

EE2029: Introduction to Electrical Energy System

Per Unit Analysis: Three Phase Transformers

Lecturer : Dr. Sangit Sasidhar (elesang)

Department of Electrical and Computer Engineering



Three-Phase Transformers

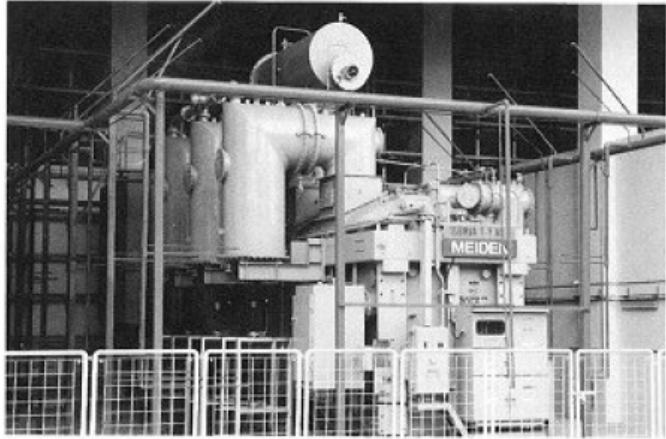


*Three-phase transformers
at substations*

*Pole-mounted
three single-phase
transformers.*



230 kV, 150 MVA oil-immersed forced-air cooled transformer
at Kampong Java substation, PowerGrid, Singapore



Source: <http://www.meidensg.com.sg>



Three-Phase Transformer Nameplate

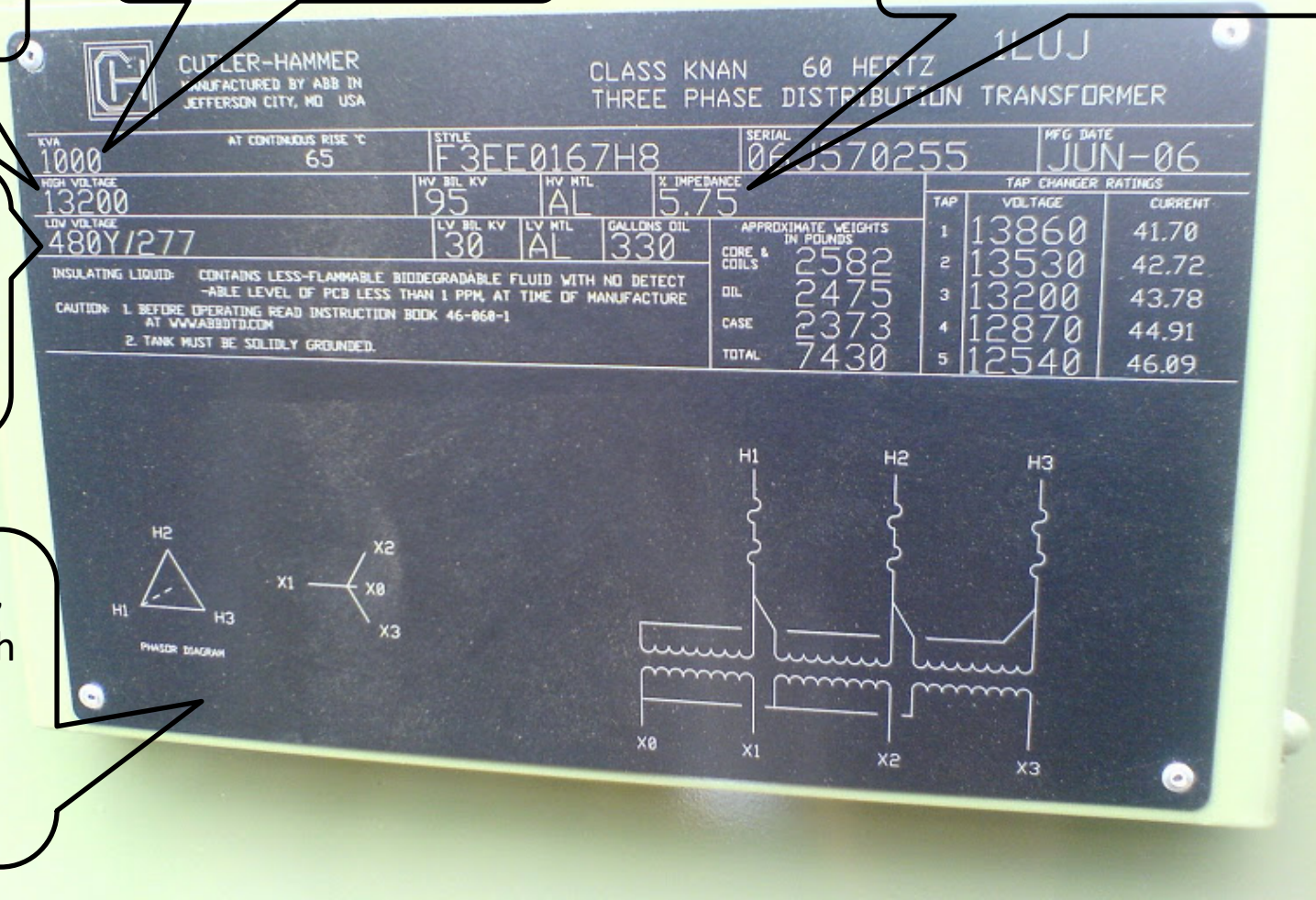
High voltage 13.2kV
(line-to-line)

KVA rating, 1000 KVA

Impedance = 5.75%

Low voltage 480V
(line-to-line) or
277V(line-to-neutral)

Circuit connection,
 Δ -connected at high
voltage and Y-
connected at low
voltage



CUTLER-HAMMER
MANUFACTURED BY ABB IN
JEFFERSON CITY, MO USA

CLASS KNAN 60 HERTZ 12UJ
THREE PHASE DISTRIBUTION TRANSFORMER

| | | | | |
|-------------------------|-----------------------------|---------------------|---------------------|--------------------|
| KVA 1000 | AT CONTINUOUS RISE °C 65 | STYLE F3EE0167H8 | SERIAL 06J570255 | MFG DATE JUN-06 |
| HIGH VOLTAGE 13200 | HV BIL KV 95 | HV NTL AL | % IMPEDANCE 5.75 | |
| LOW VOLTAGE 480Y/277 | LV BIL KV 30 | LV NTL AL | GALLONS OIL 330 | |

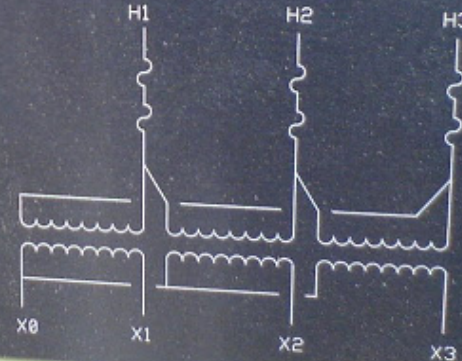

INSULATING LIQUID: CONTAINS LESS-FLAMMABLE BIODEGRADABLE FLUID WITH NO DETECTABLE LEVEL OF PCB LESS THAN 1 PPM, AT TIME OF MANUFACTURE
CAUTION: 1. BEFORE OPERATING READ INSTRUCTION BOOK 46-060-1 AT WWW.ABBTD.COM
2. TANK MUST BE SOLIDLY GROUND.

| TAP CHANGER RATINGS | | |
|---------------------|---------|---------|
| TAP | VOLTAGE | CURRENT |
| 1 | 13860 | 41.70 |
| 2 | 13530 | 42.72 |
| 3 | 13200 | 43.78 |
| 4 | 12870 | 44.91 |
| 5 | 12540 | 46.09 |

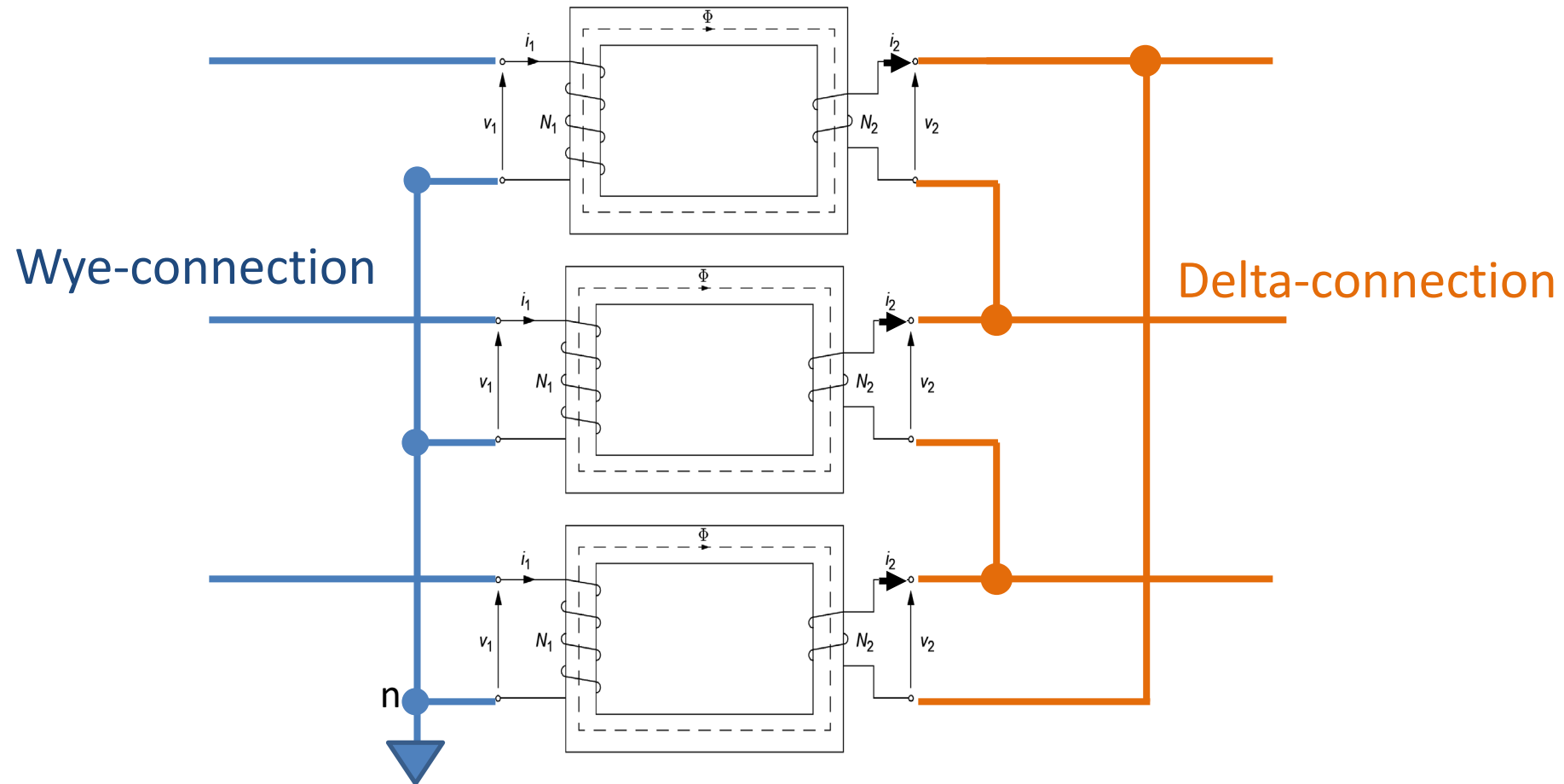
APPROXIMATE WEIGHTS IN POUNDS

| | |
|--------------|------|
| CORE & COILS | 2582 |
| OIL | 2475 |
| CASE | 2373 |
| TOTAL | 7430 |

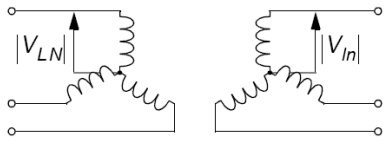
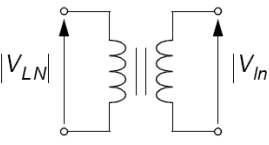
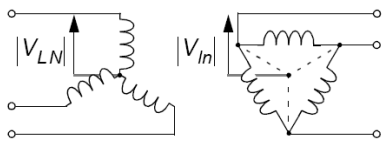
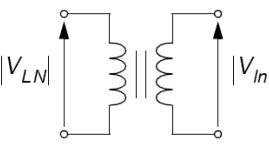
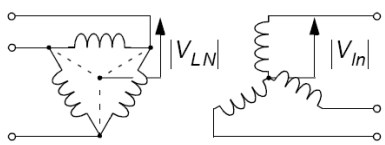
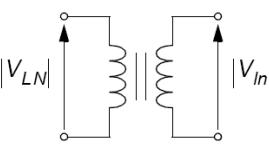
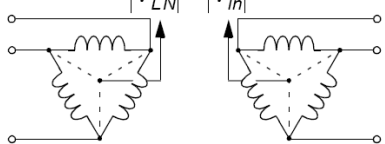
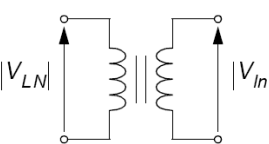
PHASOR DIAGRAM



Three Single-Phase Transformers

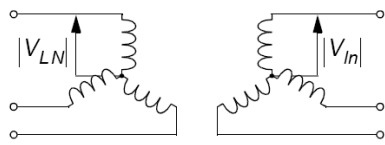
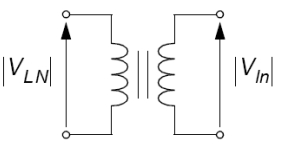
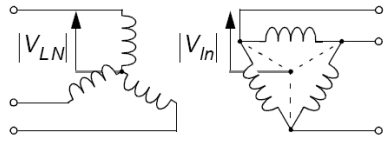
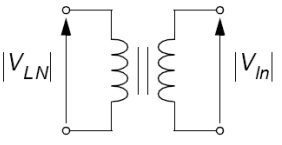
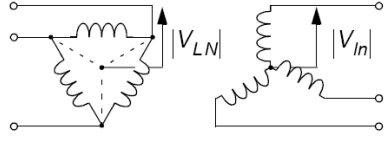
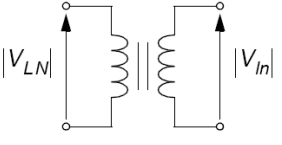
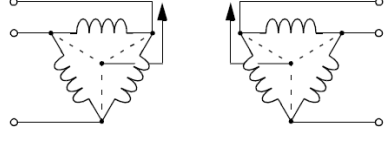
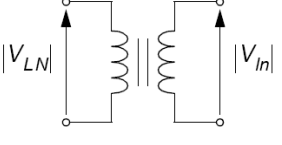


3 Φ Transformer Connections

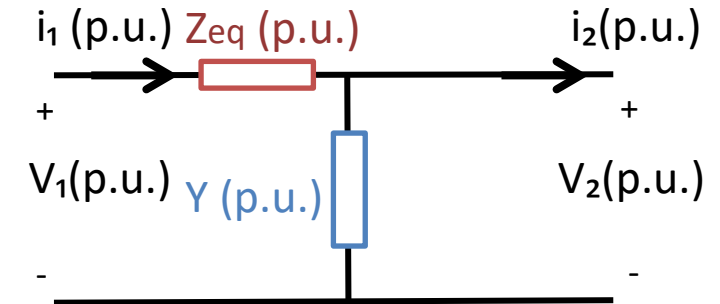
| designation | winding connection | single-phase equivalent |
|-------------|---|---|
| Yy |  |  |
| Yd |  |  |
| Dy |  |  |
| Dd |  |  |

- The voltage rating of a three phase transformer is the ratio between **line-to-line** voltage at the primary side and **line-to-line** voltage at the secondary side.
- The single-phase equivalent shows line-to-neutral voltage.
- For Y-Y and Δ - Δ transformers, voltage and current in both primary and secondary are in phase. The ratio of the voltage and current follows the turn ratio of the transformer.
- The same does not apply to Y- Δ and Δ -Y connections.

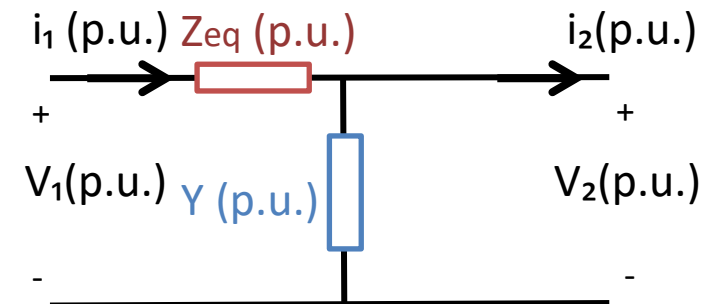
3 Φ Transformer Connections

| designation | winding connection | single-phase equivalent |
|-------------|---|--|
| Yy |  |  |
| Yd |  |  |
| Dy |  |  |
| Dd |  |  |

Per phase
per unit
circuit



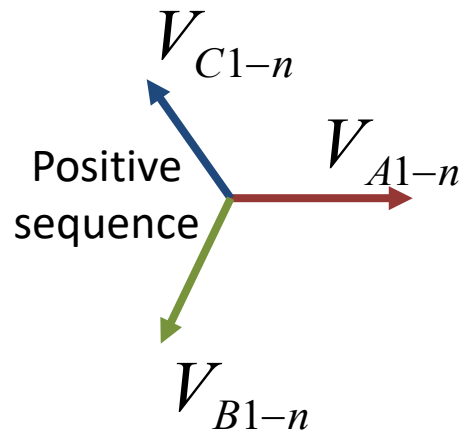
Wye-Delta and Delta-Wye transformer connections introduce some phase shift to the voltage.



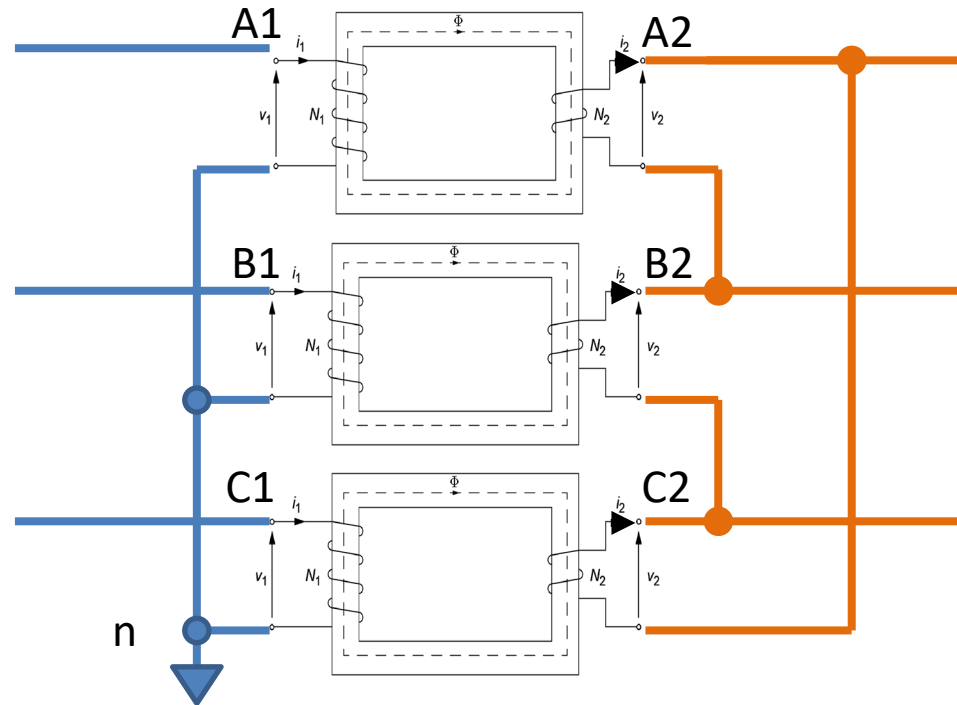
Wye-Delta 3 Φ Transformers

Wye-connected

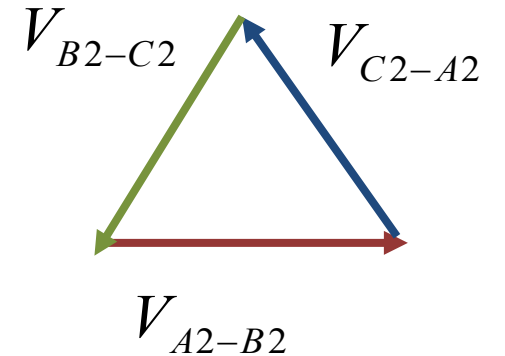
Delta-connected



Line-to-neutral voltage



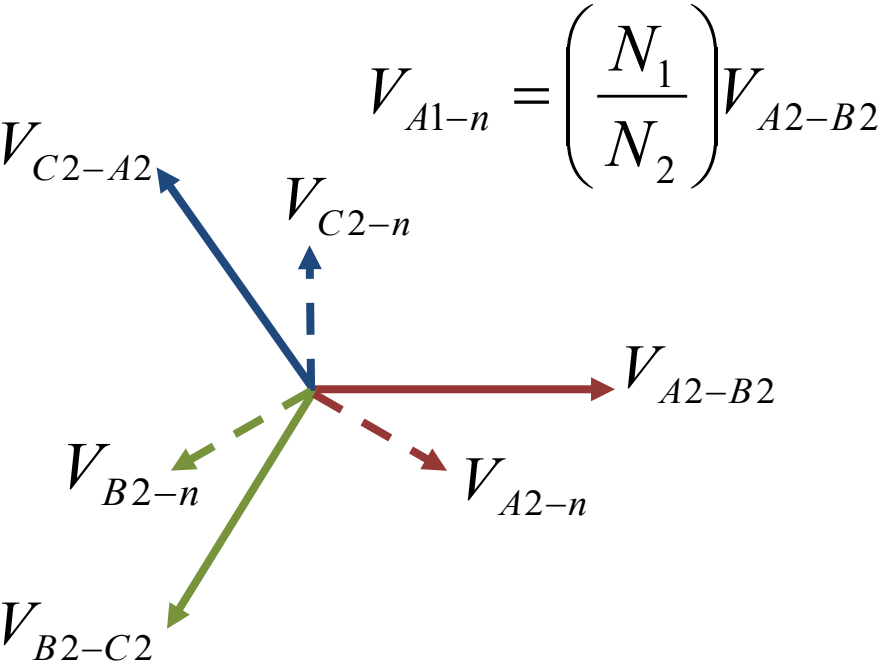
$$V_{A1-n} = \left(\frac{N_1}{N_2} \right) V_{A2-B2}$$



Line-to-line voltage!!



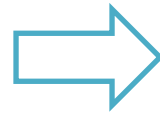
Wye-Delta 3Φ Transformer



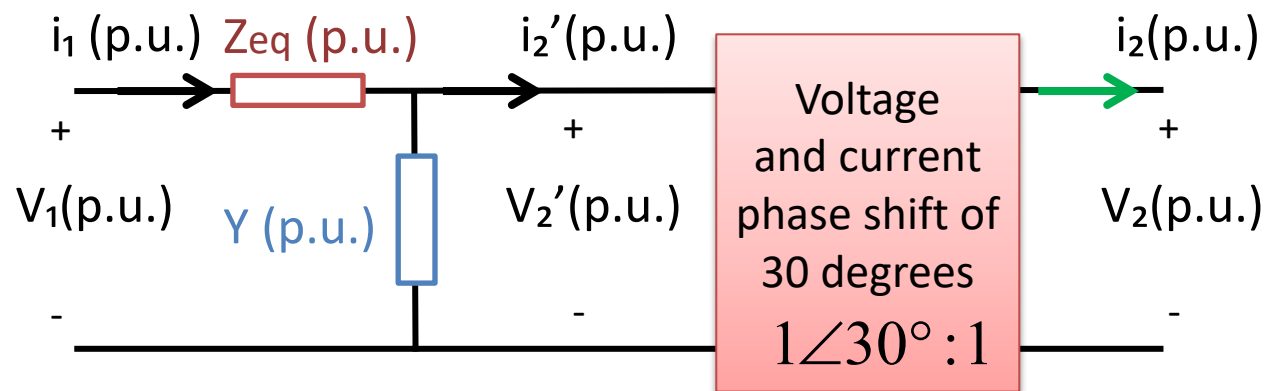
Y-Δ 3Φ Transformer: Per Phase Model

For a positive sequence voltage source,

$$V_{A1-n} = \left(\frac{N_1}{N_2} \right) \sqrt{3} V_{A2-n} \angle 30^\circ$$



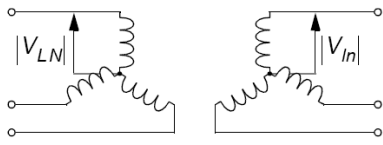
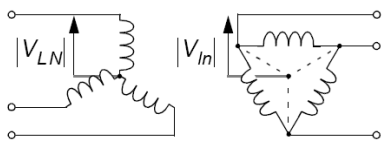
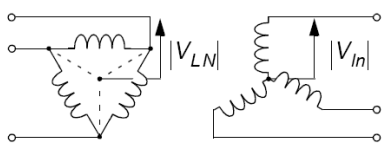
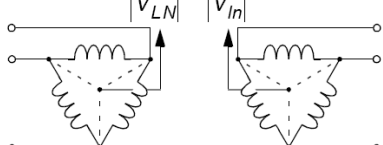
$$\angle V_{A1-n} : \angle V_{A2-n} = 1 \angle 30^\circ : 1$$



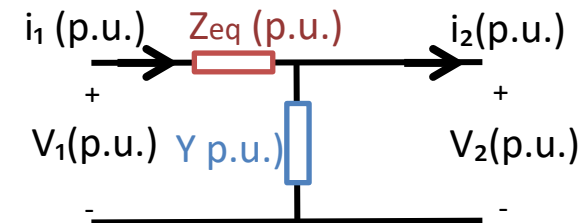
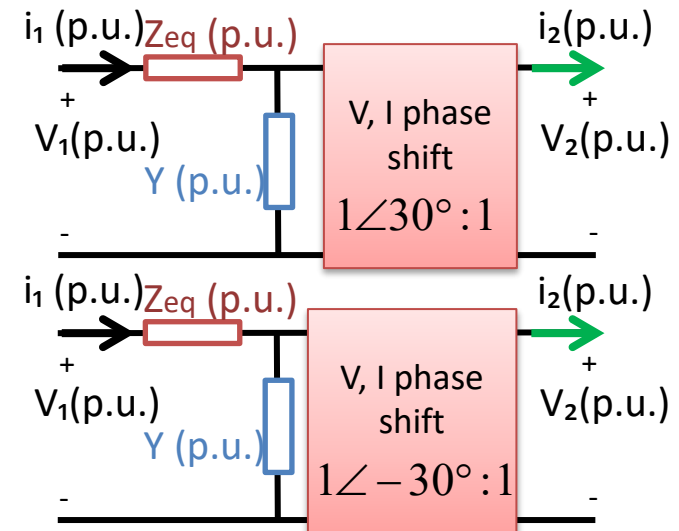
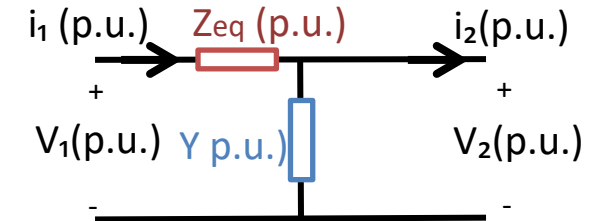
$$i_2 = i_2' \angle -30^\circ$$

$$V_2 = V_2' \angle -30^\circ$$

3 Φ Transformer Per Unit Model

| designation | winding connection |
|-------------|---|
| Yy |  |
| Yd |  |
| Dy |  |
| Dd |  |

Per phase
per unit
circuit





Summary

