UNIT -2

SHORT CIRCUIT ANALYSIS

Basic Units

- The 4 basic electrical quantities are

  Voltage V (volt)

  Current I (amp)

  Impedance Z (ohm)

  Power S (VA)
- For single-phase circuits

  V(volt) = Z(ohm) × I(amp);

  S (VA) = V(volt) × I(amp)*

Per unit notation

- In per unit notation, the physical quantity is expressed as a fraction of the reference value, i.e.
- per unit value = actual value/base value in the same unit.
- e.g. V(in per unit) = V(in kV)/V base (in kV) where the base value is a reference value for magnitude.

Base Quantities

- In per unit notation we would like to keep

the basic relations:

- $V_{pu} = Z_{pu} I_{pu}$; $S_{pu} = V_{pu} I_{pu}^*$
- Hence the base quantities should be chosen

such that

- Base voltage (V_B) = base impedance (Z_B) × base current (I_B)
- Base power (S_B) = base voltage (V_B) × base current(I_B)

Base Quantities

- It is common practice to specify base power (S_B) and base voltage (V_B)
- Then it follows

base current $I_B = S_B/V_B$

base impedance $Z_B = V_B/I_B$

Percentage Values

- An equivalent way to express the per unit value is the percentage value where

Percentage value = per unit value $\times$ 100%

Base Value for 3-phase systems

- For 3-phase systems it is common practice
to describe system operation with:
- total 3-phase power $S = S_{3\text{-}Ø}$
- line voltage $V = V_{line}$
- line current $I = I_{line}$
- equivalent impedance/phase $Z = Z_{ph}$
with (in magnitude)
- $V = \sqrt{3}ZI$; $S = \sqrt{3}VI$

Base Value for 3-phase systems

- per unit=actual value/base value
- Let KVA_b=Base KVA
- kV_b=Base voltage
- Z_b=Base impedance in Ω

$$Z_b = \frac{(kV_b)^2}{MVA_b} = \frac{(kV_b)^2}{\frac{KVA_b}{1000}}$$

Changing the base of per unit quantities

- Let z = actual impedance(Ω)
- = base impedance (Ω)

$$Z_{p.u} = \frac{Z}{Z_b} = \frac{Z}{\frac{(kV_b)^2}{MVA_b}} = \frac{Z * MVA_b}{(kV_b)^2}$$

$$kV_{b,old} \ \& \ MVB_{b,old}$$

$$kV_{b,new} \ \& \ MVB_{b,new}$$

Changing the base of per unit quantities

$$Z_{p.u,old} = \frac{Z * MVA_{b,old}}{\left(kV_{b,old}\right)^2} \rightarrow (1)$$

$$Z = \frac{Z_{p.u,old} * MVA_{b,old}}{\left(kV_{b,old}\right)^2} \rightarrow (2)$$

$$Z_{p.u,new} = \frac{Z * MVA_{b,new}}{\left(kV_{b,new}\right)^2} \rightarrow (3)$$

$$Z_{p.u,new} = Z_{p.u,old} * \frac{\left(kV_{b,old}\right)^2}{\left(kV_{b,new}\right)^2} * \frac{MVA_{b,new}}{MVA_{b,old}}$$

Advantages of Per Unit System

- Normally we are dealing with numerics near unity rather than over a wide range.
- Provides a more meaningful comparison of parameters of machines with different ratings.
- As the per unit values of parameters of a machine of a given design normally falls within a certain range, a typical value can be used if such parameters are not provided.

Symmetrical Fault Analysis

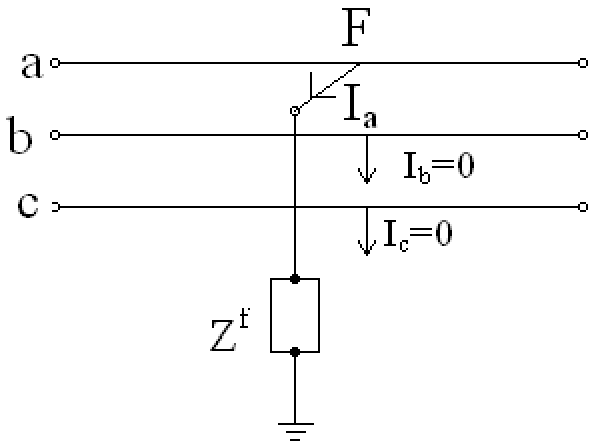
- One or two phases are involved Voltages and currents become unbalanced and each phase is to be treated individually
- The various types of faults are
- Shunt type faults

  1.Line to Ground fault (LG)

  2. Line to Line fault (LL)

  3. Line to Line to Ground fault (LLG)

Single Line To Ground Fault



$$I_b = 0$$

$$I_c = 0$$

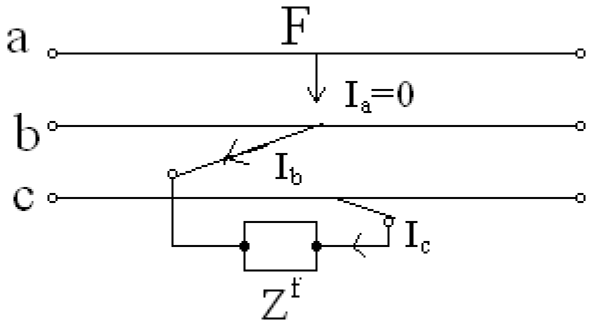
$$V_a = Z^f I_a$$

$$I_{a1} = I_{a2} = I_{a0} = I_a / 3$$

$$I_{a1} = \frac{E_a}{Z_1 + Z_2 + Z_0 + 3Z^f}$$

Consider a fault between phase a and ground through an impedance z_f

Line To Line (LL) Fault



Consider a fault between phase b and c through an impedance z_f

$$I_a = 0$$

$$I_c = -I_b$$

$$V_b - V_c = I_b Z^f$$

$$I_{a2} = -I_{a1}$$

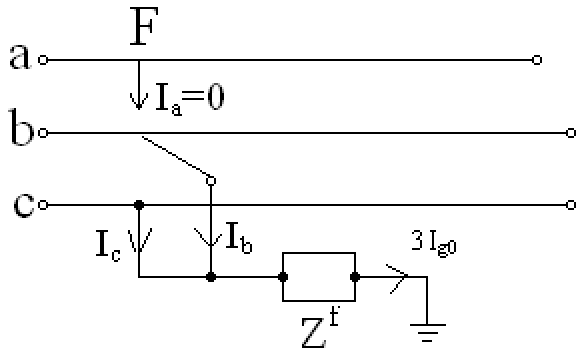
$$I_{a0} = 0$$

$$V_{a1} - V_{a2} = Z^f I_{a1}$$

$$I_{a1} = \frac{E_a}{Z_1 + Z_2 + 3Z^f}$$

$$I_b = -I_c = \frac{-jE_a}{Z_1 + Z_2 + 3Z^f}$$

Double Line To Ground (LLG) Fault



$$I_{a0} = 0$$

$$I_{a1} + I_{a2} + I_{a0} = 0$$

$$V_b = V_c = Z^f (I_b + I_c) = 3Z^f I_{a0}$$

$$V_{a0} - V_{a1} = V_b = 3Z^f I_{a0}$$

$$I_{a1} = \frac{E_a}{Z_1 + Z_2(Z_0 + 3Z^f)/(Z_2 + Z_0 + 3Z^f)}$$

Consider a fault between phase b and c through an impedance z_f to ground

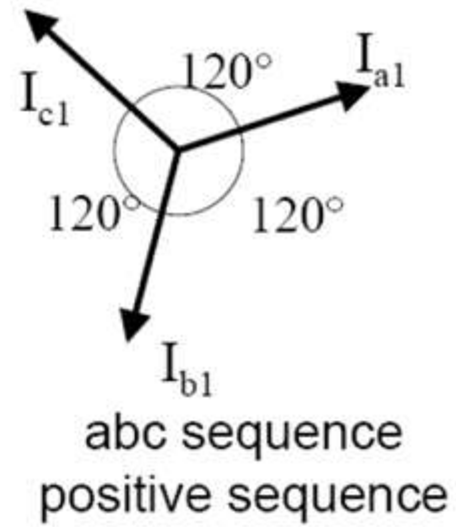
Fundamentals Of Symmetrical Components

- Symmetrical components can be used to transform
  three phase unbalanced voltages and currents to
  balanced voltages and currents
- Three phase unbalanced phasors can be resolved into
  following three sequences
  1. Positive sequence components
  2. Negative sequence components
  3. Zero sequence components

Positive sequence components

- Three phasors with equal magnitudes, equally displaced from one another by 120° and phase sequence is same as that of original phasors.

$$V_{a1}, V_{b1}, V_{c1}$$



Positive Sequence Phasors

$$I_{a1} = |I_{a1}| \angle(0^\circ) = I_{a1}$$

$$I_{b1} = |I_{a1}| \angle(+240^\circ) = a^2 I_{a1}$$

$$I_{c1} = |I_{a1}| \angle(+120^\circ) = a\, I_{a1}$$

$$a = 1\angle 120^\circ = -0.5 + j0.866$$

$$a^2 = 1\angle 240^\circ = -0.5 - j0.866$$

$$a^3 = 1\angle 0^\circ = 1 + j0$$

$$1 + a + a^2 = 0$$

Negative Sequence Phasor

$$I_{a2} = |I_{a2}| \angle (\quad 0^\circ) = I_{a2}$$

$$I_{b2} = |I_{a2}| \angle (+120^\circ) = a\, I_{a2}$$

$$I_{c2} = |I_{a2}| \angle (+240^\circ) = a^2 I_{a2}$$

Zero Sequence Phasor

$$I_{a0} = |I_{a0}| \angle (0°) = I_{a0}$$

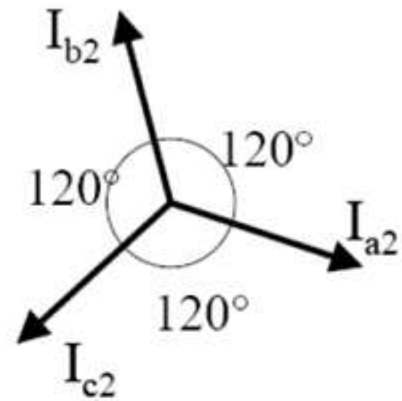
$$I_{b0} = |I_{a0}| \angle (0°) = I_{a0}$$

$$I_{c0} = |I_{a0}| \angle (0°) = I_{a0}$$

Negative sequence components

- Three phasors with equal magnitudes, equally displaced from one another by 120° and phase sequence is opposite to that of original phasors.

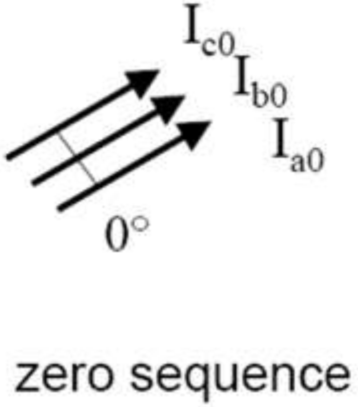
$$V_{a2}, V_{b2}, V_{c2}$$



Zero sequence components

- Three phasors with equal magnitudes and displaced from one another by 0°.

$$V_{a0}, V_{b0}, V_{c0}$$



Relationship Between Unbalanced Vectors And Symmetrical Components

$$V_a = V_{a0} + V_{a1} + V_{a2}$$
$$V_b = V_{b0} + V_{b1} + V_{b2}$$
$$V_c = V_{c0} + V_{c1} + V_{c2}$$

$$\begin{bmatrix} V_a \\ V_b \\ V_c \end{bmatrix} = \begin{pmatrix} 1 & 1 & 1 \\ 1 & a^2 & a \\ 1 & a & a^2 \end{pmatrix} \begin{bmatrix} V_{a0} \\ V_{a1} \\ V_{a2} \end{bmatrix}$$

$$A = \begin{pmatrix} 1 & 1 & 1 \\ 1 & a^2 & a \\ 1 & a & a^2 \end{pmatrix}$$

Sequence Impedance

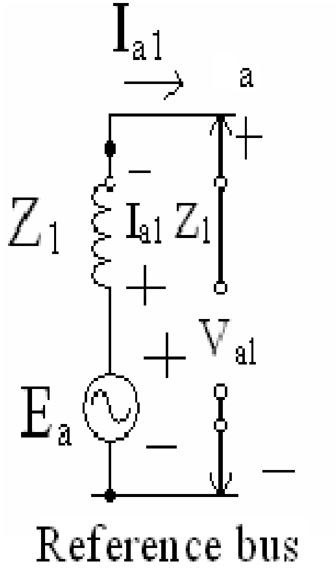
- Positive sequence impedance

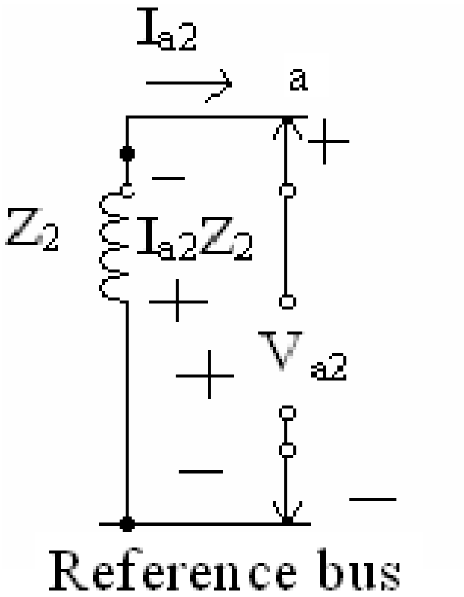
  The impedance of a component when positive sequence currents alone are flowing.
- Negative sequence impedance

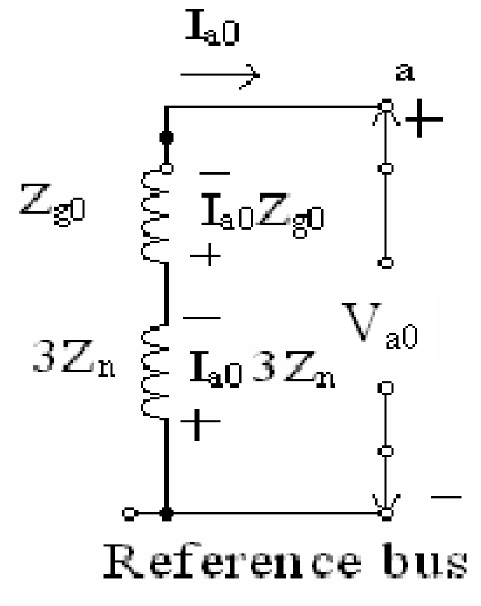
  The impedance of a component when negative sequence currents alone are flowing.
- Zero sequence impedance

  The impedance of a component when zero sequence currents alone are flowing.

Sequence Networks







Zero sequence network

positive sequence network

negative sequence network