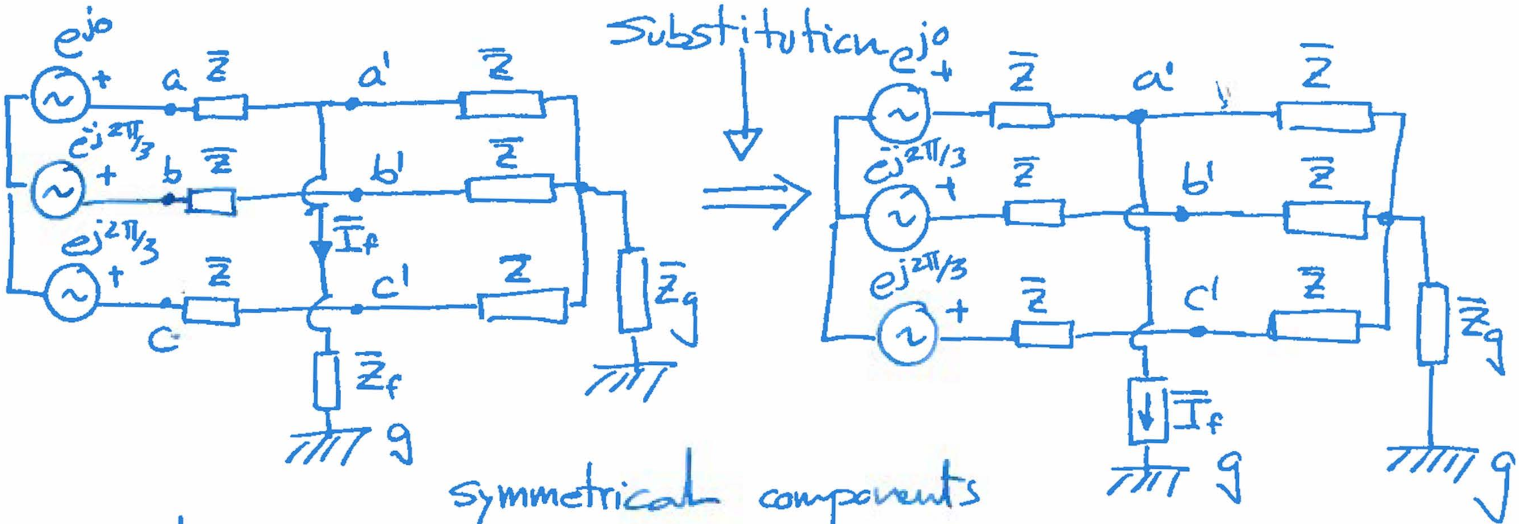
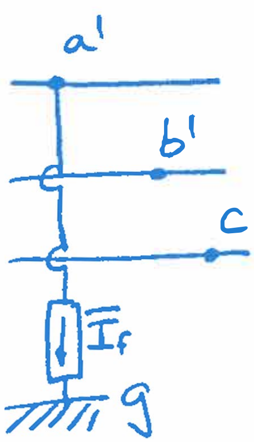
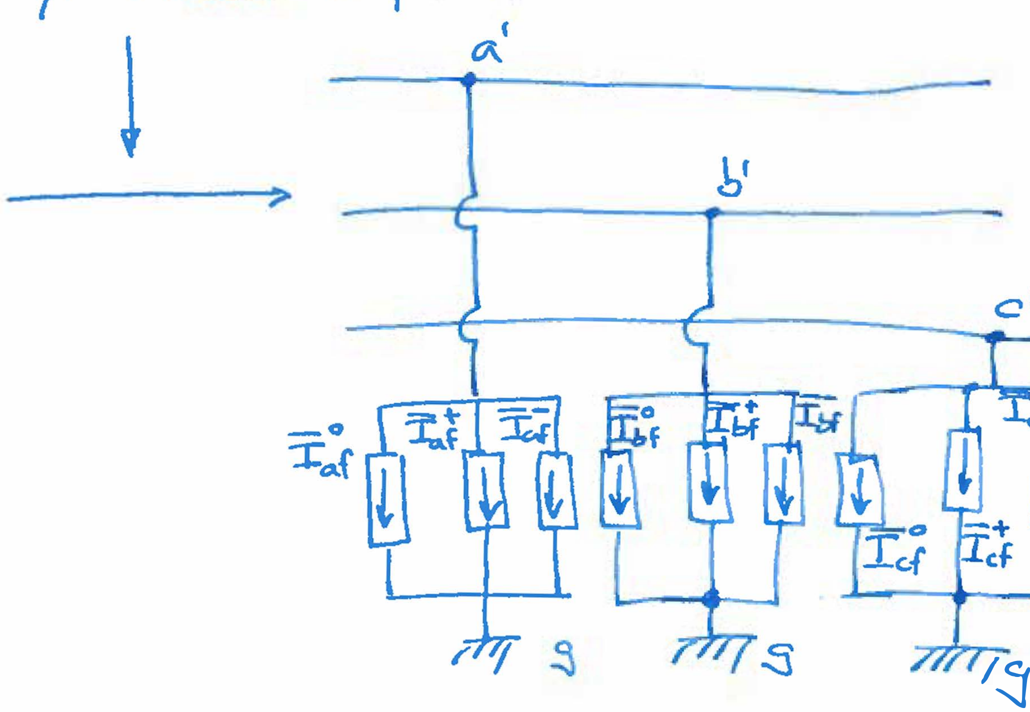
LECTURE 24

12/05/17

LINE-TO-GROUND FAULT ANALYSIS



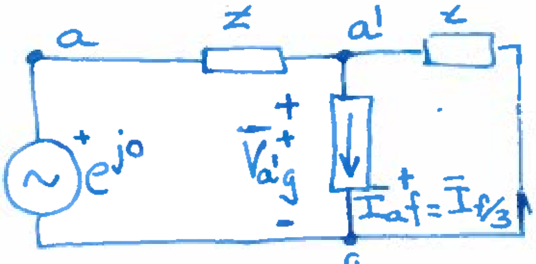




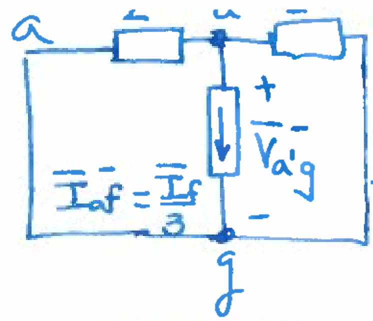
$$\overline{V}_{a'g} = \overline{Z}_f \cdot \overline{I}_f$$

- We can analyze the three components separately by using the three sequence networks constructed as follows.

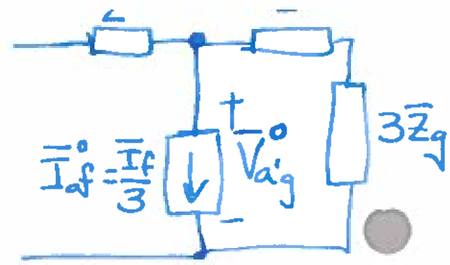
$$\begin{bmatrix} \overline{I}_{af}^{0} \\ \overline{I}_{af}^{+} \\ \overline{I}_{af}^{-} \end{bmatrix} = \frac{1}{3} \begin{bmatrix} 1 & 1 & 1 \\ 1 & a & a^2 \\ 1 & a^2 & a \end{bmatrix} \begin{bmatrix} \overline{I}_f \\ 0 \\ 0 \end{bmatrix} \rightarrow \boxed{\overline{I}_{af}^{0} = \overline{I}_{af}^{+} = \overline{I}_{af}^{-} = \frac{1}{3}\overline{I}_f}$$



+ sequence



− sequence

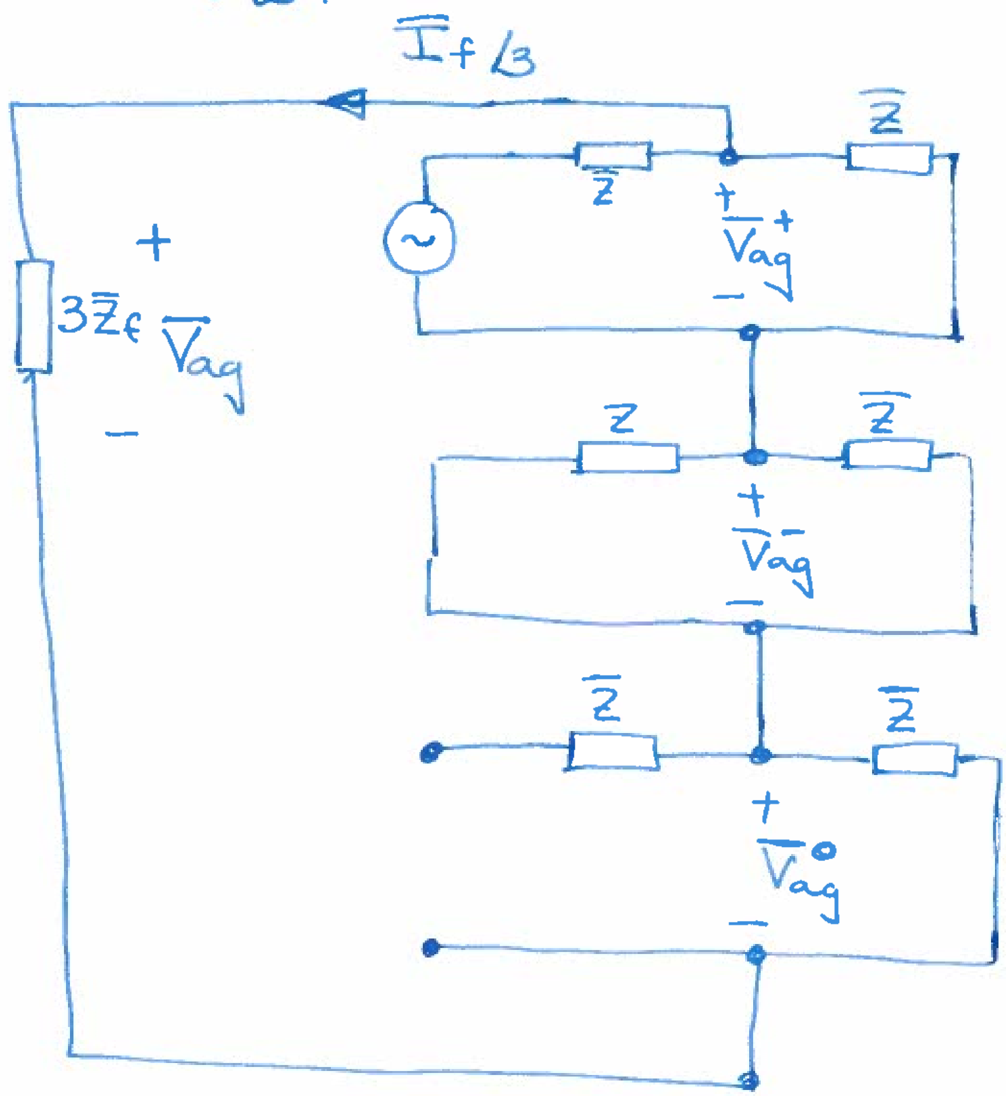


0 sequence

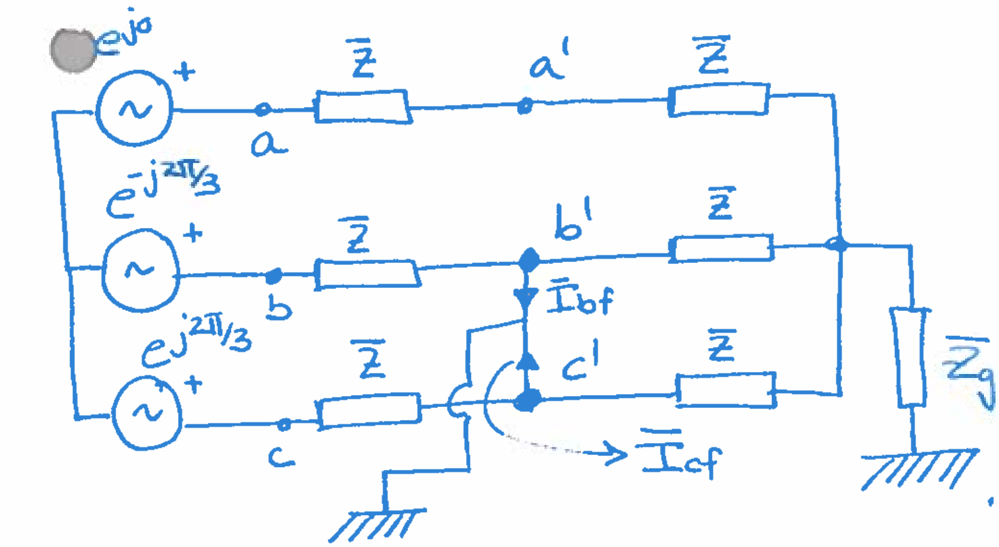
- Clearly : $\bar V_{a'g} = \bar V_{a'g}^+ + \bar V_{a'g}^- + \bar V_{a'g}^0$

- In addition : $\bar V_{a'g} = \bar Z_f \cdot \bar I_f = 3\bar Z_f \underbrace{\left(\tfrac{1}{3}\bar I_f\right)}_{\bar I_{af}^+ = \bar I_{af}^- = \bar I_{af}^0}$

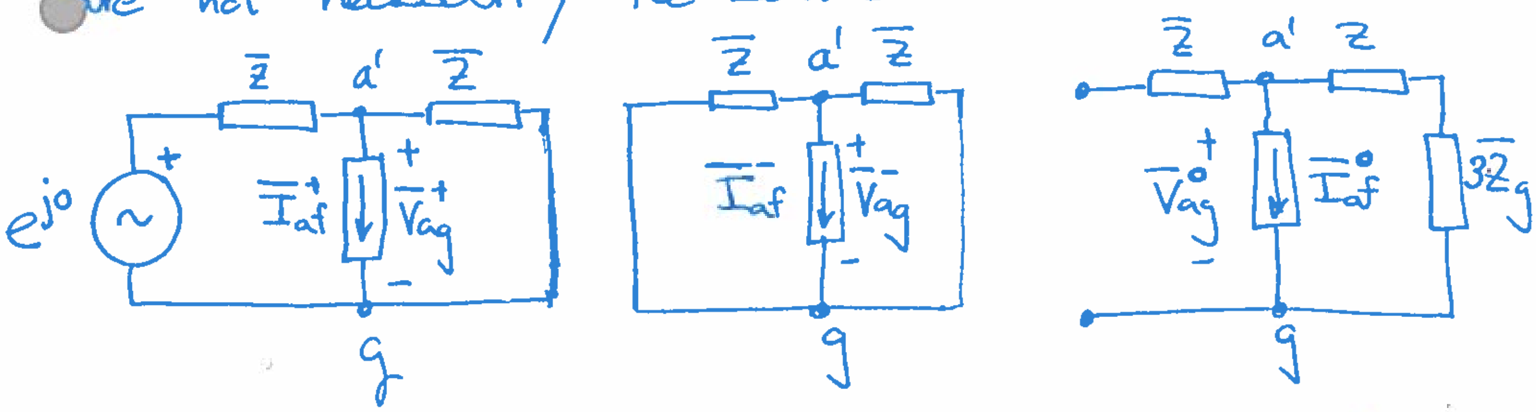
We are led to :



DOUBLE LINE-GROUND FAULT



The sequence networks are the same; except that now the fault current symmetrical components are not necessarily the same



The question is now how to interconnect them so as to satisfy the constraints of the original circuit.

As before, we need to use the information from the original system.

We Know : $\begin{cases} \bar{I}_{af} = 0 & (1) \\ \bar{V}_{b'g} = \bar{V}_{c'g} = 0 & (2) \end{cases}$

$$\begin{bmatrix} \bar{I}_{af} \\ \bar{I}_{bf} \\ \bar{I}_{cf} \end{bmatrix} = \begin{bmatrix} 1 & 1 & 1 \\ 1 & a^2 & a \\ 1 & a^2 & a^2 \end{bmatrix} \begin{bmatrix} \bar{I}^{\circ}_{af} \\ \bar{I}^{+}_{af} \\ \bar{I}^{-}_{af} \end{bmatrix} ; \quad \begin{bmatrix} \bar{V}^{\circ}_{a'g} \\ \bar{V}^{+}_{a'g} \\ \bar{V}^{-}_{a'g} \end{bmatrix} = \frac{1}{3} \begin{bmatrix} 1 & 1 & 1 \\ 1 & a & a^2 \\ 1 & a^2 & a \end{bmatrix} \begin{bmatrix} \bar{V}_{a'g} \\ \bar{V}_{b'g} \\ \bar{V}_{c'g} \end{bmatrix}$$

$\downarrow (1)$

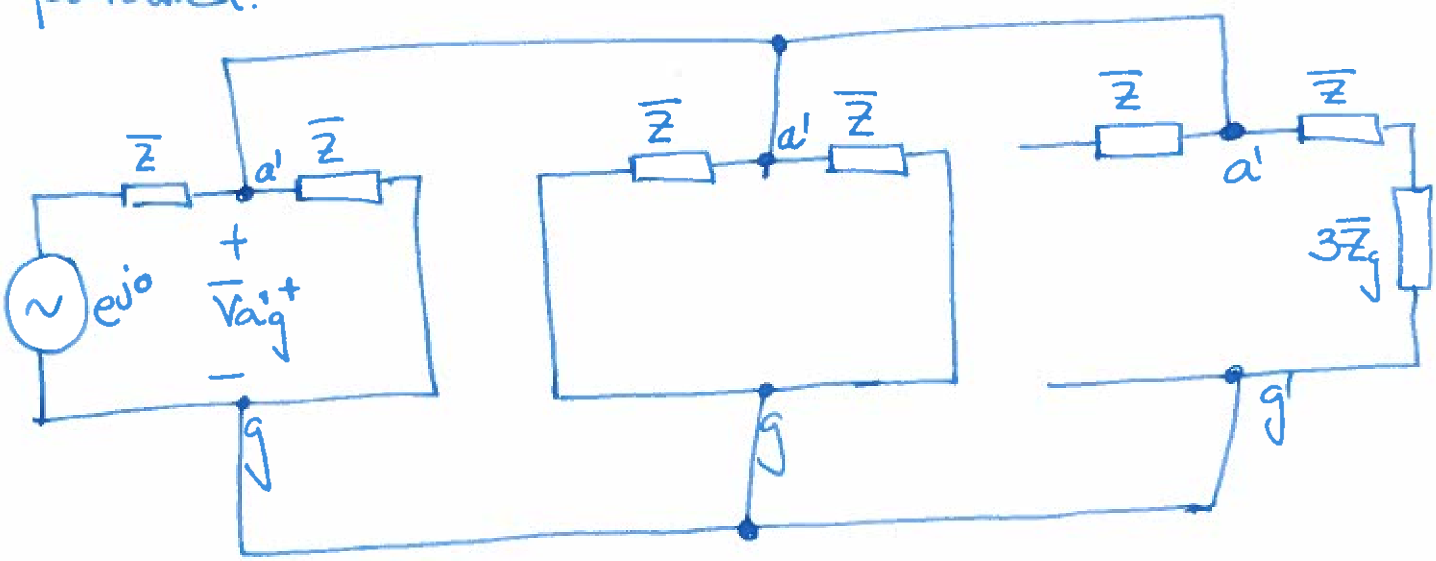
$\bar{I}_{af} = 0 \Rightarrow \bar{I}^{\circ}_{af} + \bar{I}^{+}_{af} + \bar{I}^{-}_{af}$

(3)

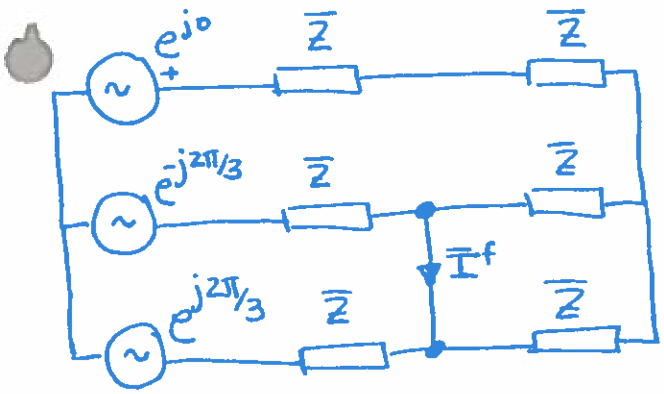
$$\Downarrow$$

$$\left.\begin{aligned} \bar{V}^{\circ}_{a'g} &= \tfrac{1}{3}\bar{V}_{a'g} \\ \bar{V}^{+}_{a'g} &= \tfrac{1}{3}\bar{V}_{a'g} \\ \bar{V}^{+}_{c'g} &= \tfrac{1}{3}V_{a'g} \end{aligned}\right\} \Rightarrow \bar{V}^{\circ}_{a'g} = \bar{V}^{+}_{a'g} = \bar{V}^{-}_{a'g} \quad (4)$$

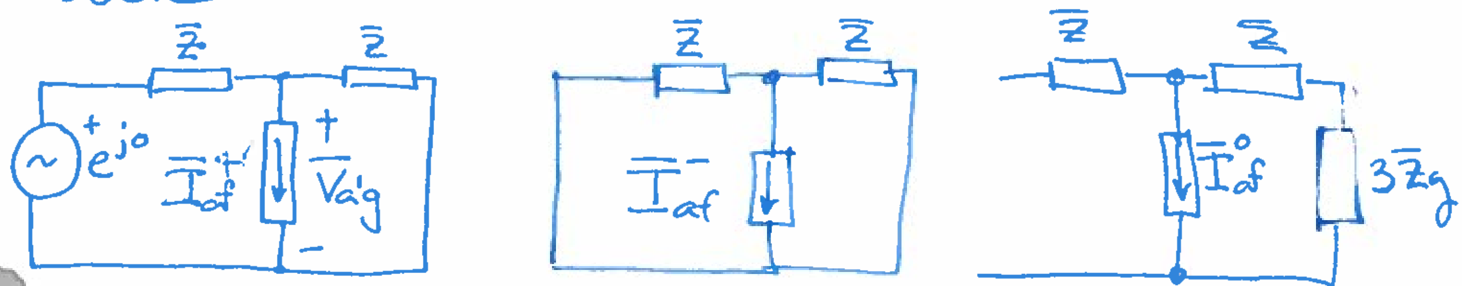
Equations (3) and (4) suggest that we need to connect the sequence networks in parallel.



LINE-LINE FAULT



The sequence networks are the same as before



We know
$$\begin{cases} \bar{I}_{af} = 0 \qquad \bar{I}_{bf} = -\bar{I}_{cf} = \bar{I}_f & (1) \\ \bar{V}_{b'g} = \bar{V}_{c'g} & (2) \end{cases}$$

$$\begin{bmatrix} \bar{I}_{af}^{0} \\ \bar{I}_{af}^{+} \\ \bar{I}_{af}^{-} \end{bmatrix} = \frac{1}{3}\begin{bmatrix} 1 & 1 & 1 \\ 1 & a & a^2 \\ 1 & a^2 & a \end{bmatrix} \underbrace{\begin{bmatrix} \bar{I}_{af} \\ \bar{I}_{bf} \\ \bar{I}_{cf} \end{bmatrix}}_{\begin{bmatrix} 0 \\ \bar{I}_f \\ -\bar{I}_f \end{bmatrix}} = \underbrace{\begin{bmatrix} 0 \\ \frac{1}{3}(a - a^2)\bar{I}_f \\ \frac{1}{3}(a^2 - a)\bar{I}_f \end{bmatrix}}_{}$$

$$\boxed{\begin{aligned} \bar{I}_{af}^{0} &= 0 \\ \bar{I}_{af}^{+} &= -\bar{I}_{af}^{-} \end{aligned}} \qquad (3)$$

$$\begin{bmatrix} \bar{V}_{a'g}^{0} \\ \bar{V}_{a'g}^{+} \\ \bar{V}_{a'g}^{-} \end{bmatrix} = \frac{1}{3}\begin{bmatrix} 1 & 1 & 1 \\ 1 & a & a^2 \\ 1 & a^2 & a \end{bmatrix}\begin{bmatrix} \bar{V}_{ag} \\ \bar{V}_{bg} \\ \bar{V}_{cg} \end{bmatrix} \longrightarrow \bar{V}_{bg} = \bar{V}_{cg}$$

$$= \begin{bmatrix} \frac{1}{3}(\bar{V}_{ag} + \bar{V}_{bg} + \bar{V}_{cg}) \\ \frac{1}{3}\bar{V}_{ag} + \frac{1}{3}(a\bar{V}_{bg} + a^2\bar{V}_{cg}) \\ \frac{1}{3}\bar{V}_{ag} + \frac{1}{3}(a^2\bar{V}_{bg} + a\bar{V}_{cg}) \end{bmatrix} = \begin{bmatrix} \frac{1}{3}(\bar{V}_{ag} + \bar{V}_{bg} + \bar{V}_{cg}) \\ \frac{1}{3}\bar{V}_{ag} + \frac{1}{3}(a + a^2)\bar{V}_{bg} \\ \frac{1}{3}\bar{V}_{ag} + \frac{1}{3}(a^2 + a)\bar{V}_{bg} \end{bmatrix}$$

$$\Longrightarrow \boxed{\bar{V}_{ag}^{+} = \bar{V}_{ag}^{-}} \quad (4)$$

Equations (3) and (4) imply that the + & − sequences must be connected in parallel, while the 0 sequence from the rest network remains disconnected