EE2029: Introduction to Electrical Energy System

Per Unit Analysis: Three Phase Transformers

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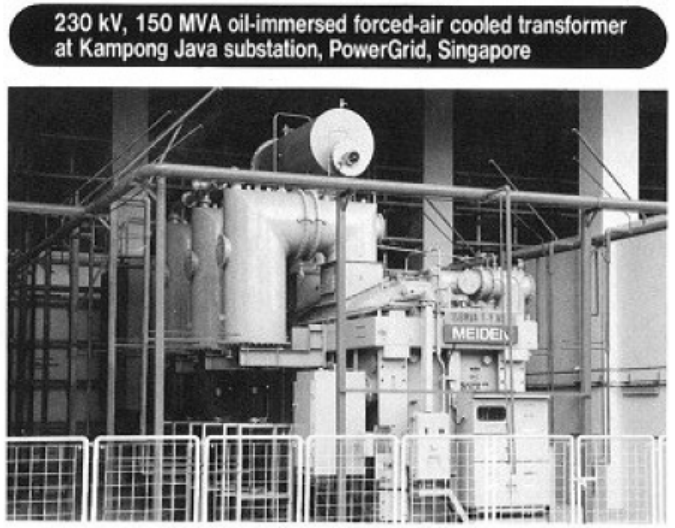
Department of Electrical and Computer Engineering

Three-Phase Transformers

Three-phase transformers at substations



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

Pole-mounted three single-phase transformers.

Three-Phase Transformer Nameplate

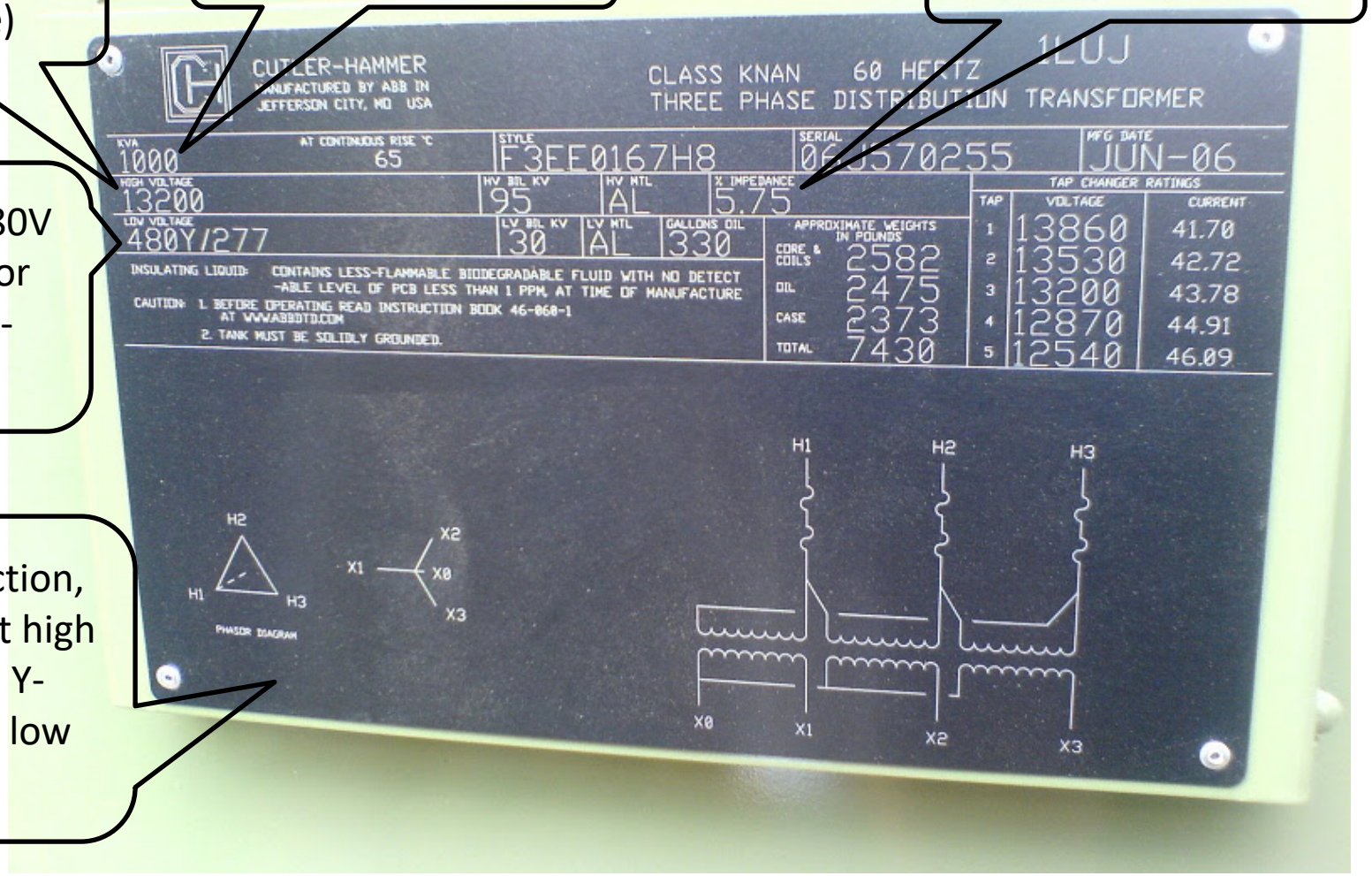
High voltage 13.2kV (line-to-line)

KVA rating, 1000 KVA

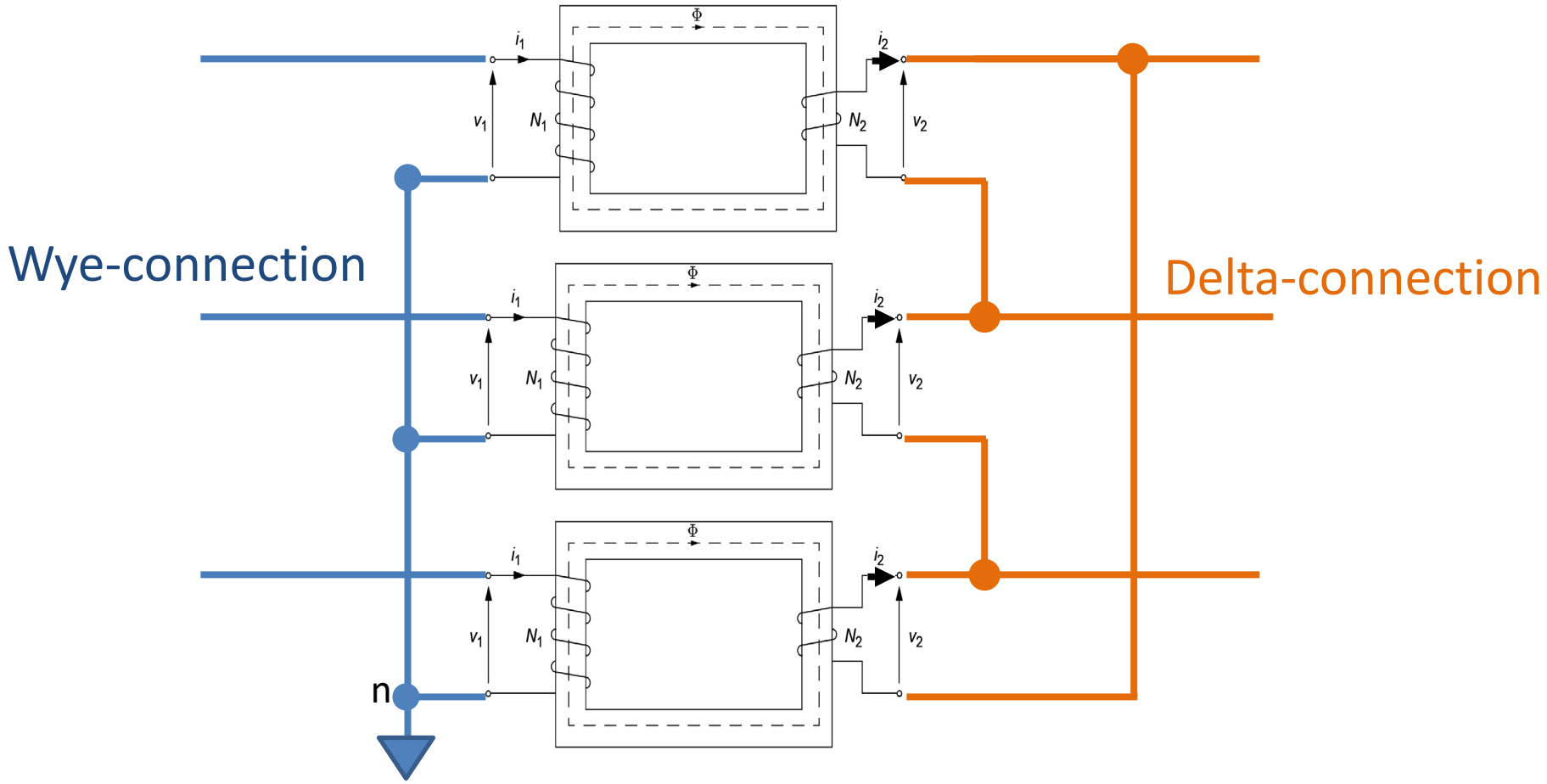
Impedance = 5.75%

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

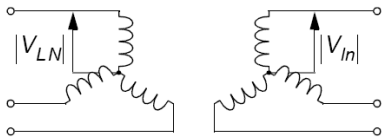
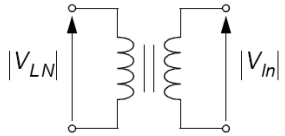
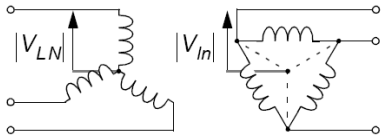
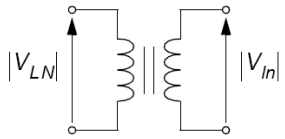
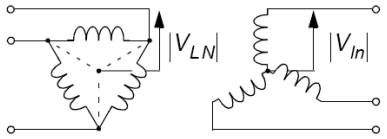
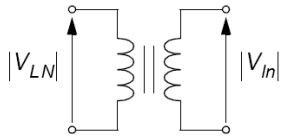
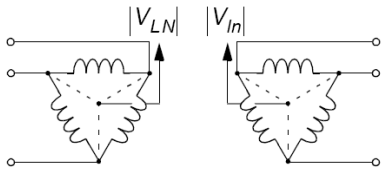
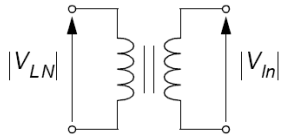
Circuit connection, Δ-connected at high voltage and Y-connected at low voltage



Three Single-Phase Transformers

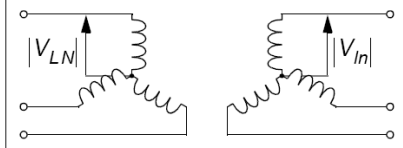
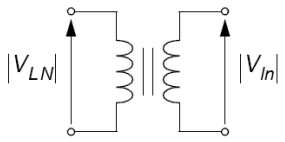
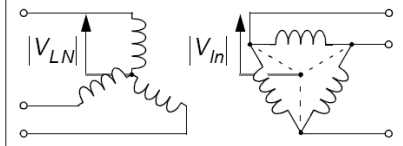
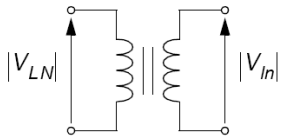
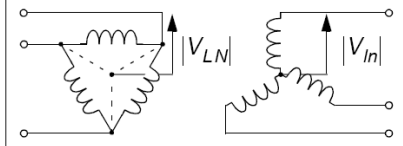
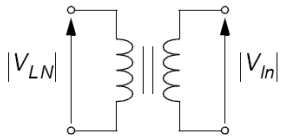
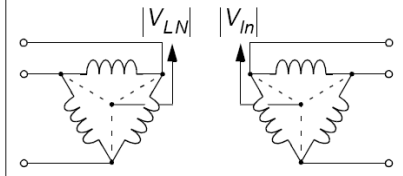
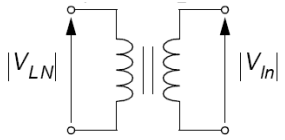


3Φ Transformer Connections

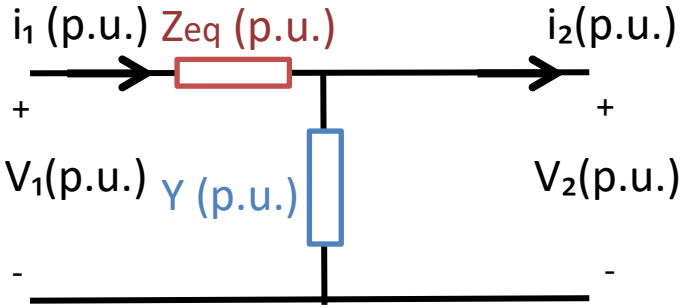
designation	winding connection	single-phase equivalent
Yy		
Yd		
Dy		
Dd		

- 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.

3Φ Transformer Connections

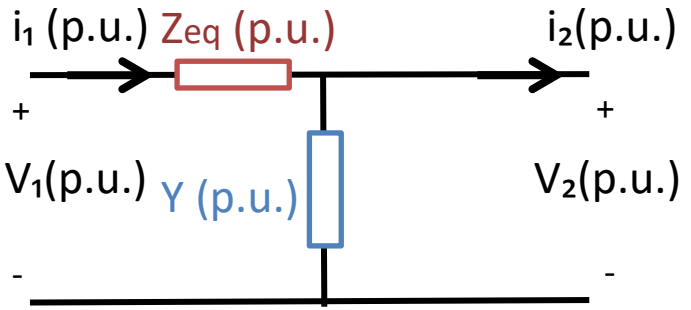
designation	winding connection	single-phase equivalent
Yy		
Yd		
Dy		
Dd		

Per phase per unit circuit



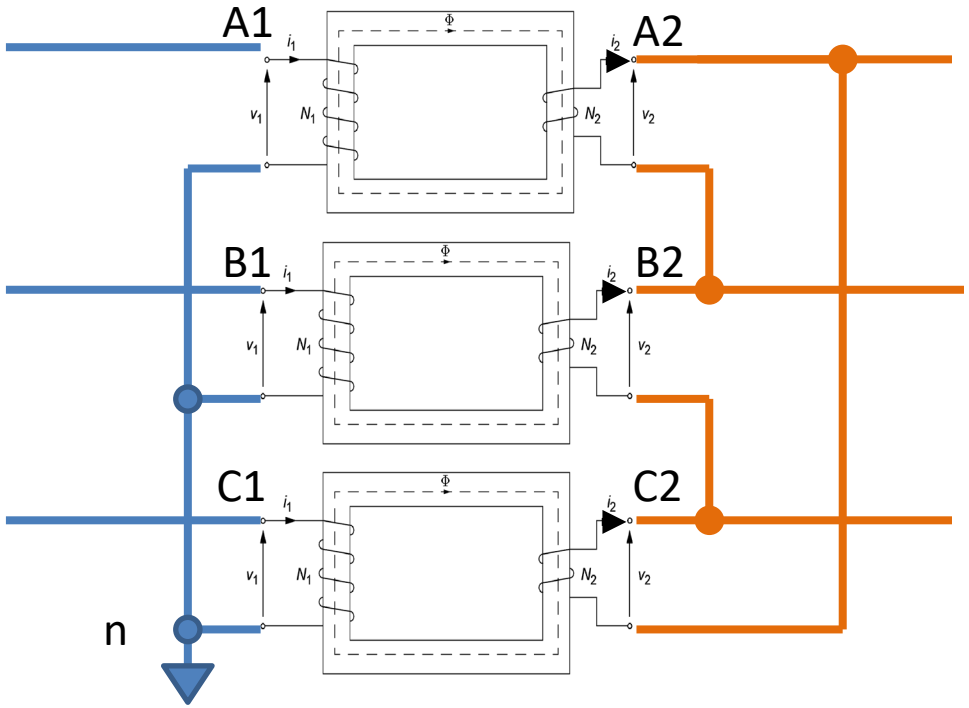
Wye-Delta and Delta-Wye transformer connections introduce some phase shift to the voltage.

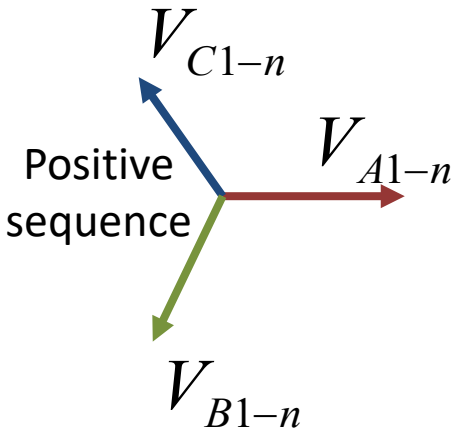
Per phase per unit circuit

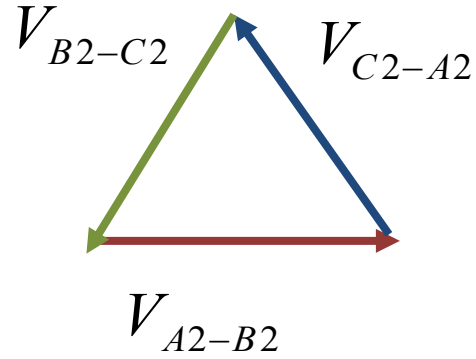


Wye-Delta 3Φ Transformers

Wye-connected Delta-connected







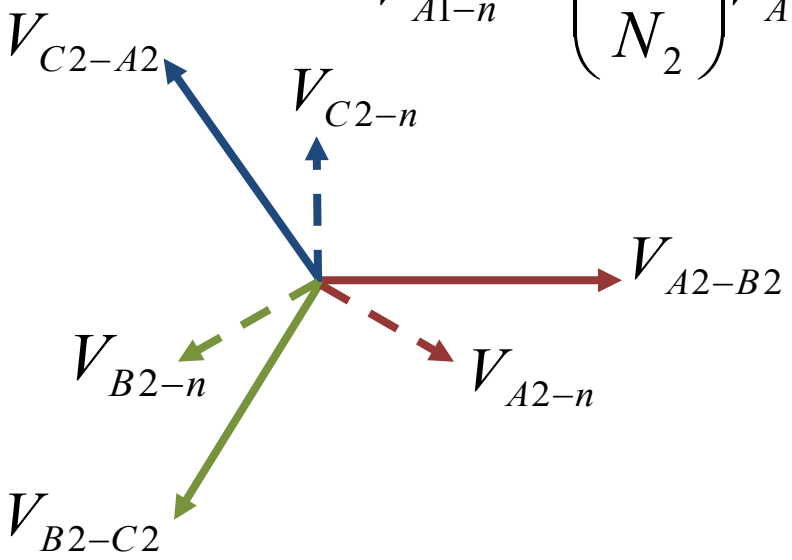
Line-to-neutral voltage

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

***Line-to-line** voltage!!*

Wye-Delta 3Φ Transformer

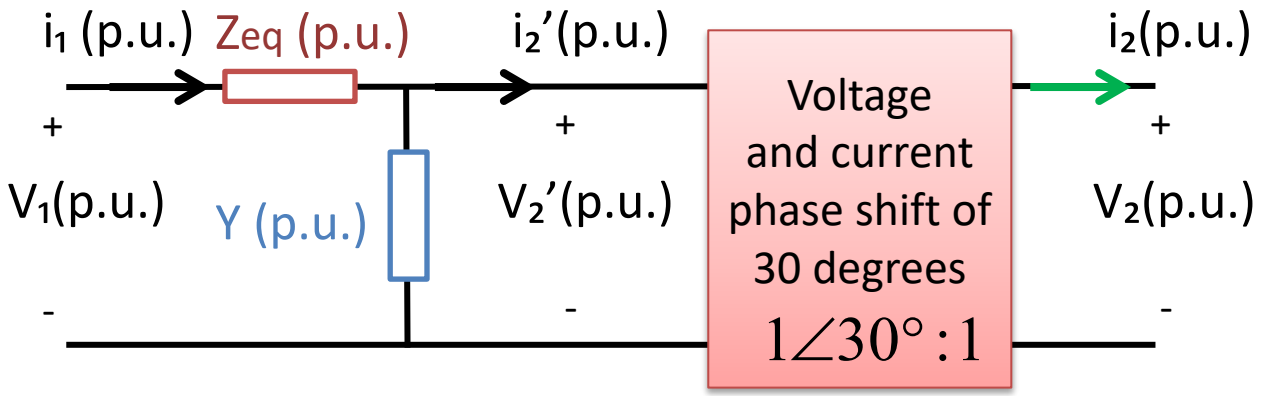
$$V_{A1-n} = \left(\frac{N_1}{N_2}\right) V_{A2-B2}$$



Y-Δ 3Φ Transformer: Per Phase Model

For a positive sequence voltage source,

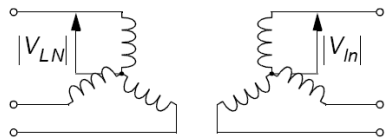
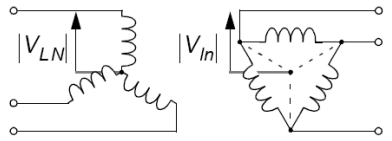
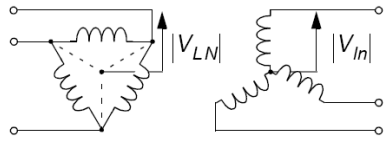
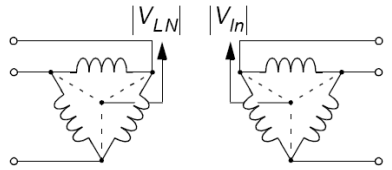
$$V_{A1-n} = \left(\frac{N_1}{N_2}\right)\sqrt{3}V_{A2-n}\angle 30° \quad \Rightarrow \quad \angle V_{A1-n} : \angle V_{A2-n} = 1\angle 30° : 1$$



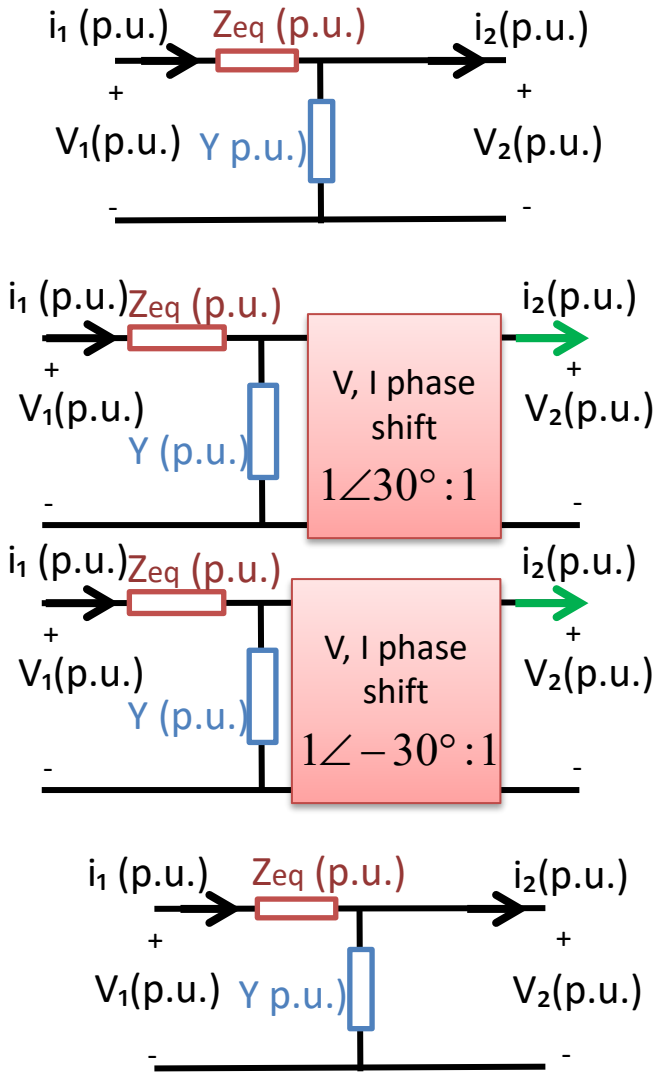
$$i_2 = i_2' \angle -30°$$

$$V_2 = V_2' \angle -30°$$

3Φ Transformer Per Unit Model

designation	winding connection
Yy	
Yd	
Dy	
Dd	

Per phase per unit circuit



Summary