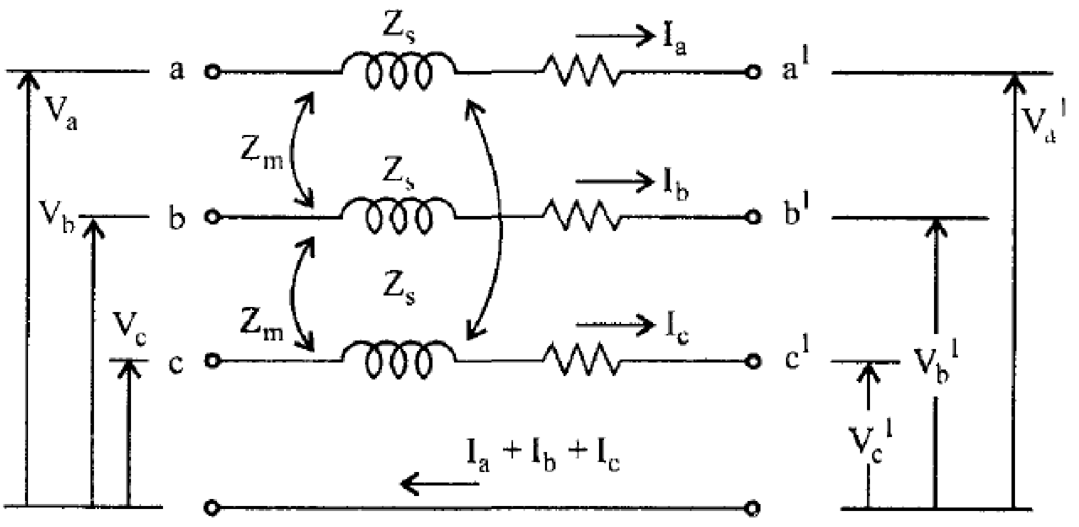
6-1-2 Sequence Impedances of Transmission Lines

Transmission lines are static components in a power system. Phase sequence has thus, no effect on the impedance. The geometry of the lines is fixed whatever may be the phase sequence. Hence, for transmission lines

$Z_1 = Z_2$

we can proceed in the same way as for the balanced 3-phase load for 3-phase transmission lines also



$$V_a - V_a' = Z_s I_a + Z_m I_b + Z_m I_c$$

$$V_b - V_b' = Z_m I_a + Z_s I_b + Z_m I_c$$

$$V_c - V_c' = Z_m I_a + Z_m I_b + Z_s I_c$$

$$\begin{bmatrix} V_a - V_a' \\ V_b - V_b' \\ V_c - V_c' \end{bmatrix} = \begin{bmatrix} Z_s & Z_m & Z_m \\ Z_m & Z_s & Z_m \\ Z_m & Z_m & Z_s \end{bmatrix} \begin{bmatrix} I_a \\ I_b \\ I_c \end{bmatrix}$$

$$[V_{abc}] = [V_{abc}] - [V_{abc'}] = [Z_{abc}]\,[I_{abc}]$$

$$[Z^{0,1,2}] = [A^{-1}]\,[Z_{abc}]\,[A]$$

$$= \begin{bmatrix} Z_s + 2Z_m & 0 & 0 \\ 0 & Z_s - Z_m & 0 \\ 0 & 0 & Z_s - Z_m \end{bmatrix}$$

The zero sequence currents are in phase and flow through the line conductors only if a return conductor is provided. The zero-sequence impedance is different from positive and negative sequence impedances.

6- 1-3 Sequence Impedances and Networks of Transformer

It is well known that almost all present day installations have three-phase transformers since they entail lower initial cost, have smaller space requirements and higher efficiency.

The positive sequence series impedance of a transformer equals its leakage impedance. Since a transformer is a static device, the leakage impedance does not change with alteration of phase sequence of balanced applied voltages. The transformer negative sequence impedance is also therefore equal to its leakage reactance. Thus. for a transformer

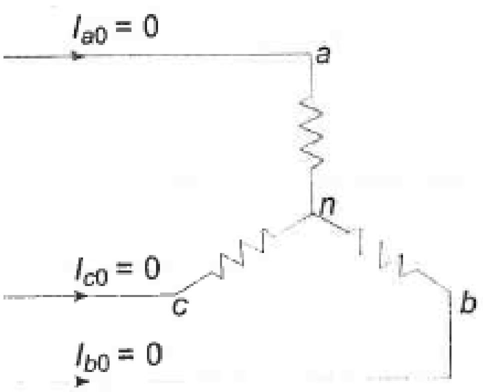
$Z_1 = Z_2 = Z_{leakage}$

Assuming such transformer connections that zero sequence currents can flow on both sides, a transformer offers a zero-sequence impedance which may differ slightly from the corresponding positive and negative sequence values. It is, however, normal practice to assume that the series impedances of all sequences are equal regardless of the type of transformer. The zero-sequence magnetizing current is somewhat higher in a core type than in a shell type transformer. This difference does not matter as the magnetizing current of a transformer is always neglected in short circuit analysis.

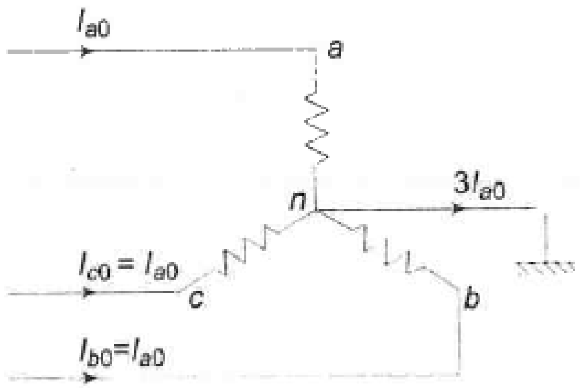
1. Zero-Sequence Networks of Transformers

Before consider in the zero sequence networks of various types of transformer connections three important observations are made:

1. when magnetizing current is neglected transformer primary would carry current only if there is current flow on the secondary side.
2. Zero sequence currents can flow in the legs of a star connection only if the star point is grounded which provides the necessary return path for zero sequence currents. This fact is illustrated by Figs. a and b



(a) Ungrounded star



(a) Grounded star

3. No zero sequence currents can flow in the lines connected to a delta connection as no return path is available for these currents. Zero sequence currents can, however, flow in the legs of a delta-such currents are caused by the presence of zero sequence voltages in the delta connection. This fact is illustrated by Fig.

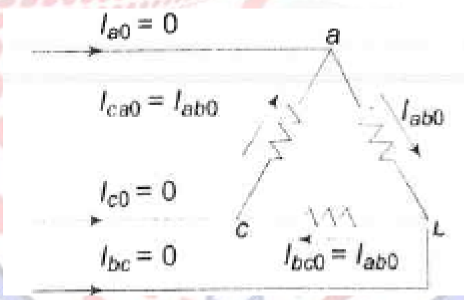


Fig. Flow of zero Sequence currents in delta connection

Let us now consider various types of transformer connections

Case I; Y-Y transformer bank with any one neutral grounded.

If any one of the two neutrals of a Y-Y transformer is ungrounded, zero sequence currents cannot flow in the ungrounded star and consequently these cannot flow in the grounded star. Hence, an open circuit exists in the zero sequence network between H and L, i.e. between the two parts of the system connected by the transformer as shown in Fig. 10.17.

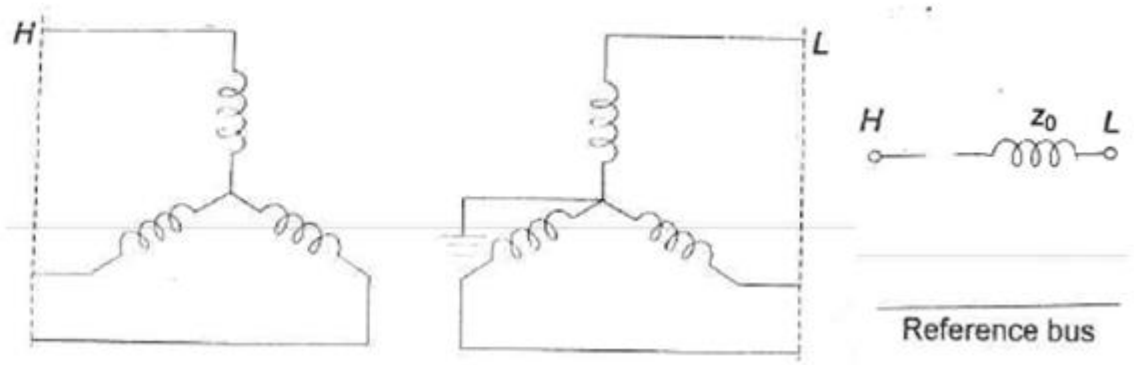


Fig. Y-Y transformer bank with one neutral grounded and its zero
Sequence network

Case 2: Y-Y Transformer Bank Both Neutrals Grounded

When both the neutrals of a Y-Y transformer are grounded, a path through the transformer exists for zero sequence currents in both windings via the two grounded neutrals. Hence, in the zero sequence network H and L are connected by the zero sequence impedance of the transformer as shown in Fig.

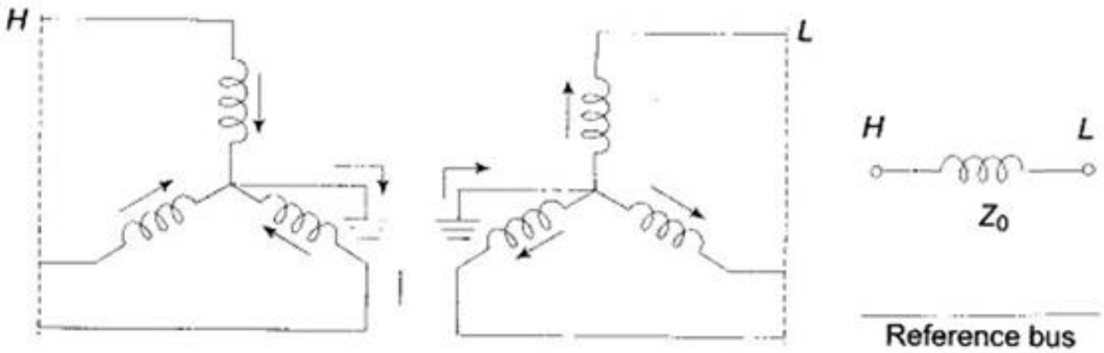
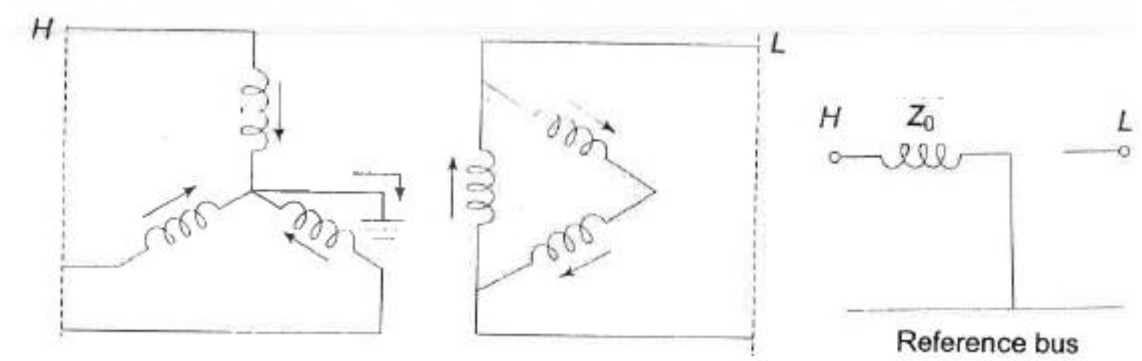


Fig. Y-Y transformer bank with sequence network neutrals grounded and its zero

Case 3: Y-Δ Transformer Bank With Grounded Y Neutral

If the neutral of stars ide is grounded, zero sequence currents can flow in star
Because a path is available to ground and the balancing zero sequence currents can flow in delta. Of course, no zero sequence currents can flow in the line on the delta side. The zero-sequence network must therefore have a path from the line H on the star side through the zero sequence impedance of the transformer to the reference bus, while an open circuit must exist on the line L side of delta (see Fig.). If the star neutral is grounded through Z_n an impedance $3Z_n$ appears in series with Z_o in the sequence network



Cas 4: Y-Δ Transformer Bank With Ungrounded Star

This is the special case of Case 3 where the neutral is grounded through $Z_n = \infty$. There are no zero-sequence current can flow in the transformer windings. The zero-sequence network then modifies to that shown in Fig.

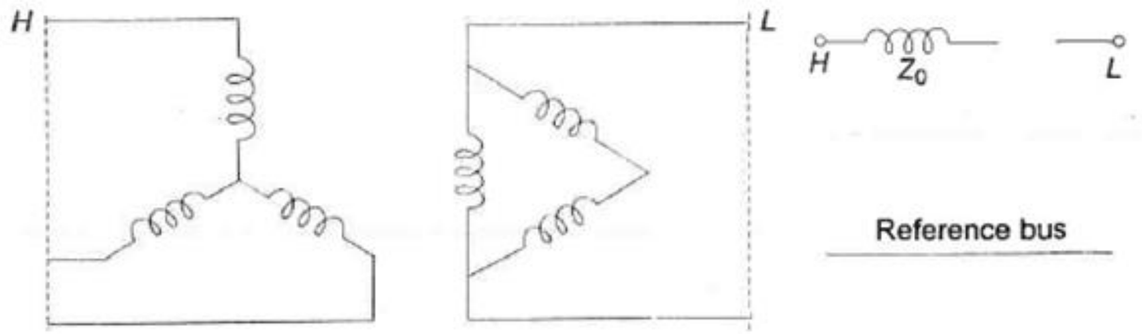
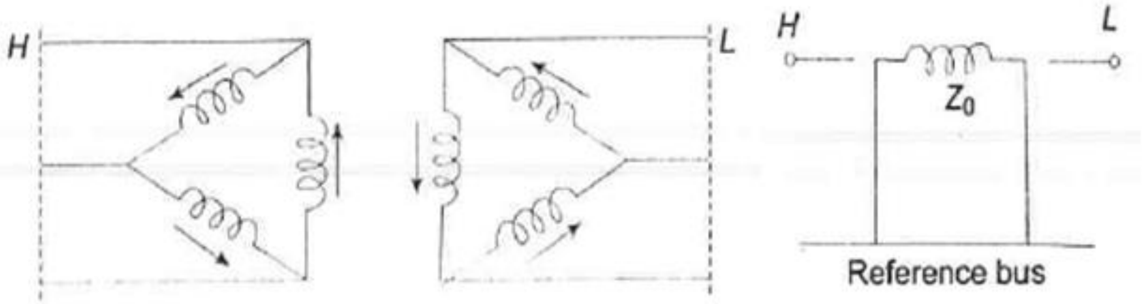


Fig. Y-Δ transformer bank with ungrounded star and its zero sequence network

Case 5: Δ-Δ Transformer Bank

Since a delta circuit provides no return path, the zero sequence currents cannot flow in or out of Δ-Δ transformer; however, it can circulate in the delta windings*. Therefore, there is an open circuit between H and L and Zo is connected to the reference bus on both ends to account for any circulating zero sequence current in the two deltas (see Fig.).



∆-∆ transformer bank and its zero-sequence network

SUMMARY