

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

Fault Current Path

Day-2-F

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Single-phase-to-earth fault currents - 1

- For a single-phase-to-earth fault current to flow, there must be a path for the current to flow to ground
 - The grounded star point of a star connected transformer allows earth fault currents to flow
 - A delta winding of a transformer does not present a path to earth, and acts as a trap for zero sequence currents, which will not lead to any significant single phase fault currents on the delta side of the transformer

Single-phase-to-earth fault currents - 2

- Most common fault in electrical distribution systems
- Magnitude depends upon the method of earthing
- Transmission systems are usually solidly earthed through the 400/132kV, star-star transformers
- This leads to 400kV and 132kV busbars having:

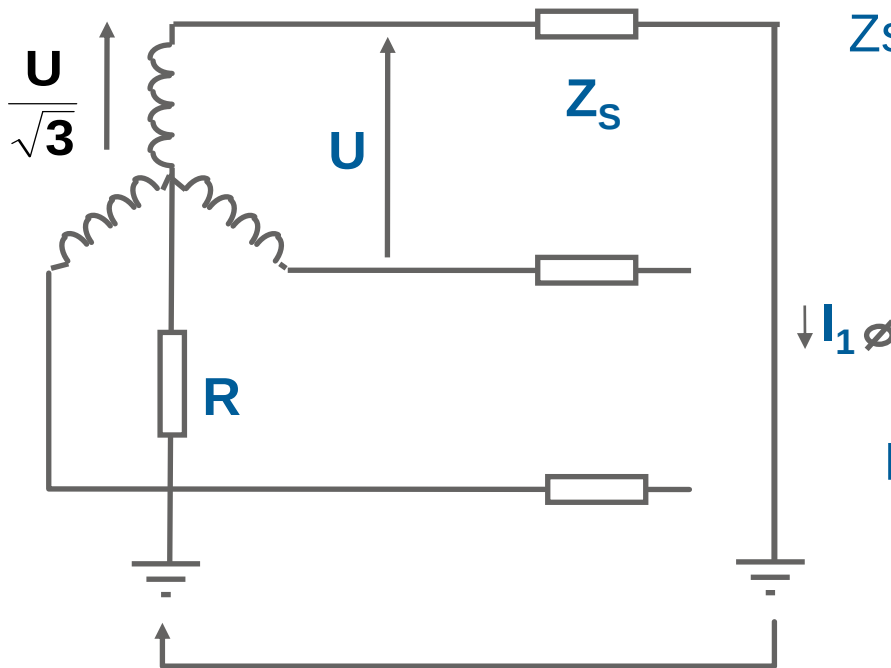
$$I_{1\Phi} \approx I_{3\Phi}$$

- In a solidly earthed system, the maximum single phase fault current may be greater than three-phase currents on the transmission system.

Single-phase-to-earth fault currents - 3

- Distribution systems (33 kV and 11 kV) are generally resistively earthed using earthing resistors and earthing transformers. The single phase fault current is limited by the earthing impedance. For 33kV and 11 kV busbars: $I_{\text{Single phase}} \ll I_{\text{Three phase}}$

Resistance Earthed System



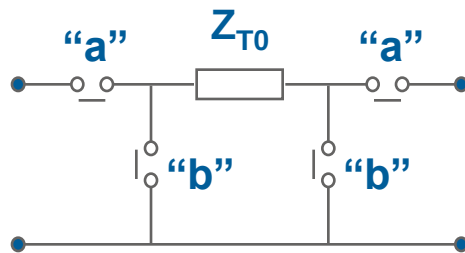
Z_s negligible compare to R

$$I_{1\Phi} \approx \frac{U}{\sqrt{3} \cdot R}$$

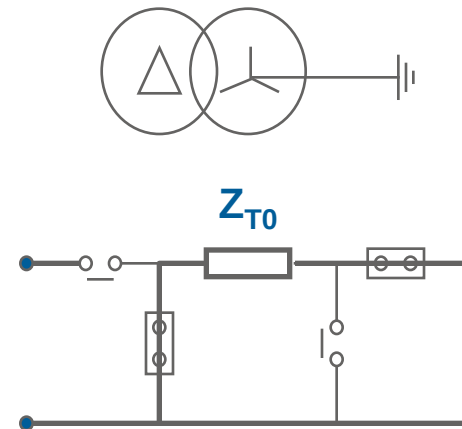
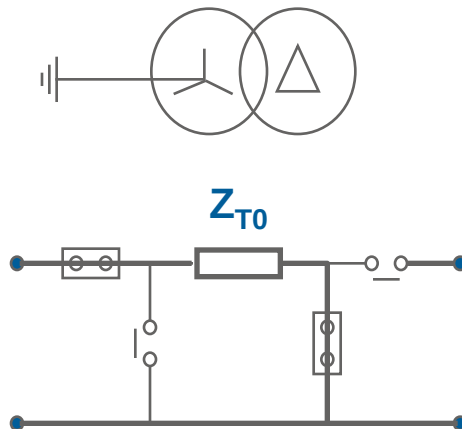
Practical values at 11kV:

$$100\text{A} \leq I_{1\Phi} \leq 1\text{kA}$$

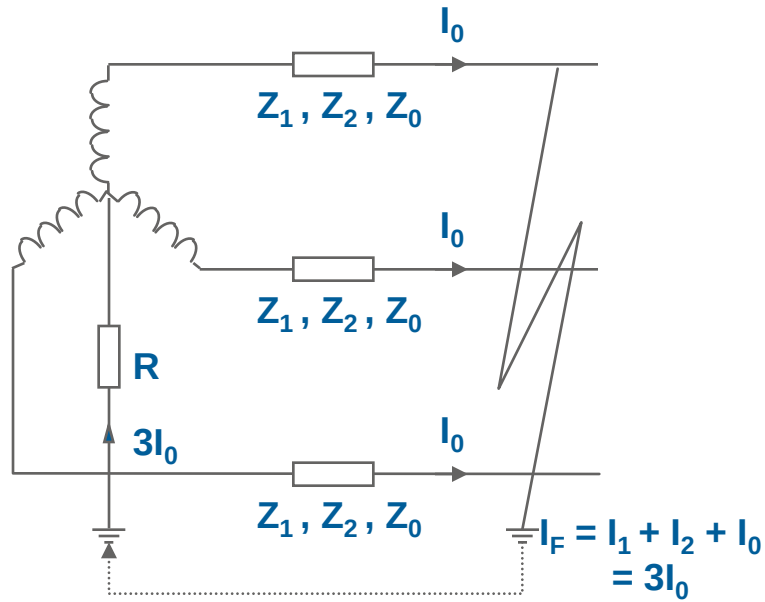
Transformer Zero Sequence Circuit



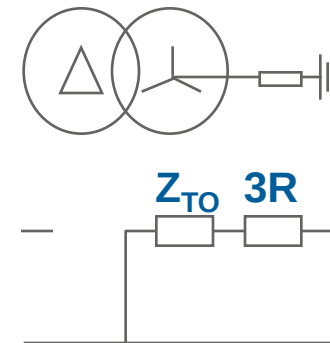
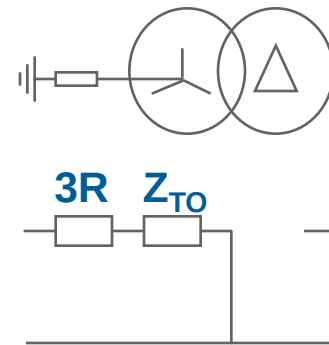
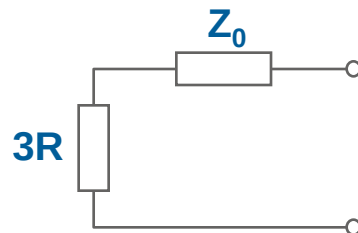
- Link "a" is closed if zero sequence current can flow into and out of a winding e.g. solidly earthed star winding
- Link "b" is closed if zero sequence current can circulate within a winding without flowing in the external circuit e.g. delta winding



Earthing Resistors

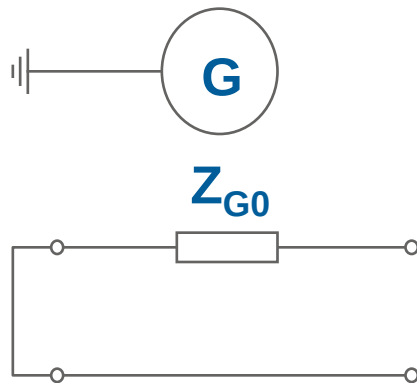
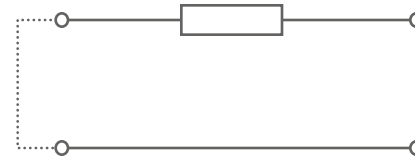


zero sequence circuit :

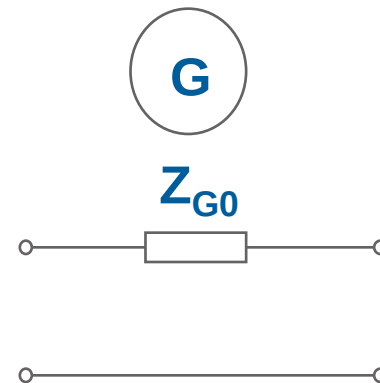


Zero Sequence Circuit for Unearthed Equipment

Connection can only be made to neutral in zero sequence circuit if equipment is earthed



Earthed generator



Unearthed generator

Induction Motors and Faults Levels

Effect of Induction Motor Loads

- Induction motors will transiently generate current upon occurrence of a fault
- Motor Contribution to initial short circuit current

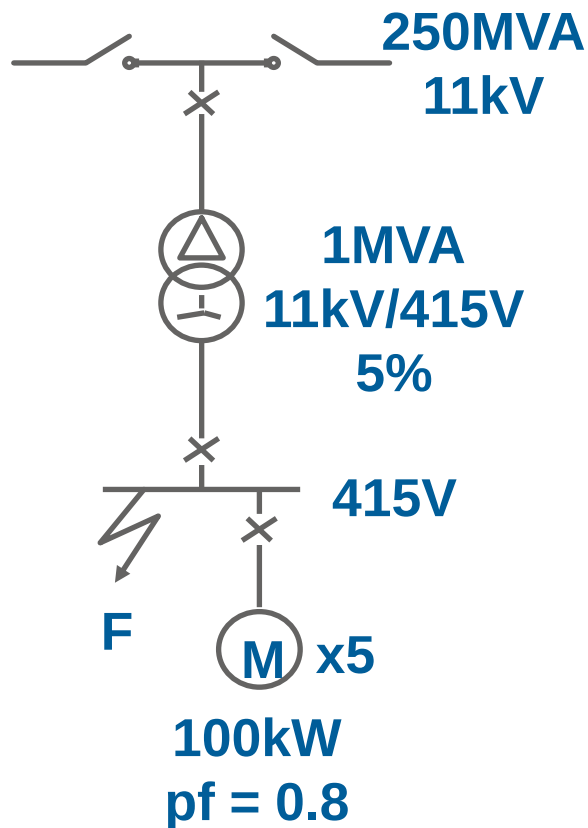
$$I_{FM} = \frac{I_{LR}}{I_{rM}} \times \text{motor rated current}$$

where $\frac{I_{LR}}{I_{rM}}$ is the ratio of the machine locked rotor current to

rated current - typically between 4 and 6

- Motor contribution may be ignored for steady state fault calculations

Distribution system with induction motor loads - 1



Calculate the initial value of fault current for a 3-phase fault at F

assume $\frac{I_{LR}}{I_{rM}} = 4$

Distribution system with induction motor loads - 2

100kW Motor Rated Current I_{rM}

$$I_{rM} = \frac{100\text{kW}}{0.8 \times \sqrt{3} \times 415\text{V}} = 174\text{A at } 415\text{V}$$

Motor Transient Contribution I_{FM}

$$I_{FM} = 5 \times \left(\frac{I_{LR}}{I_{rM}} \times I_{rM} \right) = 5 \times (4 \times 174\text{A}) = 3480\text{A at } 415\text{V}$$

$$I_{FM} = 3480 \times \frac{415\text{V}}{11\text{kV}} \text{ A at } 11\text{kV} = 131\text{A at } 11\text{kV}$$

Distribution system with induction motor loads - 3

Fault Current Supplied Via Transformer I_{FT}

$$I_{FT} = \frac{100}{5} \times \frac{1\text{MVA}}{\sqrt{3} \times 11\text{kV}} = 1050\text{A at } 11\text{kV}$$

Initial r.m.s. Value of Fault Current I_F''

$$I_F'' = I_{FT} + I_{FM}$$

$$I_F'' = 1050\text{A} + 131\text{A} = 1181\text{A at } 11\text{kV}$$