EE2029: Introduction to Electrical Energy System

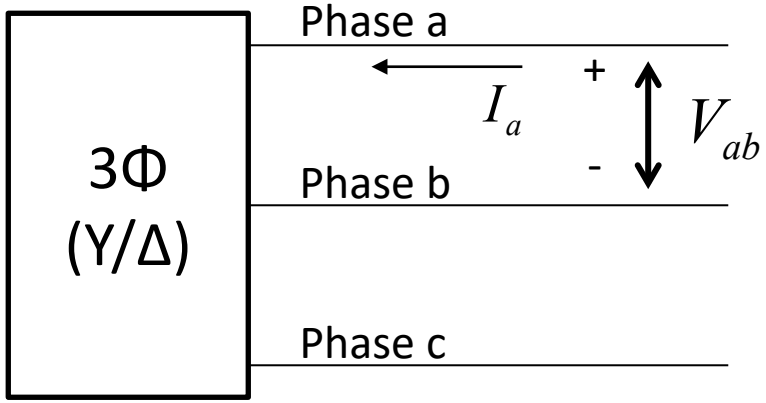
Per Unit Analysis: Three Phase Per Unit Analysis

Lecturer : Dr. Sangit Sasidhar (elesang)

Department of Electrical and Computer Engineering

Per Unit Analysis in 3Φ Circuit

- Recall that in three phase circuit:
  - Voltage is given as line-to-line voltage.
  - Current is given as line current.
  - Apparent power is given as three-phase power.



$$\left|S_{3\Phi}\right| = \sqrt{3}\left|V_{\text{Line-To-Line}}\right|\left|I_{\text{Line}}\right|$$

Base Value for Voltage: 3Φ Case

- Base values are **real numbers**, denote by subscript '*B*'.
- Voltage base values follow transformer voltage ratings.

$$V_B^{line-to-neutral} = \frac{V_B^{line-to-line}}{\sqrt{3}}$$

- Note that the voltage ratios are given as line-to-line voltage at both ends. This means that it already incorporates the factor of term in Y or Δ configurations.

Base Value for Power: 3Φ Case

- Only **single** base complex power $S_B^{3\Phi}$ in the system.
- The base value of power is used to normalize the quantity. Thus, the base values of real power, reactive power, and complex power are all the same real number.

Base Value for Current and Impedance: 3Φ Case

- Current base values are calculated from the base power and base voltage.

- Impedance base values (same value for impedance, resistance, or reactance) are calculated from voltage and current.

Change of Base Value-Per Unit Value for Impedance

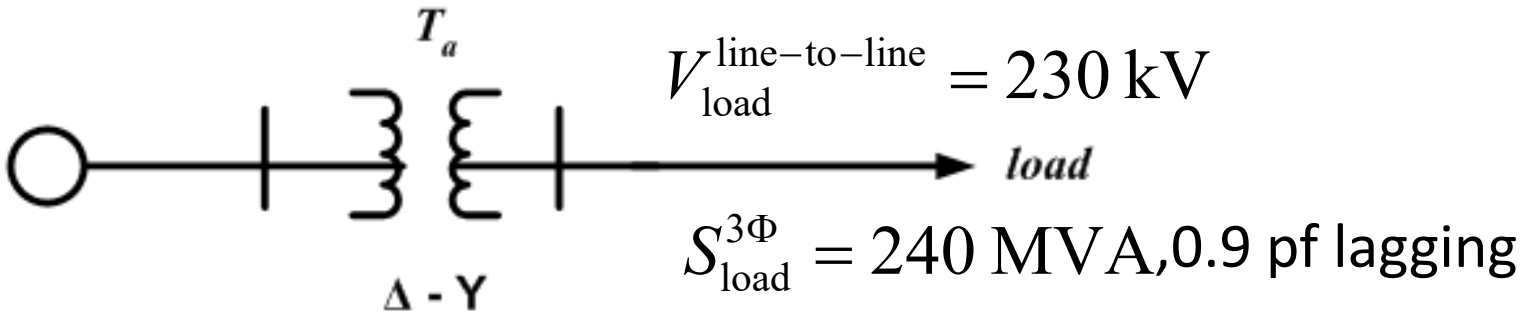
Steps of Calculation: 3Φ Case

1. Choose $S_B^{3\Phi}$ for the system.
2. Select $V_B^{\text{line-to-neutral}}$ or $V_B^{\text{line-to-line}}$ for different zones.
3. Calculate Z_{B} for different zones.
4. Express all quantities in p.u.
5. Draw impedance diagram and solve for p.u. quantities.
6. Convert back to actual quantities if needed.

Note that the **per unit circuit is** the circuit in **per-phase analysis** with normalization of the voltage magnitude at different locations. This means that **the phase of voltage** in per unit analysis **refers to** the **line-to-neutral voltage**.

Example : Δ-Y 3Φ Transformer

- Three-phase generator rated 300 MVA,23 kV supplying a system Y-connected load of 240 MVA, 0.9 power factor lagging at 230 kV through a 330 MVA 23Δ/ 230Y kV **step-up** transformer of leakage reactance 11%.
- Use **base values at the load of 100 MVA and 230 kV**, find the current supplied by the generator. Use *load voltage for an angle reference*.

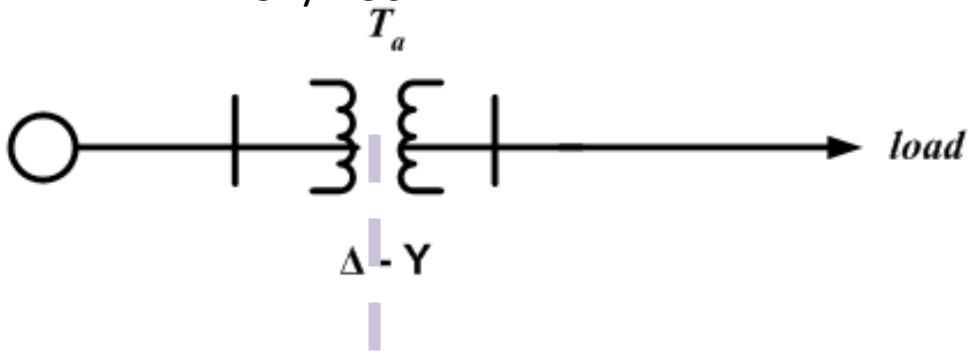


Example : Transformer Reactance

$S_B^{3\Phi} = 100\ \text{MVA}$

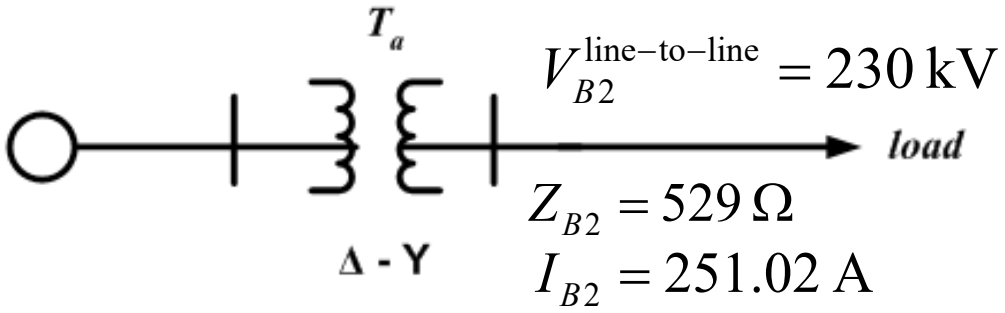
330 MVA $X_{T1} = 0.11\ \text{p.u.}$

23Δ/ 230Y kV

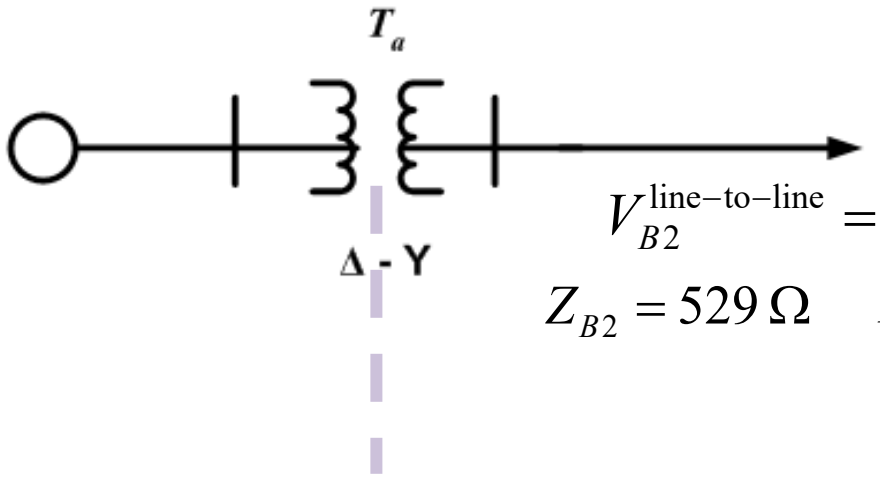


Example : Load Voltage and Current

$$S_B^{3\Phi} = 100\ \text{MVA}$$



Example : Per Unit Values

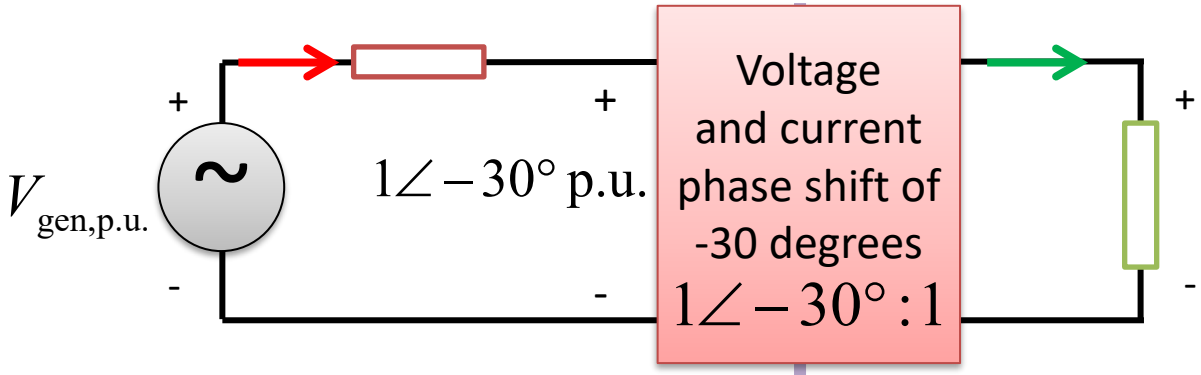


$$V_{B2}^{\text{line-to-line}} = 230\,\text{kV}$$

$$Z_{B2} = 529\,\Omega \qquad I_{B2} = 251.02\,\text{A}$$

Example : Per Unit Circuit

$I_{B1} = 2510.2\ \text{A}$ $I_{B2} = 251.02\ \text{A}$



Summary