Lecture-4

phase shift in star-delta transformation

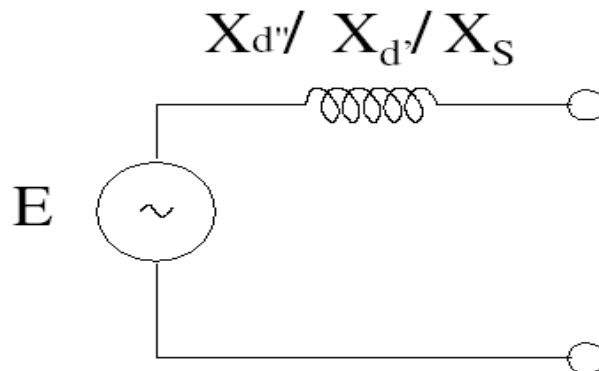# Topic Covered

- Sources of Fault Current
- Sequence Components
- Advantages of Sequence Transformation

◆ Sources of Fault Current

- Synchronous Generators
- Synchronous Motors and Condensers
- Induction Machines
- Electrical Utility System
- Distributed Generation (modeling in fault analysis. research problem!)

➤Representation of Rotating Machines.

This fault current diminishes as the magnetic field in the machine decays.

◆What does a fault Analysis program do?

- Simulates a fault (steady state analysis)
  - ✓ SLG
  - ✓ LLG
  - ✓ LL
  - ✓ Three phase
- Results
  - ✓ SC – MVA

$$SC\text{-}MVA(3\text{-}phase) = \sqrt{3} \ |V|_{prefault} \ In\,KV \times \ |I|_{sc} \ In\ KA \ ....\ in\,MVA.$$

$$SC\text{-}MVA(3\text{-}phase) = \sqrt{3} \ |V|_{prefault} \times \ |I|_{sc} \times (MVA)_{Base} ....in\,p.u.$$

  - ✓ Fault current (in A)
  - ✓ Contribution of various lines to fault current analysis.

What are Sequence Components?

$$\underbrace{\begin{bmatrix} \Delta V_a \\ \Delta V_b \\ \Delta V_c \end{bmatrix}}_{\Delta V^{abc}} = \begin{bmatrix} Z_s & Z_m & Z_m \\ Z_m & Z_s & Z_m \\ Z_m & Z_m & Z_s \end{bmatrix} \underbrace{\begin{bmatrix} I_a \\ I_b \\ I_c \end{bmatrix}}_{I^{abc}}$$

$$\begin{bmatrix} I_a \\ I_b \\ I_c \end{bmatrix} = \begin{bmatrix} T \end{bmatrix} \begin{bmatrix} I_a^0 \\ I_a^1 \\ I_a^2 \end{bmatrix}$$

$$\begin{bmatrix} \Delta V_a \\ \Delta V_b \\ \Delta V_c \end{bmatrix} = \begin{bmatrix} T \end{bmatrix} \begin{bmatrix} \Delta V_a^0 \\ \Delta V_a^1 \\ \Delta V_a^2 \end{bmatrix}$$

Where,

$$[\ T\ ] = \begin{bmatrix} 1 & 1 & 1 \\ 1 & a^2 & a \\ 1 & a & a^2 \end{bmatrix} \quad And \ a = e^{j\pi/3}$$

$$\begin{bmatrix} \Delta V_a^0 \\ \Delta V_a^1 \\ \Delta V_a^2 \end{bmatrix} = \begin{bmatrix} Z_s + 2Z_m & 0 & 0 \\ 0 & Z_s - Z_m & 0 \\ 0 & 0 & Z_s - Z_m \end{bmatrix} \begin{bmatrix} I_a^0 \\ I_a^1 \\ I_a^2 \end{bmatrix}$$
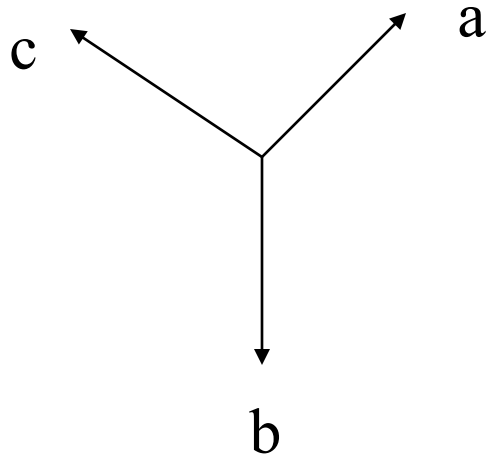
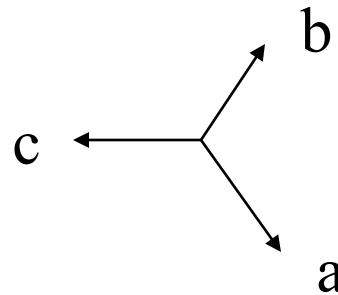a $\Rightarrow$ Reference Phase.

T changes with Reference Phasor.

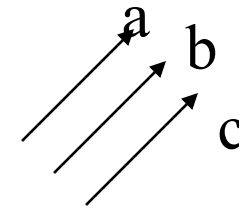**Q.] Write a transformation with b-Phase as Reference Phase.**

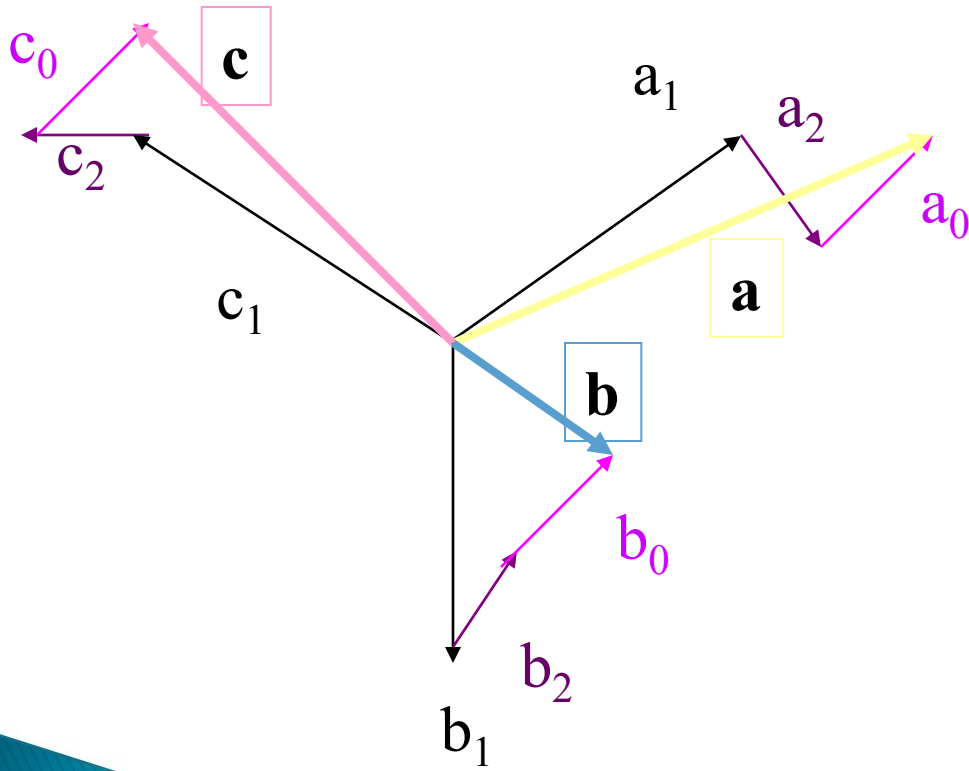# Sequence components

+ve Seq. Component   -ve Sequence   0 Sequence

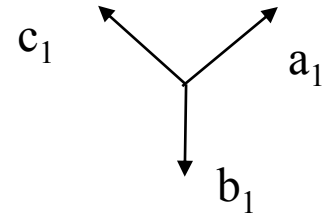
- Unbalanced 3-phase system has six degrees of freedom.
- Every balanced set of phasors has two degrees of freedom (Forteskue,1918).
- Together +ve,-ve and 0 sequence phasors have six degrees of freedom.
- Hence they can be used to synthesize 3phase unbalanced systems.
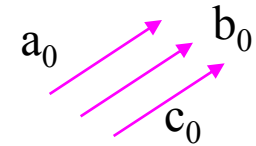
Unbalanced System and Sequence Components

Extracting Sequence Components
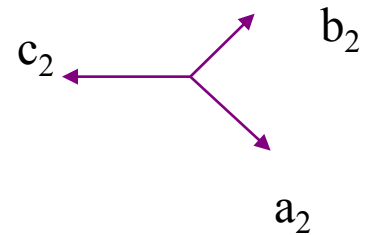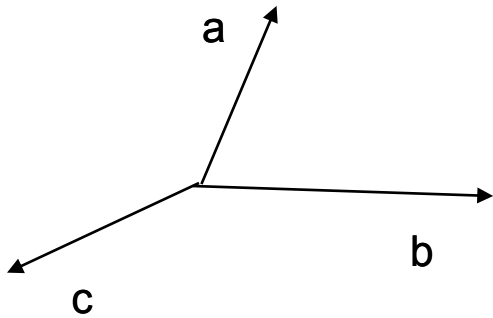
Unbalanced System

a

b

c

Zero Seq. Components

b

a

c

$3a_0$
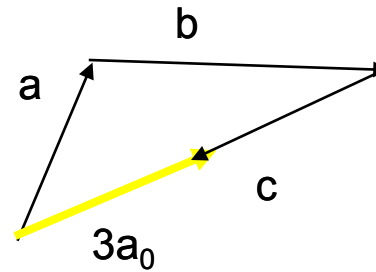
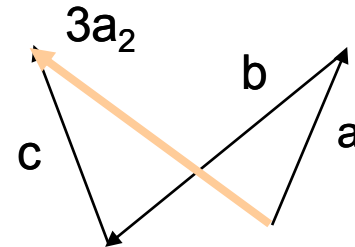**Positive Seq. Components**

c

b

a

$3a_1$
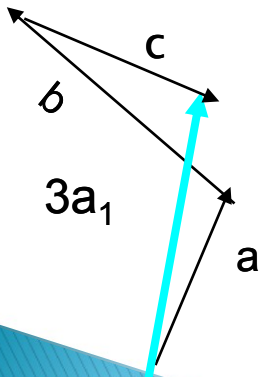
Negative Seq. Components

$3a_2$

b

c

a

Advantages of Sequence Transformation

- Used when the network is balanced. Provides decoupling in the network. A 3nX3n Linear System Solver is decoupled into three n X n Linear System Solver.

- Load may be balanced or unbalanced.

- Zero sequence currents provide sensitive earth fault detection technique.