ET 332b Ac Motors, Generators and Power Systems

LESSON 11: TRANSFORMER NAME PLATE DATA AND CONNECTIONS

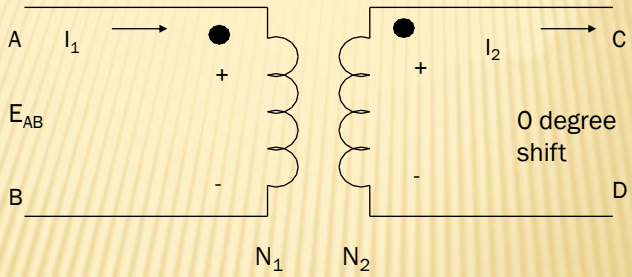
LEARNING OBJECTIVES

After this presentation you will be able to:

- Identify transformer polarity using dot and conventional labeling.
- Explain and interpret information found on transformer name plates.
- Compare and contrast the performance of three phase transformer connections.
- Indentify the schematic symbols of potential and current transformer. List characteristics on these devices and explain how they relate to performance.

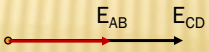
TRANSFORMER MARKINGS AND POLARITY

Dot Notation - Terminals marked with a dot are considered instantaneously positive



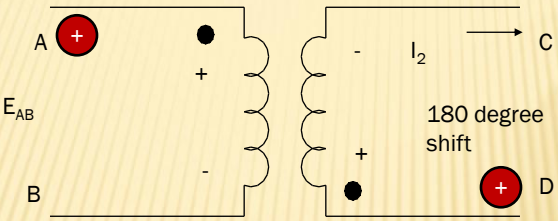
Above Terminals A and C are positive at the same time

Phasor Diagram



0 degrees

TRANSFORMER MARKINGS AND POLARITY



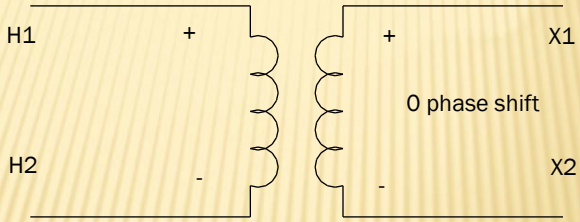
Above Terminals A and D are positive at the same time

Phasor Diagram

180 degrees

TRANSFORMER MARKINGS AND POLARITY

Conventional Labeling H = high voltage side
X = low voltage side



Terminal H1 more positive than H2. On secondary side X1 more positive than X2

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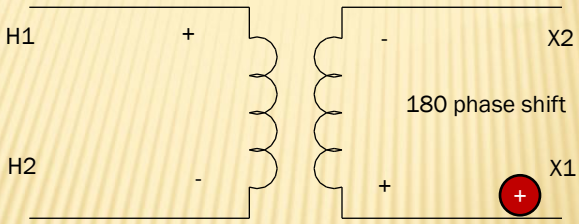
TRANSFORMER MARKINGS AND POLARITY

Conventional Labeling H = high voltage side
X = low voltage side



Note: Polarity of secondary is reversed creating 180 degree phase shift across transformer

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TRANSFORMER NAMEPLATE DATA

Voltage ratings → high side and low side values (no-load values)

Additional Voltage Markings

Dash (-) = Indicates voltages from different windings
Slant (/) = voltages from same winding
Cross(x) = voltages obtained by series or parallel connection of two part windings
Wye (Y) = wye-connected windings

TRANSFORMER VOLTAGE RATINGS

Single Phase Examples

240/120 — 240 V winding with a center tap

240x120 — Two part winding that can be connected in series for 240 V and parallel for 120 V

240-120 — A 240 V and separate 120 V winding

Three Phase Example

12470-480Y-277 V — Two winding transformer. Wye connected secondary with 277V and 480 V available

OTHER NAME PLATE DATA

Frequency	Rated frequency of transformer
kVA	Rated Apparent power of transformer

Apparent power rating determined by construction and cooling- oil cooled. Oil also provides insulation

Power ratings

AO rating - natural convection air and oil.

FA rating - natural convection of oil and forced air

FOA rating - forced air and oil circulation

TRANSFORMER POWER RATINGS

Typical ratings 30/40/50 MVA AO/FA/FOA

Forced oil by circulating pumps

Forced air by radiators and fans

Dry Type Insulated transformers (no oil) Typical at voltages of 15 kV and below

Classes

AA - dry type, self-cooled, natural convection of air

AFA - Dry type, forced-air cooling

AA/FA Dry type self-cooled/forced air cooled

Dual rating that requires fans

OTHER NAME PLATE DATA

Percent Impedance — Impedance measured at indicated temperature. Base S and V values are the ratings of the transformer

Temperature Rise — Maximum allowable temperature rise

Heat effects the insulation Excessive heating reduces life of transformer

Class — Insulating medium and cooling (see previous slide)

BASIC IMPULSE LEVEL

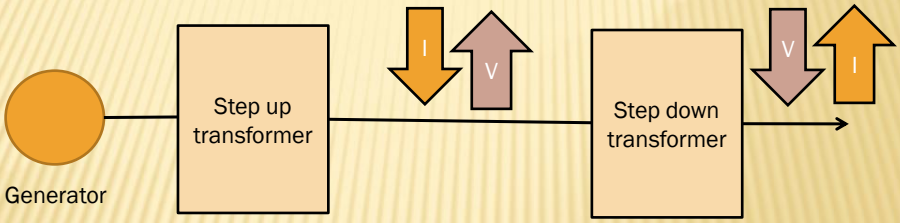
BIL — (Basic Impulse Level) Measures the maximum voltage stresses that the transformer can handle

Impulse tests used to simulate the effects of lightning over-voltages

Voltage surges in excess of the BIL can cause insulation failures

THREE PHASE TRANSFORMER CONNECTIONS

Transformers increase voltage, decreasing current in power systems. Lower I means less power loss due to I^2R losses in lines, cables, transformers, etc



Three phase transformers

3 single-phase units can form 3-phase bank

or

Single three-phase transformer (3 separate cores in a single tank)

Step up/down transformers are different connections of 1-ϕ units or coils based on wye-delta configurations

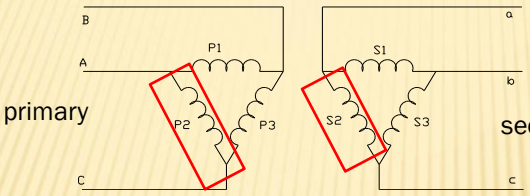
THREE PHASE TRANSFORMER CONNECTIONS

Examples from the field

Three-Phase Transformer Single Unit, Substation Type

Three Phase Bank
Three individual Transformers

DELTA-DELTA (Δ-Δ) CONNECTION



primary

secondary

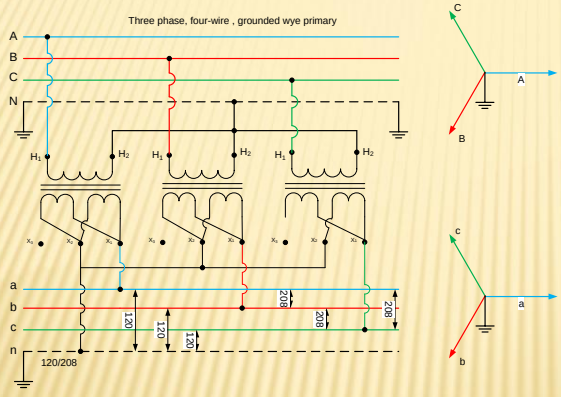
Parallel coils are part of same transformer or core

Phase diagram

Advantages: Absorbs unbalance of load. Unbalance I circulates in delta. Lose one transformer and can still operate

Disadvantages: No natural neutral

WYE-WYE CONNECTION



Three 7200 - 240/120 V transformers
Primary $V_{An} = V_{Bn} = V_{Cn} = 7200$ V $H_1 - H_2$ $V_{LL} = 12470$ V
Secondary $V_{an} = V_{an} = V_{cn} = 120$ V $X_1 - X_2$ $V_{LL} = 208$ V

Advantages:

Two voltage levels available
Graded High voltage insulation
Easy balancing between 1-ϕ and 3-ϕ loads

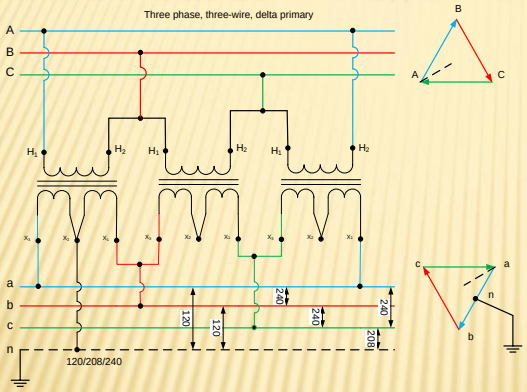
Disadvantages:

Single phase short circuit currents passed. Zero sequence (3rd Harmonics passed)

Total Bank power:

$$S_1 + S_2 + S_3 = S_T$$

DELTA-DELTA (180^0 SHIFT)



3 Transformers 7200 - 240/120 V
primary $V_A = V_B = V_C = 7200$ V $V_{LL} = 7200$ V
Secondary $V_{ab} = V_{bc} = V_{ca} = 240$ V $V_{LL} = 240$ V

180^o phase shift H_1-H_2 to X_1-X_3

Advantages
Ideal for motor loads, 3-wire.
Can tolerate single line shorts with no interruption.
Traps 3rd harmonic currents

Disadvantages
Full insulation required on H.V. Windings.
T1 must be larger KVA when Serving 1-ϕ load with 3-ϕ.
No natural ground point
Unbalanced connection when serving 1-ϕ and 3-ϕ loads together

Bank power
$S_1 + S_2 + S_3 = S_T$

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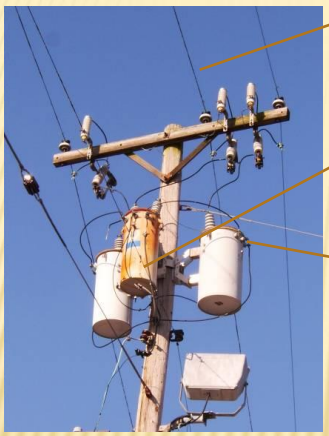
EXAMPLE FROM FIELD



12.47 kV Line-to-line primary

Smaller size indicates lower power rating

Secondary connections

Three-Phase Bank
Unequal Transformer Power Ratings

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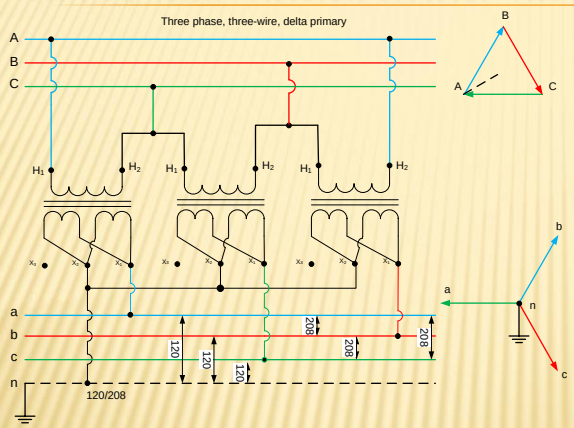
DELTA-WYE CONNECTION- 30° PHASE SHIFT



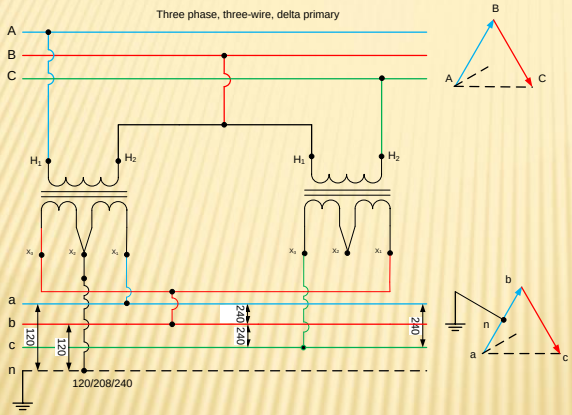
Advantages:
Single phase load easy to balance. New neutral point is established. Two voltage levels. Traps 3rd harmonics

Disadvantages:
Full insulation required on H.V. winding of transformers

Bank Power
$S_1 + S_2 + S_3 = S_T$

3 Transformers 7200-240/120 V
Primary $V_{LL} = V_p = 7200$ V
Secondary $V_{an} = V_{bn} = V_{cn} = 120$ V $V_{ab} = 208$ V
30° phase shift V_{an} to V_{An} lag is standard

OPEN DELTA-OPEN DELTA



Two transformers supply balanced 3 phase voltages and currents. Connection itself is unbalanced

Bank Power

$$S_T = \frac{S_1 + S_2}{\sqrt{3}}$$

If $S_1 = S_2$

$$S_T = \frac{2S_1}{\sqrt{3}}$$

2 transformers 7200 - 240/120 V
Primary $V_p = V_{LL} = 7200$ V Secondary $V_{LL} = V_p = 240$ V
Transformers exchange reactive power to provide balanced voltages and currents to 3-phase loads

INSTRUMENT TRANSFORMERS

High power measurement requires highly accurate transformers to reduce the levels or voltage and current to a safe range.

Meter coil ratings

Voltage coils for voltmeters, power meters and watthour meters

115 - 120 Vac

Current coils for ammeters, power meters and watthour meters

2.5-5 A (100% overload allowed)
(short time)

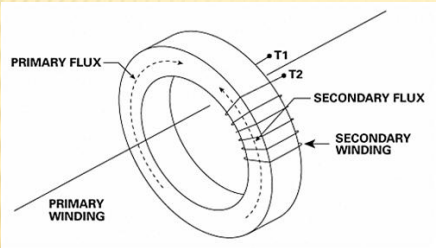
In power systems, voltage levels 100's of kV and thousands of amps

Instrument Transformers – convert high voltages and currents to measurement levels

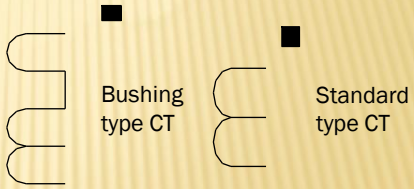
Potential transformers (PTs)
Current transformers (CTs)

CURRENT TRANSFORMERS (CTS)

Single turn primary - usually the conductor with the current to be measured
Multi-turn secondary - side connected to low power instruments



Schematic Symbols



Current transformer ratios

200/5 200 amps input gives 5 amps output (40/1)
600/5 600 amps input gives 5 amps output (120/1)
Can overload rated values 150-200% continuously

POTENTIAL TRANSFORMERS (PT'S)

High accuracy transformers with minimum power loss and very small voltage drop. Assume idea operation of both CTs and PTs

Potential transformers reduces high voltages to 110-120 Vac range

Potential Transformer Schematic Symbol

Schematic symbols should indicate polarity mark

Typical potential transformer ratios

39,837-115 Vac
6900- 115 Vac

Can exceed V_{in} ratings by approximately ±10%

PT'S AND CT'S CHARACTERISTICS

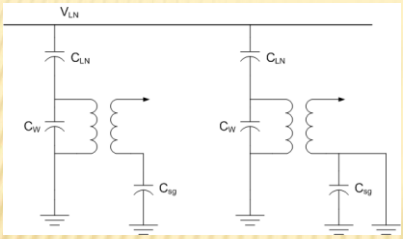
Power Ratings (burden)
VA rating of all instruments connected can not exceed this value or accuracy of transformers will suffer

Phase Shift
Typically less than 1 degree of phase shift or less through transformer

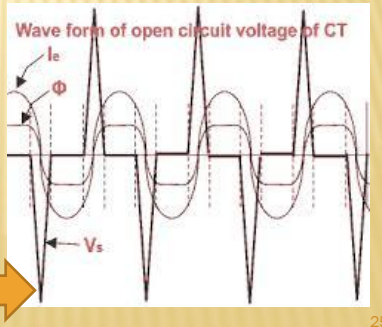
Voltage and Current Magnitude
Magnitude accuracy: Panel metering and protection < 0.5%
Revenue metering < 0.1%

PT/CT SAFETY CONSIDERATIONS

PTs - always ground secondary. Capacitive coupling can cause dangerously high voltage to develop on low voltage windings



CTs - **NEVER OPEN LOAD ON CT CIRCUIT**. ALWAYS SHORT CT SECONDARY TERMINALS BEFORE REMOVING LOAD. Can induce **2-6 kV on open secondary leads**



2-6 kV

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END LESSON 11: TRANSFORMER NAME PLATE DATA AND CONNECTIONS