VEBKO ONLINE HELP

Zero Sequence Elimination

Category	**tester**
Section	**Transformer Module**
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1 Imported Content

To explain this concept, consider a transformer with a vector group of YNd5.

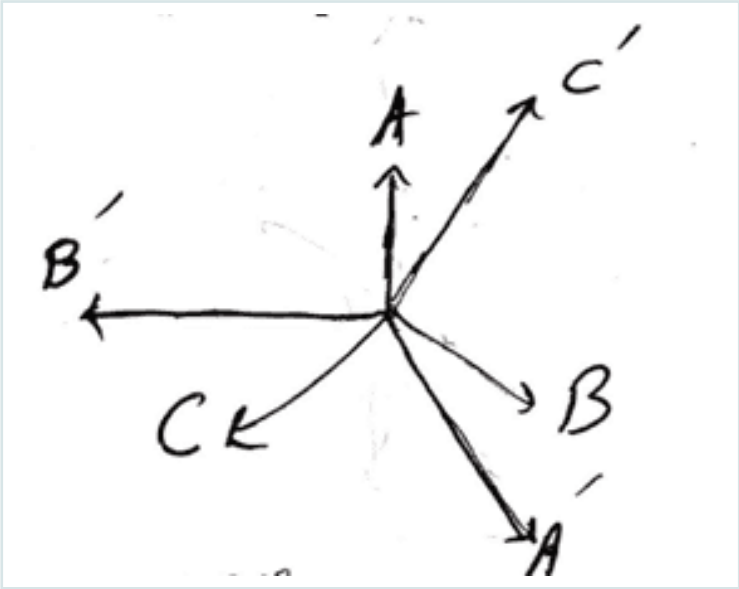


Figure 1

In the transformer with the specified vector group, the secondary vectors relative to the primary are derived using the following equations.

$$A' = B - A$$

$$B' = C - B$$

$$C' = A - C$$

Figure 2

Using these equations, the schematic of the winding connections and the direction of the currents on the secondary side can be drawn. For example, in the first step, the connection of the windings and

the direction of currents for phase A' is shown as illustrated.

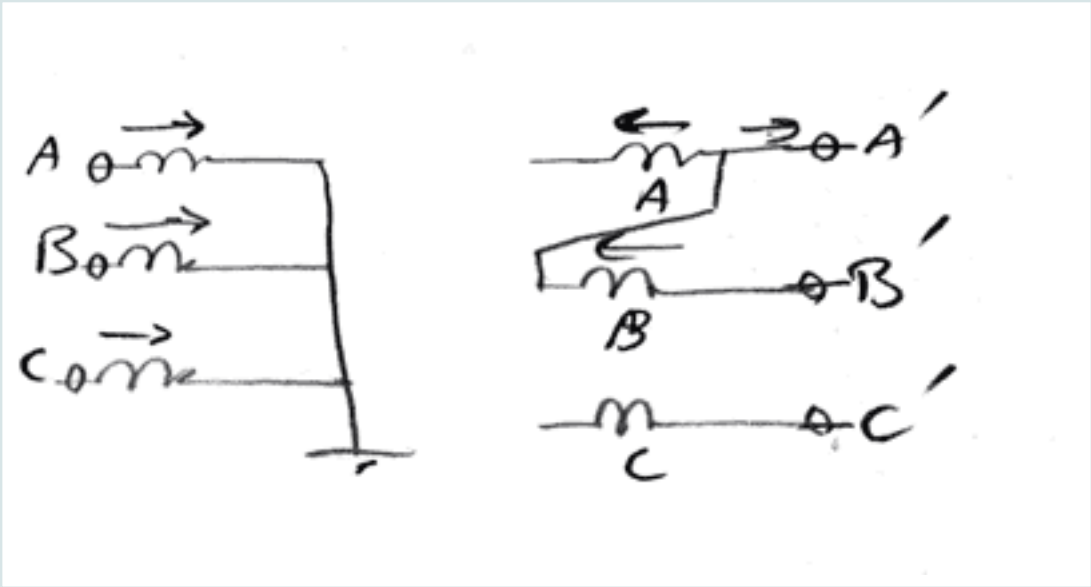


Figure 3

Finally, the connections will look as shown in the following diagram.

Figure 4

Given the figure above, the matrix of currents on the star side is as shown below.

$$\begin{bmatrix} IA \\ IB \\ IC \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} A \\ B \\ C \end{bmatrix}$$

Figure 5

The overall transfer matrix from the secondary side to the primary side is also as shown:

$$\begin{bmatrix} I_a^{**} \\ I_b^{**} \\ I_c^{**} \end{bmatrix} = \frac{2}{3} \cdot \begin{bmatrix} \cos[k \cdot 30°] & \cos[(k+4) \cdot 30°] & \cos[(k-4) \cdot 30°] \\ \cos[(k-4) \cdot 30°] & \cos[k \cdot 30°] & \cos[(k+4) \cdot 30°] \\ \cos[(n+4) \cdot 30°] & \cos[(k-4) \cdot 30°] & \cos[k \cdot 30°] \end{bmatrix} \cdot \begin{bmatrix} I_a^{*} \\ I_b^{*} \\ I_c^{*} \end{bmatrix}$$

Figure 6

For YNd5, it is represented as shown below.

$$\begin{bmatrix} IA' \\ IB' \\ IC' \end{bmatrix} = \frac{1}{\sqrt{3}} \begin{bmatrix} -1 & 0 & 1 \\ 1 & -1 & 0 \\ 0 & 1 & -1 \end{bmatrix} \begin{bmatrix} A' \\ B' \\ C' \end{bmatrix}$$

Figure 7

In the differential protection of a transformer with the given vector group and a 1:1 turn ratio, if an earth fault occurs outside the protective zone, the relay will operate. In the event of an earth fault outside the protection zone, the currents shown will be present on both sides:

$$\frac{V1}{V2} = \frac{n1}{n2} \Rightarrow \frac{\frac{V}{\sqrt{3}}}{V} = \frac{n1}{n2} \Rightarrow \frac{n1}{n2} = \frac{1}{\sqrt{3}} \Rightarrow \frac{n1}{n2} = \frac{I2}{I1} = \frac{1}{\sqrt{3}} \Rightarrow I2 = \frac{I1}{\sqrt{3}}$$

Figure 8

According to the equation above, if a fault with current If occurs in phase C, the corresponding winding on the secondary side will have If/sqrt(3) flowing through it.

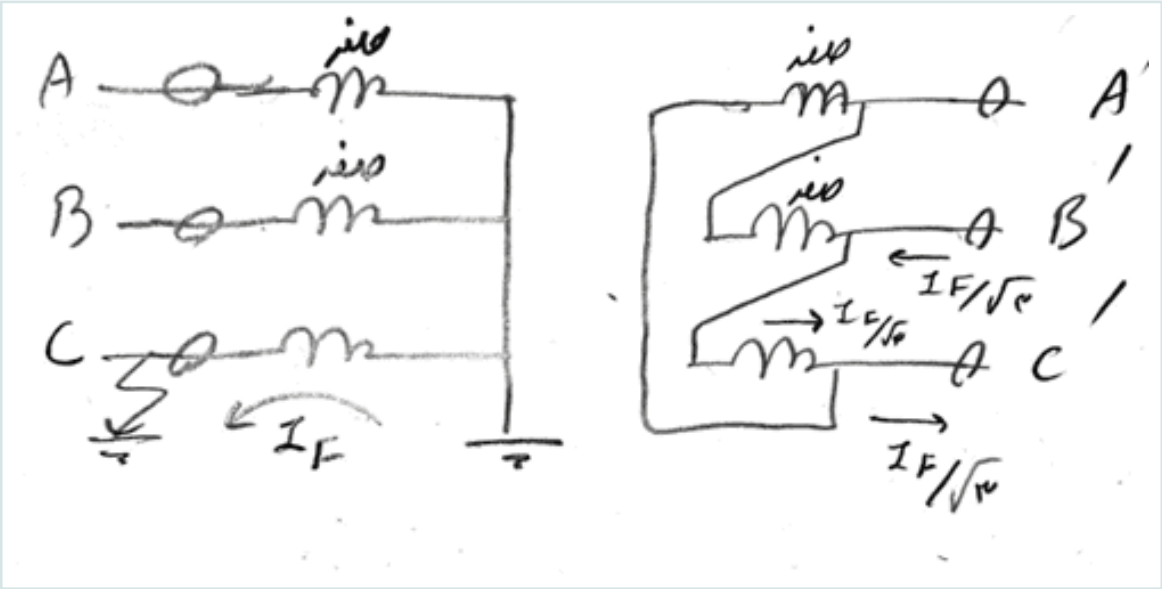


Figure 9

According to the differential protection convention, the currents entering the transformer are considered positive, and those leaving the transformer are negative. Therefore, the matrices shown will apply for the primary side and the transfer from secondary to primary.

$$\begin{bmatrix} IA \\ IB \\ IC \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 0 \\ 0 \\ -IF \end{bmatrix} => \begin{bmatrix} IA \\ IB \\ IC \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \\ -IF \end{bmatrix}$$

$$\begin{bmatrix} IA' \\ IB' \\ IC' \end{bmatrix} = \frac{1}{\sqrt{3}} \begin{bmatrix} -1 & 0 & 1 \\ 1 & -1 & 0 \\ 0 & 1 & -1 \end{bmatrix} \begin{bmatrix} 0 \\ \frac{IF}{\sqrt{3}} \\ -\frac{IF}{\sqrt{3}} \end{bmatrix} => \begin{bmatrix} IA' \\ IB' \\ IC' \end{bmatrix} = \begin{bmatrix} -\frac{IF}{3} \\ -\frac{IF}{3} \\ \frac{2*IF}{3} \end{bmatrix}$$

Figure 10

The differential current of the above will be as shown below:

$$\begin{bmatrix} Diff(A) \\ Diff(B) \\ Diff(C) \end{bmatrix} = \begin{bmatrix} \frac{IF}{3} \\ \frac{IF}{3} \\ \frac{IF}{3} \end{bmatrix}$$

Figure 11

With these differential currents, the relay will trip. However, if the zero-sequence current from the YN side is eliminated, the primary side current will be as shown:

$$IA = IA - \frac{IA + IB + IC}{3}$$

$$IB = IB - \frac{IA + IB + IC}{3}$$

$$IC = IC - \frac{IA + IB + IC}{3}$$

Figure 12

$$\begin{bmatrix} IA \\ IB \\ IC \end{bmatrix} = \frac{1}{3}\begin{bmatrix} 2 & -1 & -1 \\ -1 & 2 & -1 \\ -1 & -1 & 2 \end{bmatrix}\begin{bmatrix} A \\ B \\ C \end{bmatrix} => \begin{bmatrix} IA \\ IB \\ IC \end{bmatrix} = \begin{bmatrix} \frac{IF}{3} \\ \frac{IF}{3} \\ -\frac{2IF}{3} \end{bmatrix}$$

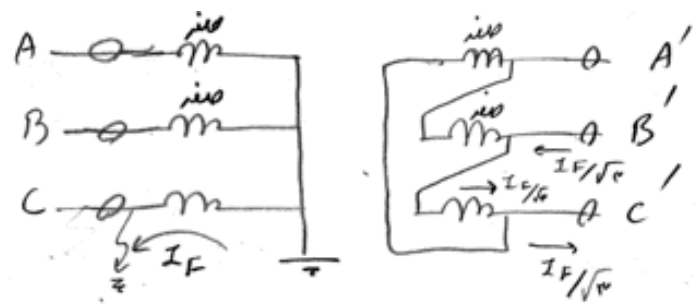
Figure 13

With the changes made, the differential currents will be as shown and will remain stable:

$$\begin{bmatrix} Diff(A) \\ Diff(B) \\ Diff(C) \end{bmatrix} = \left[\begin{bmatrix} \frac{IF}{3} \\ \frac{IF}{3} \\ \frac{-2IF}{3} \end{bmatrix} + \begin{bmatrix} -\frac{IF}{3} \\ -\frac{IF}{3} \\ \frac{2IF}{3} \end{bmatrix}\right] = \begin{bmatrix} 0 \\ 0 \\ 0 \end{bmatrix}$$

Figure 14

However, if the fault is inside the protection zone, the current seen by the CTs on the YN side will be zero:



$$\begin{bmatrix} IA \\ IB \\ IC \end{bmatrix} = \frac{1}{3}\begin{bmatrix} 2 & -1 & -1 \\ -1 & 2 & -1 \\ -1 & -1 & 2 \end{bmatrix}\begin{bmatrix} 0 \\ 0 \\ 0 \end{bmatrix} \Rightarrow \begin{bmatrix} IA \\ IB \\ IC \end{bmatrix} = [0]$$

Figure 15

Therefore, for an earth fault within the protective zone, the differential will be as shown below, and the relay will trip.

$$\begin{bmatrix} Diff(A) \\ Diff(B) \\ Diff(C) \end{bmatrix} = \left| \begin{bmatrix} 0 \\ 0 \\ 0 \end{bmatrix} + \begin{bmatrix} -\frac{IF}{3} \\ -\frac{IF}{3} \\ \frac{2IF}{3} \end{bmatrix} \right| = \begin{bmatrix} \frac{IF}{3} \\ \frac{IF}{3} \\ \frac{2IF}{3} \end{bmatrix}$$

Figure 16

[jg1]ZERO_SEQUENCE_ELIMINATION