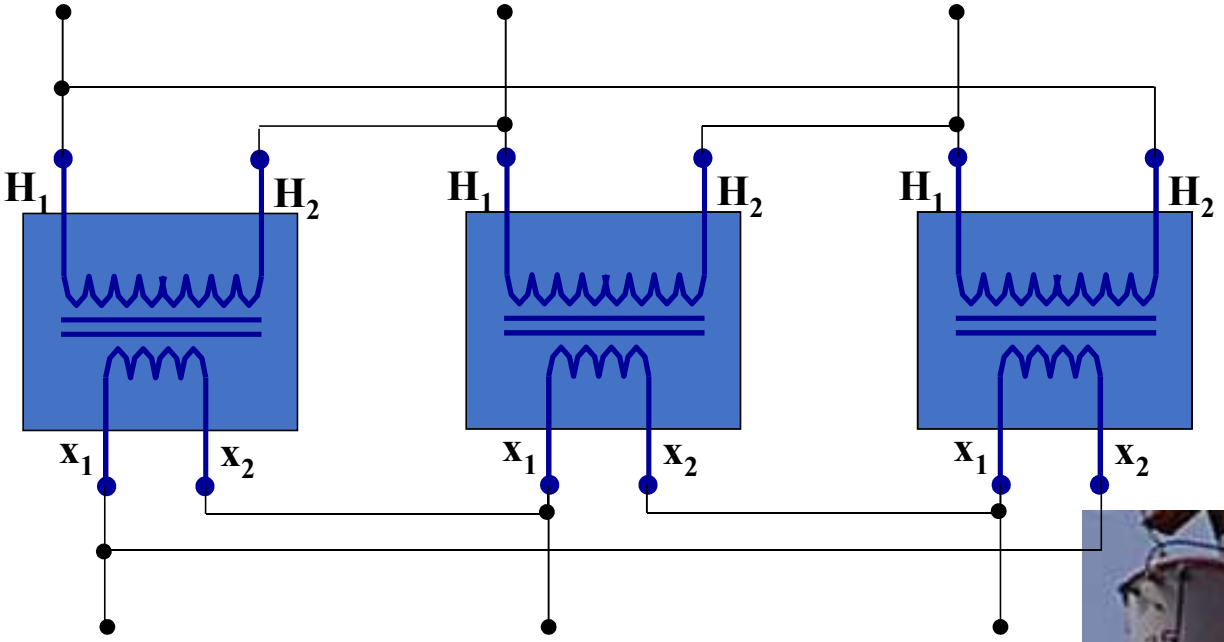
Three-Phase Transformers



WYE-WYE (Y-Y)

Three Phase Transformer Bank

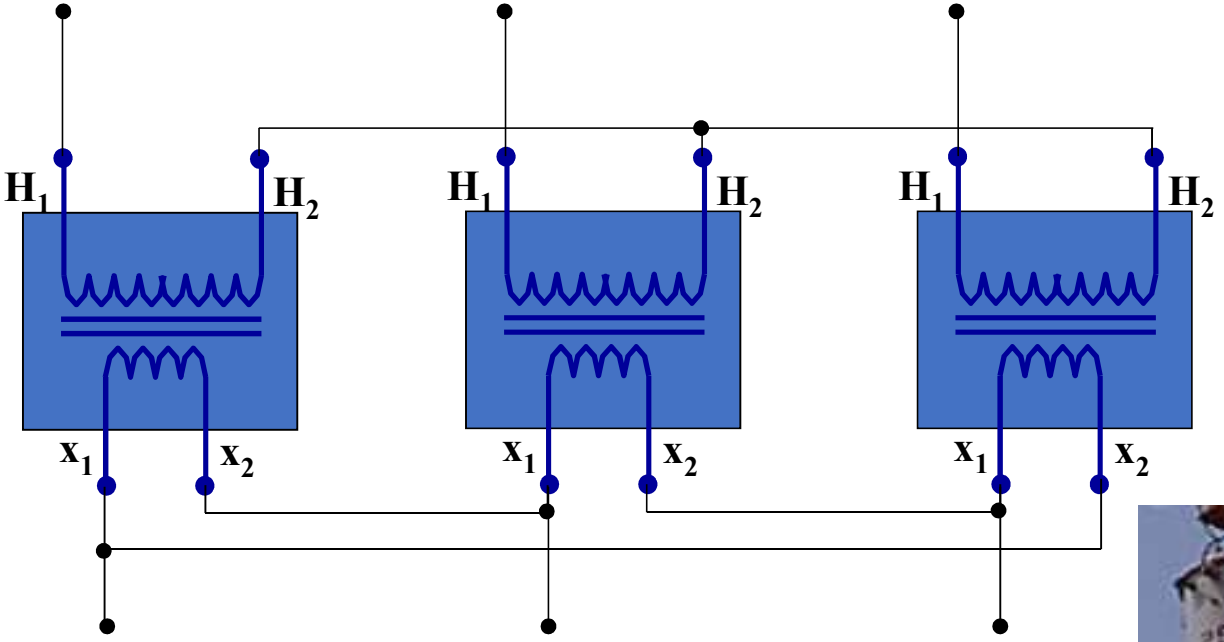
Three-Phase Transformers



DELTA-DELTA (Δ-Δ)

Three Phase Transformer Bank

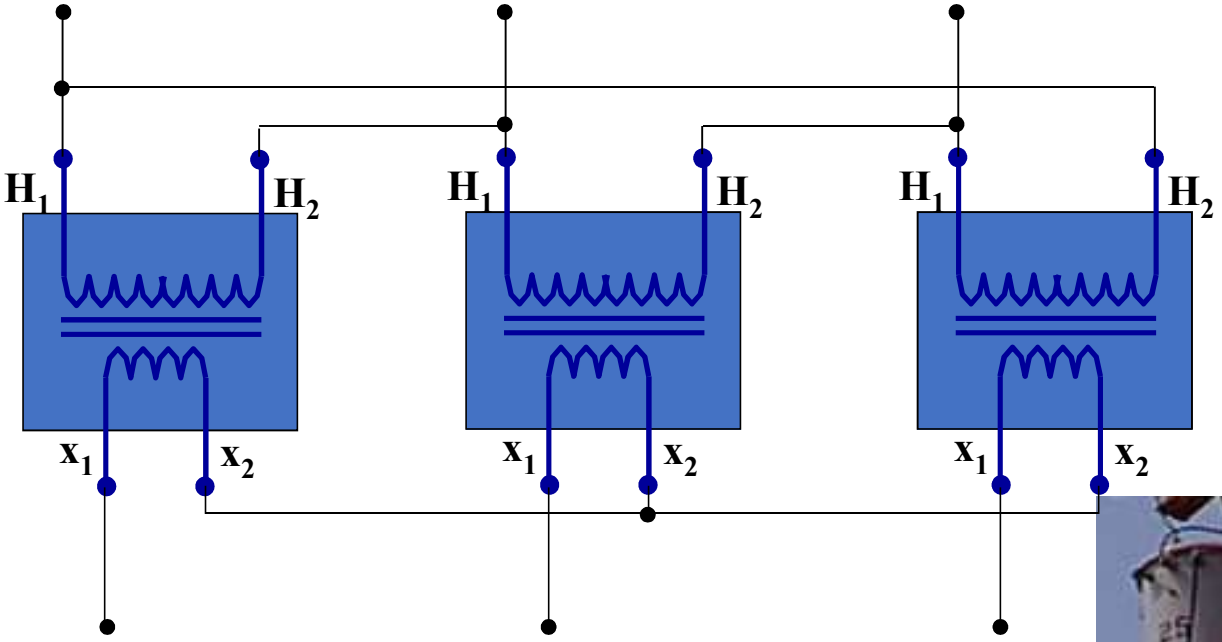
Three-Phase Transformers



WYE-DELTA (Y-Δ)

Three Phase Transformer Bank

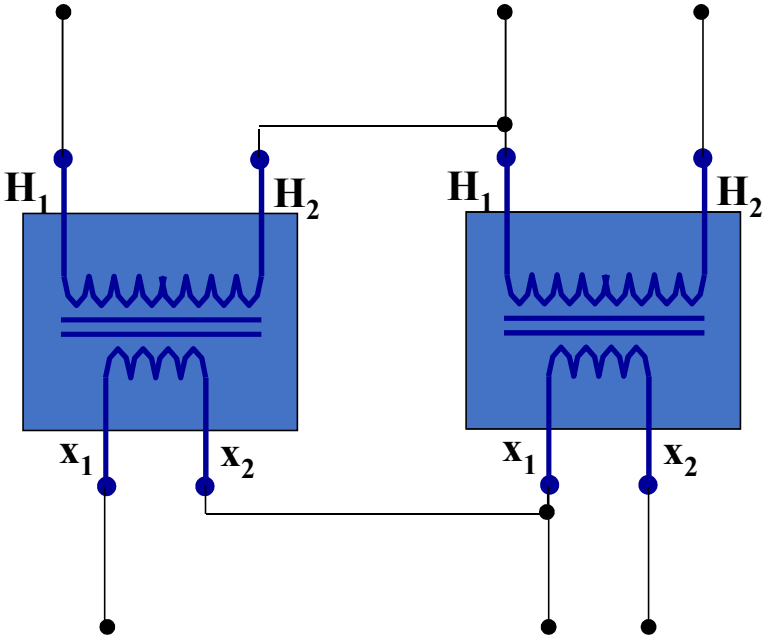
Three-Phase Transformers



DELTA-WYE (Δ-Y)

Three Phase Transformer Bank

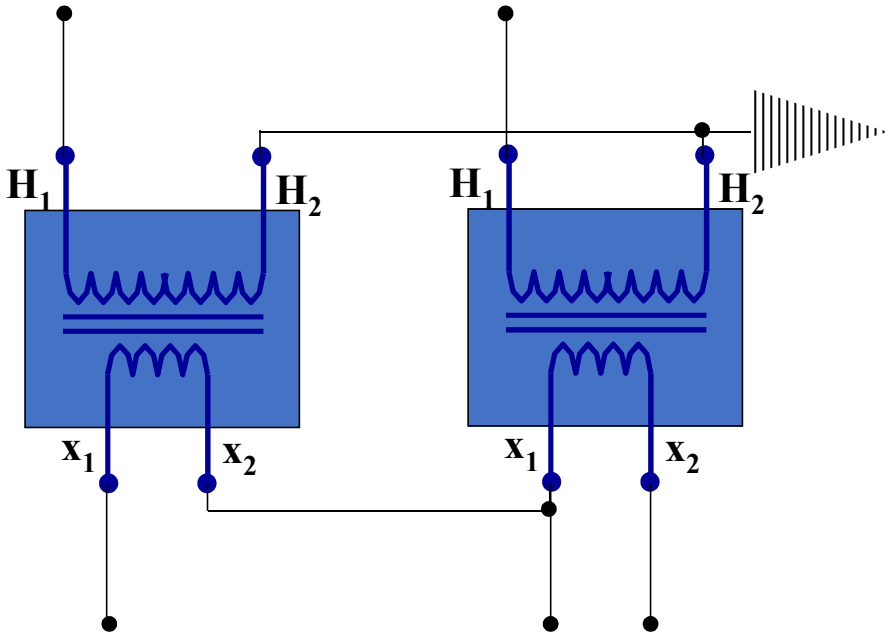
Three-Phase Transformers



OPEN DELTA – OPEN DELTA

Three Phase Transformer Bank

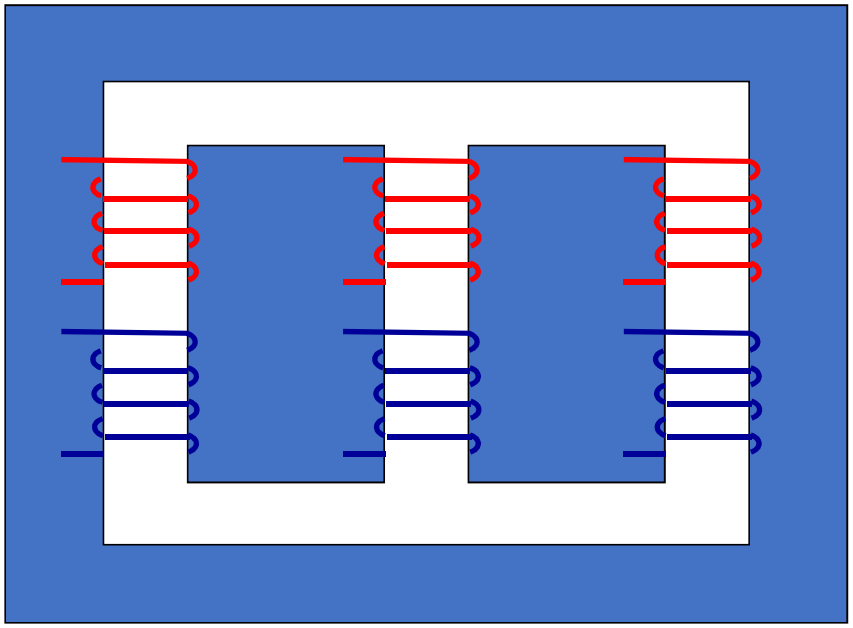
Transformer Connection



OPEN WYE - OPEN DELTA

Three Phase Transformer Bank

Three-Phase Transformer



Windings are connected Wye or Delta internally

HOMEWORK

Example 2–2. The equivalent circuit impedances of a 20-kVA, 8000/240-V, 60-Hz transformer are to be determined. The open-circuit test and the short-circuit test were performed on the primary side of the transformer, and the following data were taken:

Open-circuit test (on primary)	Short-circuit test (on primary)
$V_{OC} = 8000$ V	$V_{SC} = 489$ V
$I_{OC} = 0.214$ A	$I_{SC} = 2.5$ A
$V_{OC} = 400$ W	$P_{SC} = 240$ W

Find the impedances of the approximate equivalent circuit referred to the primary side, and sketch that circuit.