4.1 INTRODUCTION:

In recent years, power system analysts have considered the application of six phase power transmission systems as a viable solution to the transmission of large blocks of energy at transmission voltage levels less to those used in three phase transmission systems. Also, the rising costs associated with the acquisition of rights-of-way for new transmission lines have contributed to the support of the idea of using six phase transmission systems for major power-pool inter connections or long transmission lines.

If these were to come to reality, careful planning of such systems is crucial. The most important aspect of the planning is the design of protective schemes for six phase systems. Such a design requires detailed fault analysis of these systems, which includes normally shunt, series faults and simultaneous faults.

A considerable amount of research work has been directed towards the analysis of shunt faults. Transformation techniques [5], phase-co-ordinate methods [13], generalised treatments [7-11], Dual Three Phase Transformation [6,14,15] have been employed. However series faults, arising out of a break in a conductor connecting two power systems or two sections on the same system have not been investigated in detail. Since a multi phase line employs several conductors, even at lower voltage levels, the probability of such faults is much greater in multi phase systems than in three phase systems, a group of medium and fast transients in six phase system are created by faults which do not involve any connection between conductors or between conductors and ground. This type of imbalance is referred to as a series fault. It arises in most instances, when
poles of a circuit breaker fail to open, thus creating an unbalanced series fault condition. The number of types of series faults likely to occur on twelve phase system may be as large as eleven, as compared with only five and two on six phase and three phase systems respectively. Therefore the total number of series fault combinations for a twelve phase system is 4094, where as that for a six phase and three phase systems is 62 and 6 respectively. This makes series faults analysis a more difficult task in multi phase systems. However this difficulty may be alleviated by concentrating only on analyzing significant combinations in multi phase systems. While in the analysis of shunt faults, there is only one fault point, that point to which the unbalanced connection is attached in an otherwise balanced system. But in series faults there are two fault points, one on either side of the imbalance. Thus, the sequence network is still that of a completely symmetric system and the unbalanced portion is isolated outside the sequence network.

A few cases of series faults or open conductor faults for six phase systems are analyzed using the method of symmetrical components and Thevenin's Theorem for two-port networks and a couple of open conductor faults using phase Co-ordinate method [40,41]. These methods requires phase shifting transformers for some types of open conductor faults. In this chapter the analysis of series faults on six phase transmission system has been carried out by using (1) Six phase symmetrical components method (2) Dual Three Phase Transformation (DTPT) method, treating the six phase system as two mutually coupled three phase systems. The inter-connection of different sequence network for various faults that are likely to occur in practice have been developed. They are (i) One conductor open, (ii) Two conductors open, (iii) Three conductors open, (iv) Four conductors open, (v) Five conductors open. Also the calculations for the fault currents are found for the 138 KV, double circuit line between the Mc-calmont and Springdale sub-stations of the Allegheny Power System, Pennsylvania, USA [41].
4.2 Analysis of series faults using symmetrical components method:-

The different types of series faults are analyzed using six phase symmetrical components method, viz. (i) One conductor open, (ii) Two conductors open, (iii) Three conductors open, (iv) Four conductors open, (v) Five conductors open.

(a) One open conductor fault:- This type of fault is most probable type of fault occur on a power system due to phase conductor breaking at a point nearer to a tower.

\[ (V_A)_{PQ} \neq 0; \quad (V_B)_{PQ} = (V_C)_{PQ} = (V_D)_{PQ} = (V_E)_{PQ} = (V_F)_{PQ} = 0 \quad \text{---(4.1)} \]
\[ I_A = 0; \quad I_B \neq I_C \neq I_D \neq I_E \neq I_F \neq 0 \quad \text{---(4.2)} \]

The symbols \((V_A)_{PQ}\) \(\text{-}(V_F)_{PQ}\) represent the series voltage drops along the phase conductors between P and Q. Equations (4.1) and (4.2) imply

\[ (V_{A0})_{PQ} = (V_{A1})_{PQ} = (V_{A2})_{PQ} = (V_{A3})_{PQ} = (V_{A4})_{PQ} = (V_{A5})_{PQ} \quad \text{---(4.3)} \]
and \(I_{A0} + I_{A1} + I_{A2} + I_{A3} + I_{A4} + I_{A5} = 0 \quad \text{---(4.4)} \)

The equations (4.3) and (4.4) clearly suggest that all the sequence networks should be connected in parallel for simulating the fault. Using these equations in (2.6) gives

\[ I_{A1} = \frac{E_{A1}}{Z_1 + \left[ Z_0 || Z_1 || Z_2 || Z_3 || Z_4 || Z_5 \right]} \quad \text{---(4.5)} \]
Fig 4.2 Connection of sequence networks for one open conductor fault (A).

The conditions of the fault location from the fig 4.3 are

\[ I_A = 0, \quad I_D = 0 \]

\[ (V_B)_{PQ} = (V_C)_{PQ} = (V_E)_{PQ} = (V_E)_{PQ} = 0 \]

The equations (4.6) and (4.7) gives

\[ V_{A0} = V_{A2} = V_{A4} ; \quad V_{A1} = V_{A3} = V_{A5} \]

and \[ I_{A0} + I_{A2} + I_{A4} = 0 ; \quad I_{A1} + I_{A3} + I_{A5} = 0 \]

The equation (4.8) and (4.9) suggest that the even number sequence networks are connected in parallel and the odd number sequence networks are connected in parallel separately. Using these equations in (2.6) implies.

\[ I_{A1} = \frac{E_{A1}}{Z_1 + Z_3 || Z_5} \]
The connection of sequence networks from the equations (4.8) and (4.9) as shown in figure 4.4.

Fig 4.4 Sequence networks for a Two open conductors fault (AD).

c) Three open conductors fault :- Let three phases A, C and E get open circuited.

The valid relations at the fault point are from fig4.5

\[ I_A = I_C = I_E = 0 \]  \hspace{1cm} (4.11)
\[ (V_B)_{PQ} = (V_D)_{PQ} = (V_F)_{PQ} = 0 \]  \hspace{1cm} (4.12)

The equations leading to

\[ V_{A0} = V_{A3} ; V_{A1} = V_{A4} ; V_{A2} = V_{A5} \]  \hspace{1cm} (4.13)
\[ I_{A0} + I_{A3} = 0 ; I_{A1} + I_{A4} = 0 ; I_{A2} + I_{A5} = 0 \]  \hspace{1cm} (4.14)

Substituting above equations in the equation (2.6) gives

\[ I_{A1} = \frac{E_{A1}}{Z_1 + Z_4} \]  \hspace{1cm} (4.15)
The fig 4.6 shows the interconnection of sequence networks for Three open conductors fault on a six phase line.

Fig 4.6 Sequence networks for a Three open conductors fault (ACE).

d) Four open conductors fault: - Let the phases B,C,E and F are open circuited.

The valid relations are

\[(V_A)_{PQ} = (V_D)_{PQ} = 0 \]  
\[I_B = I_C = I_E = I_F = 0 \]

The sequence voltages and sequence currents are

\[V_{A0} + V_{A2} + V_{A4} = 0 \quad ; \quad V_{A1} + V_{A3} + V_{A5} = 0 \]

Similarly \[I_{A0} = I_{A2} = I_{A4} \quad ; \quad I_{A1} = I_{A3} = I_{A5} \]
Using these equations in (2.6) gives

\[
I_{A1} = \frac{E_{A1}}{Z_1 + Z_3 + Z_5}
\]

The interconnection of sequence networks are shown in fig 4.8. The even number sequence networks are connected in series and odd number sequence network are connected in series separately.

![Diagram of sequence networks](image)

**Fig 4.8 Inter connection of sequence networks for four conductors open (BCEF).**

e) **Five open conductors fault**: This type of fault is least probable to occur. Consider the phases B,C,D,E and F are open circuited.

![Diagram of five open conductors](image)

**Fig 4.9 Schematic for a Five conductors open(BCDEF).**

From fig 4.9 the valid conditions are

\[
(V_A)_{PQ} = 0 \quad \text{-------------------}(4.21)
\]

\[
I_B = I_C = I_D = I_E = I_F = 0 \quad \text{-------------------}(4.22)
\]
The relation between sequence voltages and sequence currents are

\[ I_{A0} = I_{A1} = I_{A2} = I_{A3} = I_{A4} = I_{A5} \]  \hspace{1cm} \text{(4.23)}

\[ V_{A0} + V_{A1} + V_{A2} + V_{A3} + V_{A4} + V_{A5} = 0 \]  \hspace{1cm} \text{(4.24)}

The equations (4.23) and (4.24) suggest that the sequence networks should be connected in series through the fault point.

Substituting (4.23) and (4.24) in (2.6) gives

\[ I_{A1} = \frac{E_{A1}}{Z_0 + Z_1 + Z_2 + Z_3 + Z_4 + Z_5} \]  \hspace{1cm} \text{(4.25)}

Fig 4.10: Interconnection of sequence networks for five conductors open (BCDE). 

4.3 Analysis of series faults using Dual Three Phase Transformation (DTPT) method:

The same type of faults which have taken in the previous case, are for the analysis using Dual Three Phase Transformation method.

i) One open conductor fault: - Consider the phase a is open.

\[ \begin{align*}
  & \text{a} & \text{b} & \text{c} \\
  \text{a'} & I_a & I_{b'} & I_c \\
  \text{b'} & I_b & I_{c'} & I_a \\
  \text{c} & I_c & I_a & I_{b'} \\
  \text{b} & I_{b'} & I_c & I_a \\
\end{align*} \]

Fig 4.11: Schematic for a one conductor open(a).
The valid conditions at the fault location from fig 4.11 are

\[ I_c = 0 \]

\[ (V_c^1)_{PQ} = (V_b)_{PQ} = (V_a^1)_{PQ} = (V_c)_{PQ} = (V_b^1)_{PQ} = 0 \]

(4.26) \hspace{2cm} (4.27)

Imposing these equations in the equations (2.12) and (2.13) gives

\[ (V_{a0} - V_{a0}^1) = V_{a1} = V_{a2} \]

\[ V_{a1} = V_{a2} = 0 \]

(4.28)

\[ I_{a0} + I_{a1} + I_{a2} = 0 \]

(4.29)

And because of the mutual coupling \( I_{a0} = -I_{a0}^1 \)

Using (4.28) and (4.29) in (2.17) gives,

\[ I_{a1} = \frac{E_{a1}}{Z_1 + [2(Z_0 - Z_{00})||Z_1]} \]

(4.30)

\[ I_{a1}^1 = \frac{E_{a1}^1}{Z_1} \]

(4.30a)

The interconnection of sequence networks as shown in fig 4.12

Fig 4.12 Interconnection of sequence networks for one conductor open using D T P T method.
b) **Two open conductors fault**: Let the open conductor fault be on phases a and a'.

![Fig 4.13 Schematic for a Two conductors open (a a')]()

The constraints at the fault location from fig 4.13 are

\[ I_a = I_a' = 0 \]
\[ (V_c')_Q = (V_b')_Q = (V_c)_Q = (V_b')_Q = 0 \]

The sequence components of voltages and currents from equations (4.31) and (4.32) are

\[ V_{a0} = V_{a1} = V_{a2} ; \quad V_{a0} = V_{a1} = V_{a2} \]
\[ I_{0} + I_{a1} + I_{2} = 0 ; \quad I_{a0} + I_{a1} + I_{a2} = 0 \]

Substituting (4.33) and (4.34) in (2.17) gives

\[ I_{a1} = \frac{E_{a1}}{Z_1 + [Z_2 || \frac{1}{j\omega} (Z_0 - Z_{00})]} \]
\[ I_{a1}' = \frac{E_{a1}'}{Z_1 + [Z_2 || \frac{1}{j\omega} (Z_0 - Z_{00})]} \]
The interconnection of sequence networks for the equations (4.35) and (4.36) shown in fig 4.14.

Fig 4.14 Sequence networks of Two open conductors fault using D T P T method.

c) Three open conductors fault:- Consider the phases a, b and c are open circuited.

\[
\begin{align*}
I_a &= I_b = I_c = 0 \\
(V_a^1)_{PQ} &= (V_b^1)_{PQ} = (V_c^1)_{PQ} = 0
\end{align*}
\]  

(4.37)  

(4.38)

Imposing these conditions in equations (2.12) & (2.13) gives,

\[
\begin{align*}
V_{a0} &= V_{a1} = V_{a2} = 0 \\
I_{a0} &= I_{a1} = I_{a2} = 0
\end{align*}
\]  

(4.39)  

(4.39a)

Substituting these conditions in (2.17) yields

\[
I_{a1} = \frac{E_{a1}}{Z_1}
\]  

(4.40)
d) Four open conductors fault: - Let the phases $c'$, b, c and $b'$ be open circuited.

The valid equations from Fig 4.17 are

\begin{equation}
(V_a)_{PQ} = (V_a')_{PQ} = 0
\end{equation}

\begin{equation}
I_a^1 = I_b = I_c = I_b^1 = 0
\end{equation}

Substituting the equations (4.41) and (4.42) in (2.12) and (2.13) imply

\begin{equation}
V_{a0} + V_{a1} + V_{a2} = 0; \quad V_{a0}^1 + V_{a1}^1 + V_{a2}^1 = 0
\end{equation}

\begin{equation}
I_{a0} = I_{a1} = I_{a2}; \quad I_{a0}^1 = I_{a1}^1 = I_{a2}^1
\end{equation}

Using the equations (4.43) and (4.44) in equation (2.17) gives

\begin{equation}
I_{a1} = \frac{E_{a1}}{Z_1 + Z_2 + (Z_0 - Z_{00})}
\end{equation}

\begin{equation}
I_{a1}^1 = \frac{E_{a1}}{Z_1 + Z_2 + (Z_0 - Z_{00})}
\end{equation}
The interconnections of sequence networks for the above equations shown in the fig 4.18.

Fig 4.18 Inter connection of sequence networks for four conductors open using D T P T method.

e) Five open conductors fault:- Assume the fault to occur on phases c', b, a', c & b'. It is doubtful that this type of fault will ever occur on a six phase line. Through the probability of occurrence is very rare, it is worth while analyze this fault.

Fig 4.19 Schematic for a Five conductors open (bc a' b' c').

The valid equations from fig 4.19 are

\[(V_a)_{PQ} = 0 \quad \text{(4.47)}\]
\[I_c^1 = I_b^1 = I_a^1 = 0 \quad \text{(4.48)}\]

The equations (4.47) and (4.48) imply

\[I_{a0} = I_{a1} = I_{a2} \quad ; \quad I_a^1 = I_a^1 = I_a^1 = 0 \quad \text{(4.49)}\]
\[V_{a0} + V_{a1} + V_{a2} = 0 \quad ; \quad V_a^1 + V_a^1 + V_a^1 = 0 \quad \text{(4.50)}\]

The equations (4.49) and (4.50) suggest that the sequence networks must be connected in series, using these equations in (2.17) gives,
Fig 4.20 Interconnection of sequence networks for five conductors open using D T P T method.

4.4 Comparison of Dual Three Phase Transformation method with symmetrical components method :-

Various types of series faults on six phase system like one open conductor fault, two conductors open, three conductors open, four conductors open, five conductors open, have been analyzed using six phase symmetrical components method and Dual Three Phase Transformation method.

i) In the case of One open conductor fault on phase A the six phase symmetrical network obtained was found to have $Z_1$ component in series with the parallel combination of remaining five components.

ii) In the case of Two open conductor fault on A and D the six phase symmetrical network obtained was found to have $Z_1$ in series with the parallel combination of $Z_3$ and $Z_5$.

iii) In the case of Three open conductor fault ACE the two pairs of sequence networks are connected in parallel, i.e. zero and third sequence networks, First and Fourth sequence networks and Second and Fifth sequence networks. Since the only active network is the First sequence, and because there is no magnetic coupling between networks, the only connection of interest to us will be between First and Fourth sequence networks.
iv) Where as in the case of Four open conductor fault on phases BCEF the six phase symmetrical obtained was found to have $Z_4$ in series with $Z_3$ and $Z_5$.

v) But in case of the Five conductor fault on phases BCDEF, the sequence network obtained was found to have $Z_1$ in series with the series combination of remaining five symmetrical components.

The Dual Three Phase Transformation sequence networks obtained making use of Dual Three Phase Transformation analysis confirmed the comparisons given under items (i) to (v).

Although it is easy to find the relationship between the sequence voltages and currents for any type of series fault, it is difficult and cumbersome to derive the sequence network connections for certain faults in multi phase systems. Therefore, some series faults may not be simulated easily by the symmetrical components method. Moreover the computation of fault currents employing this method requires an inverse transformation.

But defining the Dual Three Phase Transformation matrix in terms of the familiar three phase symmetrical components matrix for the six phase system has led to the solution of series faults in an easy way. The assembly of simple sequence networks for all the series faults requires no complex ratio transformers or mutual inductance in DTPT method. The sequence networks are given in terms of the familiar three phase symmetrical components, whose effects are well known. These sequence networks can easily be simulated on network analyzer. They give a greater insight into the system under fault conditions.
4.5 Comparison of series faults with shunt faults:

Analysis of shunt faults for six phase system had been carried out earlier in both the methods[5,13]. On comparing the results of series faults with shunt faults the following points have been observed.

In case of one conductor open fault on phase A the six phase symmetrical components network obtained was found to be the same as that obtained in the case of five line to ground fault on phases BCDEF.

In the case of two conductors open fault on phases A and D, the six phase symmetrical components network obtained was found to be same as that obtained in the case of four phase to ground fault on BCEF.

In the case of three open conductors fault on phases ACE, the six phase symmetrical components network obtained was found to be as that obtained in the case of three phase to ground fault on phases BDF.

In the case of four open conductors fault on phases BCEF, the six phases sequence components network obtained was found to be same as that obtained for two phase to ground fault on phases A D.

In the case of five open conductors fault on BCDEF the six phase sequence components network obtained was found to be same as that obtained for single phase to ground fault on phase A.

The Dual Three Phase Transformation sequence networks obtained making use of Dual Three Phase Transformation analysis for all the series faults in the six phase transformation systems also confirmed the above comparisons.
4.6 Illustrative Example on a Sample System:

Fig 4.21 shows the single line diagram of a 138 KV, six phase transmission network.

![Single Line Diagram](image)

Fig 4.21 Schematic representation of series fault at bus II.

The line is located between the Springdale and Mc-calmont buses of the Allegheny Power System with the following sequence impedances in p.u. calculated on a base of 100 MVA and 138 KV [40].

Sequence impedances of source $S_1$ i.e. Mc-calmont bus;

$$Z_0 = 0.06459 + j 0.18977$$

$$Z_1 = 0.01229 + j 0.075$$

Sequence impedances of source $S_2$ i.e. Springdale bus;

$$Z_0 = 0.039 + j 0.1247$$

$$Z_1 = 0.005 + j 0.032$$

Sequence impedances of transmission line (assuming fully transposed line);

$$Z_0 = 0.087 + j 0.3494$$

$$Z_1 = 0.017 + j 0.1075$$

The calculations of all significant types of fault currents for six phase system had been done using symmetrical component method and Dual Three Phase Transformation method. Both the methods reveal that the two phase (AC) series fault is most severe in the six phase system. On the other hand Four phase (ABCD) series fault is the least severe fault in the six phase system. The results shown in tables 4.1 and 4.2.
Table 4.1 series faults for all significant faults on the six phase network  
(Symmetrical components method)

<table>
<thead>
<tr>
<th>Type of series fault</th>
<th>Phase Currents (Amp.)</th>
<th>Phase Currents (Deg.)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>A</td>
<td>B</td>
</tr>
<tr>
<td>Single-phase series</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fault (A)</td>
<td>0</td>
<td>360.22</td>
</tr>
<tr>
<td></td>
<td>-135.16°</td>
<td>166.11°</td>
</tr>
<tr>
<td>Two-phase series</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fault (A-B)</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Two-phase series</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fault (A-C)</td>
<td>0</td>
<td>384.122</td>
</tr>
<tr>
<td></td>
<td>-141.45°</td>
<td>173.30°</td>
</tr>
<tr>
<td>Two-phase series</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fault (A-D)</td>
<td>0</td>
<td>334.425</td>
</tr>
<tr>
<td></td>
<td>-140.92°</td>
<td>159.1°</td>
</tr>
<tr>
<td>Three-phase series</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fault (A-B-C)</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Three-phase series</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fault (A-B-D)</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Three-phase series</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fault (A-C-E)</td>
<td>0</td>
<td>334.425</td>
</tr>
<tr>
<td></td>
<td>-140.92°</td>
<td>99.1°</td>
</tr>
<tr>
<td>Four-phase series</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fault (A-B-C-D)</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Four-phase series</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fault (A-B-C-E)</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Four-phase series</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fault (A-B-D-E)</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Five-phase series</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fault (A-B-C-D-E)</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The full load current 120° should be added to the above values to get the actual fault currents.
Table 4.2 series faults for all significant faults on the six phase network.
(Dual Three Phase Transformation method)

<table>
<thead>
<tr>
<th>Type of series fault</th>
<th>Phase Currents (Amp)</th>
<th>Phase Currents (Deg.)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>A</td>
<td>c¹</td>
</tr>
<tr>
<td>Single-phase series Fault(a)</td>
<td>0</td>
<td>361.32°</td>
</tr>
<tr>
<td>Two-phase series Fault(a-c¹)</td>
<td>0</td>
<td>384.34°</td>
</tr>
<tr>
<td>Three-phase series Fault(a-c¹-b)</td>
<td>0</td>
<td>335.08°</td>
</tr>
<tr>
<td>Four-phase series Fault(a-c¹-b-a¹)</td>
<td>0</td>
<td>335.02°</td>
</tr>
<tr>
<td>Five-phase series Fault(a-c¹-b-a¹-c)</td>
<td>0</td>
<td>335.06°</td>
</tr>
</tbody>
</table>

The full load current 120° should be added to the above values to get the actual fault currents.
In this chapter series fault analysis has been presented using the symmetrical components method and Dual Three Phase Transformation method. Both the methods led to the same results. Moreover, the Dual Three Phase Transformation in terms of three phase symmetrical components matrix for the six-phase systems had led to the solution of series faults in an easy way. The assembly of D T P T sequence networks for all the series faults requires no complex ratio transformers. The sequence networks can easily be simulated on network analyzer.

Further, it was found that the symmetrical components network obtained in the case of series fault on one conductor was found to be the same as that obtained in the case of five line to ground fault on other conductors. The symmetrical components network obtained in two phase series fault was the same as that of four conductors to ground fault. Similarly the three phase series fault symmetrical components network was equivalent to a three phase to ground fault network, four phase series fault symmetrical components network was equivalent to a two-phase to ground fault network and five-phase series fault network is equivalent to single phase to ground fault network. These results are confirmed by both the methods.

Based on the analytical results (tables 4.1 and 4.2) symmetrical series fault like open conductor fault on phases a b c (A C E) (i.e. one three phase group) results in equal currents for all the sound phases which are independent of the zero-sequence impedance, where as for unsymmetrical faults the currents are strongly affected by the zero-sequence impedance.

The two phase series fault is the most severe fault on the six phase system. In contrast, the four phase series fault is the least severe fault in the six phase system. Both the methods confirmed these results. These results will be useful in the planning stage, when designing adequate protective schemes.