

SAARC Training Workshop 'Power System Studies for Synchronization of Multiple Systems'

Short Circuit Analysis in Balanced 3-Phase System

Day-2-A

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Symmetrical System Balanced System

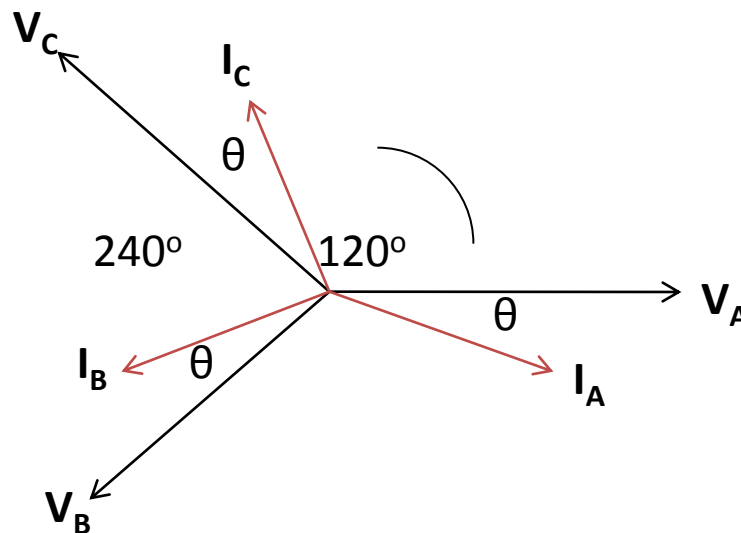
- Symmetrical means
 - Voltages are equal in magnitude and 120° apart
 - Phase impedances are same
 - Line Currents are equal in magnitude and 120° apart
- Balanced 3-Phase Symmetrical System

$$|V_A| = |V_B| = |V_C|$$

$$|I_A| = |I_B| = |I_C|$$

$$|Z_A| = |Z_B| = |Z_C|$$

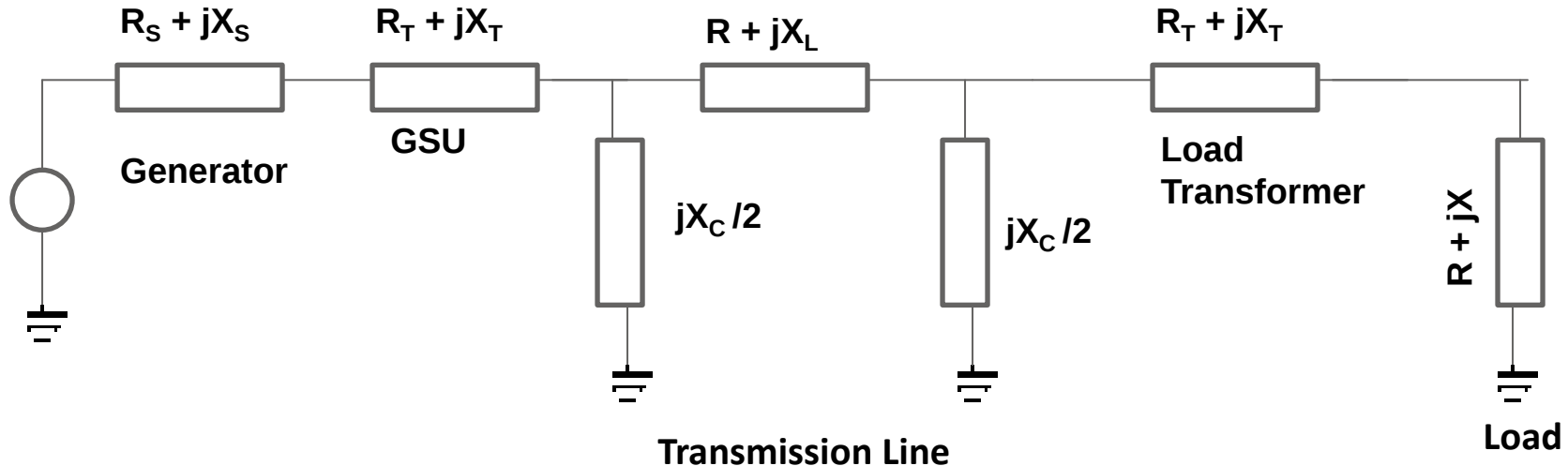
- Phases a, b and c are displaced by 120°
- All Currents lagging the Voltages by angle θ



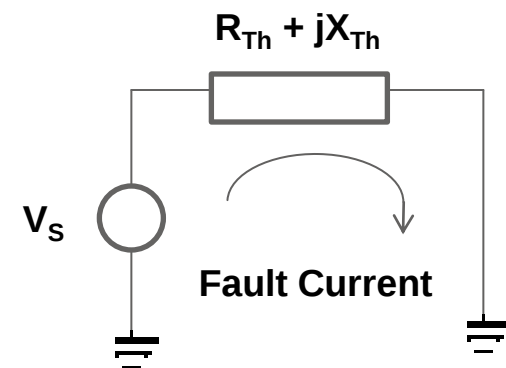
$$V_{\text{Phase}} = \frac{V_{L-L}}{\sqrt{3}}$$

$$MVA = \sqrt{3} V_{L-L} \times I$$

Equivalent Model of a Simple Power System Under Symmetrical Fault



- Thevenin Equivalent for 3-Phased Symmetrical Faults
- Thevenin Impedance, $Z_{Th} = R_{Th} + jX_{Th}$
- Pre-Fault Source Voltage = V_S
- Symmetrical 3-Phase Fault Current = $V_S / R_{Th} + jX_{Th}$
- Short Circuit MVA = $V_S * I_{Fault} = (V_S)^2 / Z_{Th}$



Symmetrical 3-Phase Fault Balanced System

- Mostly the impedance limiting the fault currents are reactive i.e. transformers, reactors, generators and reactance of line
- Percent Reactance is the percentage of the total phase –voltage dropped in the circuit when full-load current is flowing i.e.

$$\% X = \frac{IX}{V} \times 100$$

where I = Full Load Current

V = Phase Voltage

X = Reactance in ohms per phase

If X is the only reactance element then Short Circuit current is

$$\begin{aligned} I_{sc} &= \frac{V}{X} \\ &= I \times \left(\frac{100}{\% X} \right) = I \times \frac{1}{X_{pu}} \end{aligned}$$

- Short Circuit MVA for 3-phase system

$$\begin{aligned} MVA_{sc} &= \frac{3VI_{sc}}{10^6} = \frac{3VI}{10^6} \times \frac{1}{X_{pu}} \\ &= \text{Base MVA} \times \frac{1}{X_{pu}} \end{aligned}$$

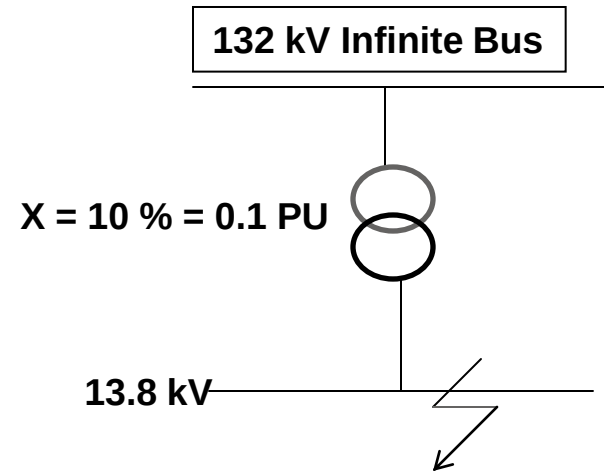
Symmetrical 3-Phase Fault Balanced System

- For 132/13.8 kV Transformers

$$MVA_{SC} = \text{Base MVA} \times \frac{1}{X_{PU}}$$

$$MVA_{SC} = 40 \times \frac{1}{0.2} = 200 \text{ MVA}$$

$$I_{SC} = I \times \frac{1}{X_{PU}} = 1673 \times \frac{1}{0.2} = 8367 \text{ A}$$

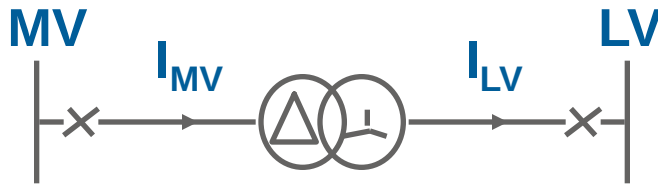


Transformer	Rated MVA	Base MVA	X at own base		Fault Calculations at kV	3-Phase MVA _{SC}	Full Load Current at Base MVA	3-Phase Fault Current I_{SC}	
			Per Cent	Per Unit				Amps	kA
110/13.8 kV	40	40	20	0.2	13.8	200	1673	8367	8.37
110/13.8 kV	67	60	26.4	0.264	13.8	227	2510	9508	9.51

Referring Through Transformers

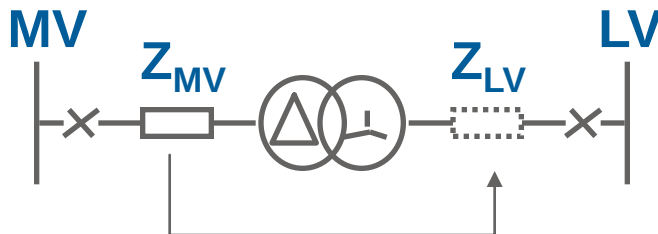
For fault calculations all quantities must be referred to a common voltage base

Current



$$I_{LV} = I_{MV} \times \frac{\text{MV Volts}}{\text{LV Volts}}$$

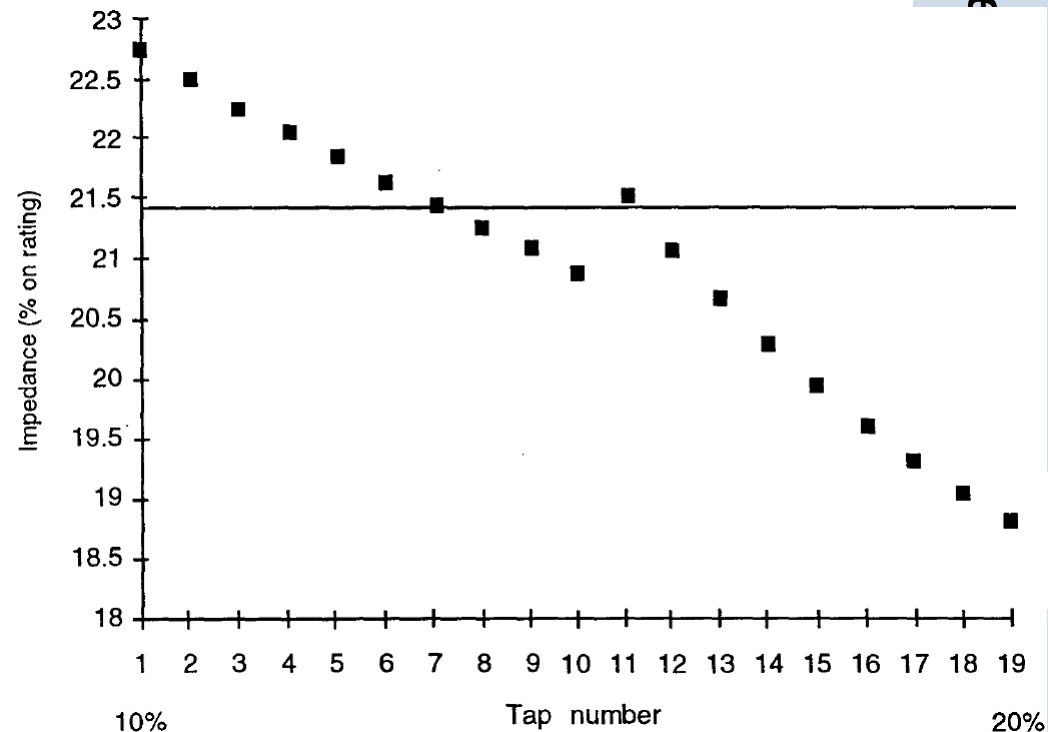
Impedance



$$Z_{LV} = Z_{MV} \times \left(\frac{\text{LV Volts}}{\text{MV Volts}} \right)^2$$

Transformer fault level issues

- The leakage reactance changes with the tap position of the transformer
- This is caused by the varying amount of winding conductors for the different taps
- This may be particularly significant in transformers with high reactance



Typical distribution transformer - 2

(With tap changer on the LV winding)

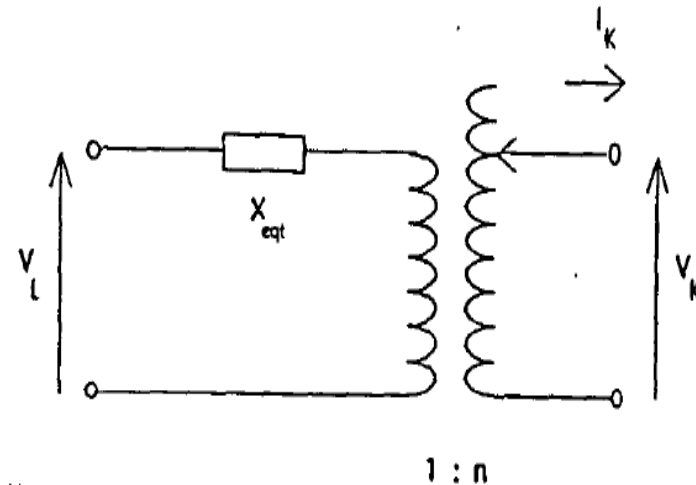
Assume fault on the LV side.

i.e. $V_K = 0$, $V_L = V_{\text{Source}}$

$$I_K = \frac{I_L}{n}$$

To change the tap position to raise the LV voltage here, one would decrease the turns ratio, n .

This would effectively decrease the fault current



$$I_K = \frac{V_K}{n \cdot X_{eqt}}$$