Simultaneous fault detection and diagnosis in electric power system using hybrid method

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Abstract

Simultaneous fault is one of the challenging issues. Faults are the major hurdles in power system designing and protection. Simultaneous fault is the combination of faults indicates that that two or more faults which occur at the same time. The main objective of simultaneous fault detection, classification and location is satisfy accelerates line restoration, maintains system stability, repairs the fault, decreases the restoration time and increases the system reliability. This paper presents an approach for analysis, detection, classification and location for simultaneous faults in bus bar and transmission line. Two port network is adapted for analysis, voltage and current measurement method is adapted in the fault detection, neural network in the fault classification and location for different types of fault and places were to estimation accurately fault location by analyzing the data available after the beginning of disturbance. All programs were written in MATLAB environment. The programs were test on IEEE-11 bus bar network. The results clarified that the voltage and current measurement method and impedance method is very effective for simultaneous fault detection, classification and location.

Keywords: Simultaneous Fault; Simultaneous Fault Analysis; Two Port Network; Simultaneous Fault Detection; Simultaneous Fault Classification; Simultaneous Fault Location.

1. Introduction

An electric power system consists of three principal divisions:
1) Generating network
2) Transmission network
3) Distribution network

Power transmission lines are vital links in electric power system that achieve the essential continuity of service for reliable and the function is to supply electric energy to customers as reliable and economical as possible. Transmission network is exposed to different failure due to lighting, short circuit, faulty equipment, misoperation, human errors, overload, etc. that may affect the human safety and system reliability. So, that mitigation of such failure might the extended the lifetime of equipment and protect lives of human beings and power supply continuity. Detecting faults and disconnecting the faulted transmission lines as quickly as possible are the important roles of protection system after that estimating the location of fault.

One of the most difficult problems in the solution of faulted networks is that involving two or more faults which occur simultaneously. Analyzing abnormal conditions in power systems, such as short circuit, and open conductor faults, is important for protection system design and transient stability assessment. On the other hand, a simultaneous fault situation may arise from the chance occurrence of two fault conditions at two (or more) remote points. Usually only two simultaneous faults are considered. This is a practical limitation because the joint probability of even two simultaneous faults is quite low since it is computed as the product of the two single-event probabilities.

Fault types experienced in power systems are generally classified into main groups [1]:

a) Shunt type faults (parallel faults)
   i) Single line-to-ground faults
   ii) Line-to-line faults
   iii) Double line-to-ground faults
b) Series type faults
   i) One open conductor faults
   ii) Two open conductor faults

A simultaneous fault detection and diagnosis scheme is a process aimed at verifying, if a fault event did occur, analysis of certain parameters to determine the type of the fault. phase(s) affected by the fault, the faulted line section, and also estimate the distance to the fault with the highest accuracy possible. Generally, electric power fault detection and diagnosis consist of detection, classification, and location.

Detection of simultaneous fault is unexpected disturbance is detected in system parameters that degrade of performance by monitoring current and voltage signals of the phases. Simultaneous Fault classification that used to define the fault type and identify the fault phases. Simultaneous Fault location is determination of the point at which a fault occurs in an electric power transmission line, is vital for economic operation of power systems. The improvement of simultaneous fault detection, classification and location in transmission lines is an important issue mainly to decrease repair times, restore the service as soon as possible and maintains system stability.

Several investigations have examined the fault location in transmission line. Several investigations have examined the fault detection and diagnosis in power transmission line.
Z.X. Han [2] describes two methods to analyze any combination of simultaneous balanced and unbalanced faults in a power system. The first method can be used to calculate the symmetrical components and phase components for any bus voltage and branch current of a faulted power system. Using the second method, an equivalent network connected to the positive sequence network can be obtained.

Julio Cesar Stacchini de Souza et al., 2001[3] proposed an artificial neural network based methodology for power system fault location, they used more than one neural network, each of them being responsible for detecting faults involving a limited number of components of the protected power system.

M. M. Tawfik and M. M. Morcos, 2001 [4] proposed a system to locate faults on transmission lines using the traveling wave phenomenon, and using Prony method to analyze the voltage or current signal at the local bus and extract its modal information which presents the traveling wave generated by the fault and using it to estimate the location referred to it by applying this modal information to a specified artificial neural network.

M. S. Pasand and H. K. Zadeh, 2003[5] achieved the use of neural networks as a protective relaying pattern classifier algorithm. The proposed method used the changes in current waveform signals to learn the hidden relationship in the input patterns and then detect the fault if it would happen.

T. Bouthiba, 2004[6] presented a study dealing with the application of ANNs to fault detection and location in Extra High Voltage (EHV) transmission lines for high speed protection by using the data from one end of the line. The proposed neural fault detector and locator were trained using various sets of data available from a selected power network model and simulating different fault scenarios.

Wei-Min Lin et al., 2004[7] presented fault detection and alarm processing with fault detection system (FDS). FDS consists of adaptive architecture with probabilistic neural network (PNN). Training PNN uses the primary/back-up information of protective devices to create the training sets. However when network topology changes; adaptation capability becomes important in neural network application.

S.SaeidiTaheri, and HoseinAskarian-Abyaneh, 2011[8] proposed coordinate Power Swing Blocking relays (PSBs) for worst out of step condition that may occurs in a system. We could simulate that condition using software that programmed for simulating of two simultaneous fault conditions, for the first time. These faults occur on two most sensitive lines that have been selected by Line Sensitivity Coefficient Analyzer module.

Jianyi Chen and R.K. Aggarwal, 2012 [9] proposed a description of the novel fault detection and fault classification scheme using the data of the current signal that was measured from only one terminal of the transmission line by Wavelet Transform and Artificial Intelligence.

Mayuresh Rao and R.P.Hasabe, 2013 [10]. In this work an approach for combined discrete wavelet transform and neural network is presented to achieve fault detection and classification in transmission line faults

2. Simultaneous fault analysis by two port network

Two-port network is best in analysis because it relies on simplifying large and complex networks into small, streamlined networks. The concept of a two-port network has two pairs of terminals and the current of each pair of terminal isolated from the other pair. The direction of the current flow of each pair from one side towards the other shown on the network of fig.1 [11]

![Two-Port Network](image)

Maintain non-overlapping currents (I1, I2) are developed by (1:1) to the ends of the network to prevent interference also between networks group and maintain the currents to facilitate the analysis of these networks. Passive two-port networks are commonly specified in terms of the network parameters defined in Table 1. [12]

<table>
<thead>
<tr>
<th>Table 1: Two-Port Network Parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td>Designation (parameters)</td>
</tr>
<tr>
<td>Z(impedance)</td>
</tr>
<tr>
<td>Y(admittance)</td>
</tr>
<tr>
<td>H(hybrid)</td>
</tr>
<tr>
<td>G(inverse hybrid)</td>
</tr>
</tbody>
</table>

The two-port impedance parameters above are the two-port Thevenin equivalent impedances. In general, the two-port Thevenin equivalent impedance is given by (5):

\[ Z_{\text{Thevenin}} = \begin{bmatrix} Z_{i-j}^{m-n} & U_{i-j}^{m-n} \\ U_{i-j}^{m-n} & Z_{m-n}^{i-j} \end{bmatrix} \]

(5)

Where

\[ U_{i-j}^{m-n} = E_{i}^{m-n} - E_{j}^{m-n} \]

(6)

\[ Z_{i-j}^{m-n} = Z_{i-j}^{m-n} - Z_{i-j}^{m-n} + Z_{m-n} \]

(7)

The term \( E_{i}^{m-n} \) represents the voltage at Node i when 1 pu current is injected between Nodes m and n, and the term \( E_{j}^{m-n} \) represents the voltage at Node j when 1 pu current is injected between Nodes m and n. The term \( (U_{i-j}^{m-n} = E_{i}^{m-n} - E_{j}^{m-n}) \) is the voltage difference between Nodes i and j when 1 pu current is injected between Nodes m and n. The Z terms in (5), (6), and (7) represent the respective bus impedance matrix elements. In general, the bus impedance matrix element represents the voltage measured at Node i when 1 pu current is injected at Node m. Note that if Nodes j and n are 0, representing the reference bus, we have the result shown in (8).

\[ U_{i-j}^{m-n} = E_{i}^{m-n} = Z_{i-j}^{m-n} \]

(8)

To obtain the two-port Y-equivalent sequence networks from the two-port \( Z_{\text{Thevenin}} \) sequence equivalents. Several methods are available for obtaining the two-port Y-equivalent sequence networks. We can use the two-port Y-equivalent sequence networks to calculate the fault currents at intermediate points along a transmission line [13]. It is necessary not to interfere between the currents and voltages of the relay networks in the simultaneous faults. This is done by placing the phase shift on the connection of sequence network[12,13]. The simultaneous faults problems to be solved can be generalized by three forms:

1) A series fault at i and a series fault at j
2) A shunt fault at i and a shunt fault at j
3) A shunt fault at i and a series fault at j
4) A series fault at i and a shunt fault at j

Actually, we can view this as only three different fault configurations since situations 3 and 4 require exactly the same computation scheme.
3. A series fault - a series fault (Z type faults)

A series-series connection of two-port sequence networks to study the following fault types:
1. Simultaneous single line to ground faults at i and j.
2. A single line to ground fault and two line open fault at i and j respectively.
3. Two line open fault and a single line to ground fault at i and j respectively.
4. Simultaneous Two line open fault at i and j respectively.

Fig. (2) shows the series-series (Z-type faults) two-port sequence network interconnection.

![Sequence Network Connection for Simultaneous Z-Type Faults](image)

We use (9) to calculate Port i and Port j positive-sequence voltages:

\[
\begin{bmatrix}
V_{i(1)} \\
V_{j(1)} 
\end{bmatrix}
= 
\begin{bmatrix}
E_{i(1)} \\
E_{j(1)} 
\end{bmatrix}
- 
\begin{bmatrix}
Z_{ii(1)} & Z_{ij(1)} \\
Z_{ji(1)} & Z_{jj(1)} 
\end{bmatrix}
\begin{bmatrix}
I_{i(1)} \\
I_{j(1)} 
\end{bmatrix}
\tag{9}
\]

From fig. (2), we can also write (9) and (10), where k = 0, 1, and 2:

\[
n_{i(k)} = \frac{V_{x(k)} / V_{y(k)}}{I_{x(k)} / I_{y(k)}}
\tag{10}
\]

\[
n_{j(k)} = \frac{V_{y(k)} / V_{y(k)}}{I_{y(k)} / I_{y(k)}}
\tag{11}
\]

\[
\begin{bmatrix}
V_{x(1)} \\
V_{y(1)} 
\end{bmatrix}
= 
\begin{bmatrix}
n_{i(1)} & E_{i(1)} \\
n_{j(1)} & E_{j(1)} 
\end{bmatrix}
- 
\begin{bmatrix}
Z_{ii(1)} & \frac{n_{i(1)}Z_{ij(1)}}{n_{j(1)}} \\
Z_{ji(1)} & \frac{n_{j(1)}Z_{jj(1)}}{n_{i(1)}} 
\end{bmatrix}
\begin{bmatrix}
I_{x} \\
I_{y} 
\end{bmatrix}
\tag{12}
\]

To calculate the negative sequence network at port i and port j, we write (13):

\[
\begin{bmatrix}
V_{x(2)} \\
V_{y(2)}
\end{bmatrix}
= 
\begin{bmatrix}
Z_{ii(2)} & n_{i(2)}Z_{ij(2)} \\
Z_{ji(2)} & n_{j(2)}Z_{jj(2)}
\end{bmatrix}
\begin{bmatrix}
I_{x} \\
I_{y}
\end{bmatrix}
\tag{13}
\]

To calculate the zero sequence network at port i and port j, we write (14):

\[
\begin{bmatrix}
V_{x(0)} \\
V_{y(0)}
\end{bmatrix}
= 
\begin{bmatrix}
Z_{ii(0)} & n_{i(0)}Z_{ij(0)} \\
Z_{ji(0)} & n_{j(0)}Z_{jj(0)}
\end{bmatrix}
\begin{bmatrix}
I_{x} \\
I_{y}
\end{bmatrix}
\tag{14}
\]

However, from fig. (2) we observe that, for a series-series connection,

\[
\begin{bmatrix}
V_{x} \\
V_{y}
\end{bmatrix}
= 
\begin{bmatrix}
V_{x(1)} \\
V_{y(1)}
\end{bmatrix}
+ 
\begin{bmatrix}
V_{x(2)} \\
V_{y(2)}
\end{bmatrix}
+ 
\begin{bmatrix}
V_{x(0)} \\
V_{y(0)}
\end{bmatrix}
= 
\begin{bmatrix}
V_{x(1)} \\
V_{y(1)}
\end{bmatrix}
\tag{15}
\]

\[
\begin{bmatrix}
I_{x} \\
I_{y}
\end{bmatrix}
= 
\begin{bmatrix}
I_{x(1)} \\
I_{y(1)}
\end{bmatrix}
= 
\begin{bmatrix}
I_{x(2)} \\
I_{y(2)}
\end{bmatrix}
= 
\begin{bmatrix}
I_{x(0)} \\
I_{y(0)}
\end{bmatrix}
\tag{16}
\]

Performing the addition indicated in (15) and making the substitution (12), (13) and (14), we get the result in (17):

\[
\begin{bmatrix}
V_{x} \\
V_{y}
\end{bmatrix}
= 
\begin{bmatrix}
n_{i(1)} & E_{i(1)} \\
n_{j(1)} & E_{j(1)}
\end{bmatrix}
- 
\begin{bmatrix}
Z_{ii} & Z_{ij} \\
Z_{ji} & Z_{jj}
\end{bmatrix}
\begin{bmatrix}
I_{x} \\
I_{y}
\end{bmatrix}
\tag{17}
\]

Where:

\[
Z_{ii} = Z_{ii(1)} + Z_{ii(2)} + Z_{ii(0)}
\tag{18}
\]

\[
Z_{ij} = \frac{n_{i(1)}Z_{ij(1)}}{n_{j(1)}} + \frac{n_{i(2)}Z_{ij(2)}}{n_{j(2)}} + Z_{ij(0)}
\tag{19}
\]

\[
Z_{jj} = \frac{n_{j(1)}Z_{jj(1)}}{n_{i(1)}} + \frac{n_{j(2)}Z_{jj(2)}}{n_{i(2)}} + Z_{jj(0)}
\tag{20}
\]

4. A shunt fault - a shunt fault (parallel type)

A parallel-parallel connection of two-port networks is required to represent the following simultaneous fault conditions
1. Simultaneous double line to ground faults at i and j.
2. A double line to ground fault and one line open fault at i and j respectively.
3. One line open fault and a double line to ground fault at i and j respectively.
4. One line open fault and one line open fault at i and j respectively.

The sequence network connection with parallel-parallel termination is shown in fig. (3) where the ideal transformations are phase shifters with voltage and current relations

![Sequence Network Connection for Simultaneous Y-Type Faults](image)

For parallel-parallel sequence network connections, we work with the two-port admittance parameters (Y-parameters). We calculate the Y-parameters by inverting the two-port sequence network impedance parameters (Z-parameters).
We use (22) to calculate Port i and Port j positive-sequence currents:

\[
\begin{bmatrix}
I_i^{(1)} \\
I_j^{(1)}
\end{bmatrix} = \begin{bmatrix}
I_s^{(1)} \\
I_{Sj}^{(1)}
\end{bmatrix} = \begin{bmatrix}
Y_{ii}^{(1)} & Y_{ij}^{(1)} \\
Y_{ji}^{(1)} & Y_{jj}^{(1)}
\end{bmatrix} \begin{bmatrix}
V_i^{(1)} \\
V_j^{(1)}
\end{bmatrix}
\]

(22)

Where \(I_i\), the independent source term viewed from the i and j ports.

From fig. (3), we can also write (23) and (24), where \(k = 0, 1\) and 2:

\[
n_i(k) = V_x(k)/V_i(k) = I_x(k)/I_i(k)
\]

(23)

\[
n_j(k) = V_y(k)/V_j(k) = I_y(k)/I_j(k)
\]

(24)

Multiplying equation (2.33) by \(\begin{bmatrix} n_{i(i)} & 0 \\ 0 & n_{j(j)} \end{bmatrix}\), results in (25)

\[
\begin{bmatrix}
I_{x(i)}^{(1)} \\
I_{y(i)}^{(1)}
\end{bmatrix} = \begin{bmatrix}
n_{i(i)} & 0 \\
0 & n_{j(j)}
\end{bmatrix} \begin{bmatrix}
Y_{ii}^{(1)} & Y_{ij}^{(1)} \\
Y_{ji}^{(1)} & Y_{jj}^{(1)}
\end{bmatrix} \begin{bmatrix}
I_{x(i)}^{(1)} \\
I_{y(i)}^{(1)}
\end{bmatrix}
\]

(25)

To calculate the negative sequence network at port i and port j, we write (26)

\[
\begin{bmatrix}
I_{x(2)} \\
I_{y(2)}
\end{bmatrix} = \begin{bmatrix}
Y_{ii}^{(2)} & n_{i(j)}Y_{ij}^{(2)} \\
n_{j(i)}Y_{ji}^{(2)} & Y_{jj}^{(2)}
\end{bmatrix} \begin{bmatrix}
V_i^{(2)} \\
V_j^{(2)}
\end{bmatrix}
\]

(26)

To calculate the zero sequence network at port i and port j, we write (27)

\[
\begin{bmatrix}
I_{x(0)} \\
I_{y(0)}
\end{bmatrix} = \begin{bmatrix}
Y_{ii}^{(0)} & Y_{ij}^{(0)} \\
Y_{ji}^{(0)} & Y_{jj}^{(0)}
\end{bmatrix} \begin{bmatrix}
V_i^{(0)} \\
V_j^{(0)}
\end{bmatrix}
\]

(27)

Which transformers (since \(n_{i(0)}n_{j(0)} = 1\)), we get (28)

\[
\begin{bmatrix}
I_{x(0)} \\
I_{y(0)}
\end{bmatrix} = \begin{bmatrix}
V_i^{(0)} \\
V_j^{(0)}
\end{bmatrix} \begin{bmatrix}
Y_{ii}^{(0)} & Y_{ij}^{(0)} \\
Y_{ji}^{(0)} & Y_{jj}^{(0)}
\end{bmatrix} \begin{bmatrix}
V_i^{(0)} \\
V_j^{(0)}
\end{bmatrix}
\]

(28)

But, from figure (Error! No text of specified style in document.)6 we observe that, for a series-series connection,

\[
\begin{bmatrix}
I_x \\
I_y
\end{bmatrix} = \begin{bmatrix}
I_{x(1)} \\
I_{y(1)}
\end{bmatrix} + \begin{bmatrix}
I_{x(2)} \\
I_{y(2)}
\end{bmatrix} + \begin{bmatrix}
I_{x(0)} \\
I_{y(0)}
\end{bmatrix} = \begin{bmatrix} 0 \\ 0 \end{bmatrix}
\]

(29)

\[
\begin{bmatrix}
V_x \\
V_y
\end{bmatrix} = \begin{bmatrix}
V_{x(1)} \\
V_{y(1)}
\end{bmatrix} = \begin{bmatrix}
V_{x(2)} \\
V_{y(2)}
\end{bmatrix} = \begin{bmatrix}
V_{x(0)} \\
V_{y(0)}
\end{bmatrix}
\]

(30)

Performing the addition indicated in (29) and making the substitution (25), (26) and (27), we get the result in (31):

\[
\begin{bmatrix}
I_x \\
I_y
\end{bmatrix} = \begin{bmatrix}
Y_{ii}^{(1)} & Y_{ij}^{(1)} \\
Y_{ji}^{(1)} & Y_{jj}^{(1)}
\end{bmatrix} \begin{bmatrix}
V_i^{(1)} \\
V_j^{(1)}
\end{bmatrix}
\]

(31)

Where:

\[
Y_{ii} = Y_{ii(1)} + Y_{ii(2)} + Y_{ii(0)}
\]

(32)

\[
Y_{ij} = \frac{n_{ii}(0)}{n_{ji}(0)}Y_{ij(1)} + \frac{n_{ii}(2)}{n_{ji}(2)}Y_{ij(2)} + Y_{ij(0)}
\]

(33)

\[
Y_{ji} = \frac{n_{ii}(0)}{n_{ji}(0)}Y_{ji(1)} + \frac{n_{ii}(2)}{n_{ji}(2)}Y_{ji(2)} + Y_{ji(0)}
\]

(34)

\[
Y_{jj} = Y_{jj(1)} + Y_{jj(2)} + Y_{jj(0)}
\]

(35)

5. A series fault and a shunt fault (H type faults)

We use the series-parallel connection of the two-port sequence networks to study the following type of faults[31]:

1) A single line to ground fault and double line to ground fault at i and j respectively.

2) A single line to ground fault and one line open fault at i and j respectively.

3) Two line open fault and two line open fault at i and j respectively.

4) Two line open fault and one line open fault at i and j respectively.

\[
\begin{bmatrix}
I_x \\
I_y
\end{bmatrix} = \begin{bmatrix}
I_{x(1)} \\
I_{y(1)}
\end{bmatrix} + \begin{bmatrix}
I_{x(2)} \\
I_{y(2)}
\end{bmatrix} + \begin{bmatrix}
I_{x(0)} \\
I_{y(0)}
\end{bmatrix} = \begin{bmatrix} 0 \\ 0 \end{bmatrix}
\]

(36)

\[
\begin{bmatrix}
I_x \\
I_y
\end{bmatrix} = \begin{bmatrix}
I_{x(1)} \\
I_{y(1)}
\end{bmatrix} + \begin{bmatrix}
I_{x(2)} \\
I_{y(2)}
\end{bmatrix} + \begin{bmatrix}
I_{x(0)} \\
I_{y(0)}
\end{bmatrix} = \begin{bmatrix} 0 \\ 0 \end{bmatrix}
\]

(37)

Performing the addition indicated in (36) and making the substitution, we get the result in (38):

\[
\begin{bmatrix}
V_x \\
V_y
\end{bmatrix} = \begin{bmatrix}
V_{x(1)} \\
V_{y(1)}
\end{bmatrix} - \begin{bmatrix}
h_{ii} \\
h_{jj}
\end{bmatrix} \begin{bmatrix}
I_x \\
I_y
\end{bmatrix}
\]

(38)

We use (39) to calculate the hybrid parameter matrices (H-parameters) from the two-port Z-parameter matrices [14]:

\[
H(k) = \begin{bmatrix}
\frac{Z_{x(k)}}{Z_{x(k)}} & \frac{Z_{x(k)}}{Z_{x(k)}} \\
\frac{Z_{y(k)}}{Z_{y(k)}} & \frac{Z_{y(k)}}{Z_{y(k)}}
\end{bmatrix}
\]

(39)

Where \(Z_{x(k)}\) the determinant of matrix \(Z_{x(k)}\) and \(k = 0, 1, 2\) represent the zero, positive, and negative - sequence network, respectively.
of shunt and series faults, specific faulted phase and sequence network as shown in table(2)[14].

<table>
<thead>
<tr>
<th>Table 2: Isolation Transformer Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>A-G</td>
</tr>
<tr>
<td>B-G</td>
</tr>
<tr>
<td>C-G</td>
</tr>
<tr>
<td>B-C-G</td>
</tr>
<tr>
<td>C-A-G</td>
</tr>
<tr>
<td>A-B-G</td>
</tr>
<tr>
<td>A-Phase Open</td>
</tr>
<tr>
<td>B-Phase open</td>
</tr>
<tr>
<td>C-Phase Open</td>
</tr>
<tr>
<td>C&amp;A-Phases Open</td>
</tr>
<tr>
<td>A&amp;B-Phases Open</td>
</tr>
</tbody>
</table>

6. Representation of fault on the transmission lines

The system has a bus impedance/admittance matrix of dimension nxn. The bus admittance matrix before fault takes the form

$$[Y_{bus \ before \ fault}] = \begin{bmatrix} y_{11} & \cdots & y_{1k} & \cdots & y_{1n} \\ \vdots & \ddots & \vdots & \ddots & \vdots \\ y_{nk} & \cdots & y_{kn} & \cdots & y_{nn} \end{bmatrix}$$

Where $[Y_{bus \ before \ fault}]$ is the bus admittance before fault matrix, k is one of busses and n is number of busses in the system. Fig. 5 shows a transmission line supplied from both ends.

$$\text{Fig. 5: Transmission Line without Fault.}$$

If fault occurs on the line that connect two buses k & n, an imaginary bus will be generated to be. Remove all link between bus k and bus n. Fig. 6 shows that the fault point is considered as a third bus (imaginary bus) in the system.

$$\text{Fig. 6: Transmission Line during Fault.}$$

The bus admittance matrix after fault takes the form

$$[Y_{bus \ after \ fault}] = \begin{bmatrix} y'_{11} & \cdots & y'_{1k} & \cdots & y'_{1f} \\ \vdots & \ddots & \vdots & \ddots & \vdots \\ y'_{nk} & \cdots & y'_{nn} & \cdots & y'_{nf} \\ y'_{nk} & \cdots & y'_{nn} & \cdots & y'_{nf} \end{bmatrix}$$

Where $[Y_{bus \ after \ fault}]$ is the bus admittance matrix after fault

$$y_{kk} = y_{kk} - (Z^{-1}_{line \ kn}) + (Z^{-1}_{line \ kn}/m_1)$$

$$m_1 = \text{lengths from each bus (K) to the fault point (f)}$$

7. Mathematical model

a) Fault Detection

Fault detection enables faults to be sensed on buses or transmission lines by monitoring the phase impedances and/or phase-current amplitudes and/or phase-voltage amplitudes and/or zero-sequence current amplitude. The fault current magnitude may be any-where from 10 to 30 times the full-load or rated current of the equipment [15] and the voltage magnitude is reduced down to 60%-70% of the normal value [16][17]. It is difference between pre-fault measurement and fault measurement as shown: It is difference between pre-fault measurement and fault measurement as shown:

If

$$V_{bus}(0) = \begin{bmatrix} V_{1}(0) \\ V_{2}(0) \\ V_{3}(0) \end{bmatrix}$$

Where $V_{bus}(0)$ is the prefault voltages obtained from power flow solution [23].

And

$$\Delta V_{bus} = \begin{bmatrix} \Delta V_1 \\ \Delta V_2 \\ \Delta V_3 \end{bmatrix}$$

Where $\Delta V_{bus}$ is the bus voltage changes caused by the fault. Then

$$V_{bus}(f) = V_{bus}(0) + \Delta V_{bus}$$

$V_{bus}(f)$ is the voltages during the fault. Which lead to:

$$I_{bus} = Y_{bus} \cdot V_{bus}$$

Where $I_{bus}$ is the bus current entering the bus and $Y_{bus}$ is the bus admittance matrix.

$$\begin{bmatrix} 0 \\ I_{i}(f) \\ I_{j}(f) \end{bmatrix} = \begin{bmatrix} Y_{11} & \cdots & Y_{1j} & \cdots & Y_{1n} \\ \vdots & \ddots & \vdots & \ddots & \vdots \\ \vdots & \ddots & \vdots & \ddots & \vdots \\ 0 & \cdots & 0 & Y_{nj} & \cdots & Y_{nn} \end{bmatrix} \begin{bmatrix} \Delta V_{1} \\ \Delta V_{j} \\ \Delta V_{j} \end{bmatrix}$$

Where $I_{i}(f)$ and $I_{j}(f)$ is the fault current at bus i and j respectively.

Or

$$I_{bus}(f) = Y_{bus} \cdot \Delta V_{bus}$$

Solving $\Delta V_{bus}$, we have
\[ \Delta V_{bus} = Z_{bus}^{-1}I_{bus}(f) \]  
(48)

Where \( Z_{bus} = V_{bus}^{-1} \) is knowing as the bus impedance matrix. Substituting (48) into (44)

\[ V_{bus}(f) = V_{bus}(0) + Z_{bus}^{-1}I_{bus}(f) \]  
(49)

Writing above matrix equation in terms of its elements, we have

\[
\begin{bmatrix}
V(f) \\
V(0) \\
V(0) \\
V(0)
\end{bmatrix} = 
\begin{bmatrix}
Z_{11} & \ldots & Z_{1j} & \ldots & Z_{1m} & 0 \\
\vdots & \ddots & \vdots & \ddots & \vdots & \vdots \\
\vdots & \vdots & \vdots & \ddots & \vdots & \vdots \\
Z_{n1} & \ldots & Z_{nj} & \ldots & Z_{nm} & 0
\end{bmatrix}
\begin{bmatrix}
I(f) \\
I(f) \\
I(f) \\
I(f)
\end{bmatrix}
\]

(50)

b) Simultaneous fault classification and classification using Back-propagation neural network

Back-propagation Neural Network (BNN) can be used to solve problems in this research to determine the classification and location during fault in an electric power system thus can make the right decision by given input pattern in testing.

1) Back-Propagation Learning Algorithm[18]

The back-propagation algorithm is central to much current work on learning in neural networks. It was invented independently several times by Bryson and Ho (1969), Werbos (1974), Parker (1985) and Rumelhart, Hinton and Williams (1986). A closely related approach by le Chun (1985). The back-propagation method works very well by adjusting the weights, which are connected in successive layers of multi-layer perceptrons.

The back-propagation learning rules are used to adjust the weights and biases of networks so as to minimize the sum squared error of network. This is done by continually changing the values of the network weights and biases in the direction of steepest descent with respect to error. This is called a gradient descent procedure.

Changes in each weight and bias are proportional to that element’s effect on the sum-squared error of the network [19].

Trained back-propagation networks tend to give reasonable answers when presented with inputs that they have never seen. Typically, a new input will lead to an output similar to the correct output for input vectors used in training that are similar to the new input being presented. This generalization property makes it possible to train a network on a representative set of input/target pairs and get good results for new inputs without training the network on all possible input/output pairs. The architecture back propagation neural network shown in fig. (7). A summary of steps for procedure of back-propagation technique may be as follows:

1) Initialize the network weights and biases by small random elements between +1 and -1. This allows the weights and biases to be changes easily and leaves enough variation to them so that neurons in the network start with a range of behaviors that can be taken advantage of by learning rule.

2) The network consist of input units \((X_n, n=1,2,...,N)\) and output units \((O_m, m=1,2,...,M)\) and hidden units \((Z_o, o=1,2,...,O)\). Thus , the hidden unit \(Z_j\) receives a net input and procedures the output:

\[ Z_o = f(\Sigma_{k=1}^{N} W_{ok}X_k + b_o) \]  
(51)

3) The actual outputs will be calculated by sigmoid neurons.

\[ O_m = f(\Sigma_{j=1}^{O} W_{mj}X_j + b_m) \]  
(52)

4) Calculate the error, the difference between target and actual output and it will be minimized.

\[ MSE = \frac{1}{2} \Sigma_{m=1}^{M} (O_m - O_{m\text{target}})^2 \]  
(53)

Where \( O_m \) is the desired output of pattern \( m \), \( O_{m\text{target}} \) is the actual net output.

5) Derivatives of error (called delta vectors) are calculated for the output layer and then back-propagate through the network until delta vectors are available to hidden layers (i.e. delta vector of hidden layer are calculated from delta vector of next layer ‘output layer’).

\[ \delta_l = (O_m \text{target} - O_m)O_m \]  
(54)

\[ \delta_j = Z_j \Sigma_{i=1}^{N} \delta_l W_{im} \]  
(55)

6) The weights and biases changes are calculated recursively backwards from the output layer towards the input layer. Once all changes are calculated the weights and biases are updated as follows:

\[ W_{jk}(new) = W_{jk}(old) + \Delta W_{jk} \]  
(56)

\[ W_{im}(new) = W_{im}(old) + \Delta W_{im} \]  
(57)

\[ b_l(new) = b_l(old) + \Delta b_l \]  
(58)

\[ b_j(new) = b_j(old) + \Delta b_j \]  
(59)

Where

\[ \Delta W_{jk} = \eta \delta_j X_i \]  
(60)

\[ \Delta W_{im} = \eta \delta_i X_j \]  
(61)

\[ \Delta b_l = \eta \delta_j \]  
(62)

\[ \Delta b_j = \eta \delta_i \]  
(63)

\[ W_{im} = \text{Weight from Layer I to Layer M} \]

\[ B_i = \text{the Baises for the Layer J} \]

\[ \Delta_i = \text{Delta Vector of J Layer (Hidden Layer)} \]

\[ \Delta_o = \text{Delta Vector of I Layer (Output Layer)} \]

\[ O_m = \text{the Output of Network M Layer} \]

\[ H = \text{Learning Rate} \]

7) Present the next pattern in the training set and repeat steps from 1 to 6.

8) Check the error goal or a predefined maximum number of iterations. The process from 1 to 7 will be repeated until one of them is achieved.
The proposed fault classifier in this work based on the Backpropagation Neural Network (BNN) used to classify the different type of faults in transmission lines.

In this work the BNN takes in consideration input data for faulted magnitude of currents and voltage for the three phases, zero sequence current and voltage for the first and the second faults and distinguishes the grounded phases of the first and second fault.

The proposed model relies on five neural networks to process data this network as following:
1) a neural network (Voltage and current) for phase A
2) a neural network (Voltage and current) for phase B
3) a neural network (Voltage and current) for phase C
4) a neural network (zero sequence current and voltage) for the first fault
5) a neural network (zero sequence current and voltage) for the second fault

The outputs have been termed as A, B, C indicating the faulted phase, and G1, G2 indicating the grounded phase in the first and the second fault respectively. Any one of the outputs A, B, C approaching 1 indicates a fault in that phase, and if G1 or G2 is taken 1 indicates a fault related to ground. The combination of the neurons in the target of output layer classifies the phase situation according to table (3). Once the fault is classified, the relevant ANNs for fault location are activated.

### Table 3: Target for ANN Output

<table>
<thead>
<tr>
<th>Fault situation</th>
<th>Network outputs</th>
</tr>
</thead>
<tbody>
<tr>
<td>A-G</td>
<td>A</td>
</tr>
<tr>
<td>B-G</td>
<td>1</td>
</tr>
<tr>
<td>C-G</td>
<td>0</td>
</tr>
<tr>
<td>B-C-G</td>
<td>0</td>
</tr>
<tr>
<td>A-C-G</td>
<td>1</td>
</tr>
<tr>
<td>A-B-G</td>
<td>1</td>
</tr>
<tr>
<td>B-C</td>
<td>0</td>
</tr>
<tr>
<td>A-C</td>
<td>1</td>
</tr>
<tr>
<td>A-B</td>
<td>1</td>
</tr>
<tr>
<td>A-B-C</td>
<td>1</td>
</tr>
<tr>
<td>A-O</td>
<td>0</td>
</tr>
<tr>
<td>B-O</td>
<td>1</td>
</tr>
<tr>
<td>C-O</td>
<td>1</td>
</tr>
<tr>
<td>B-C-O</td>
<td>0</td>
</tr>
</tbody>
</table>

The number of neurons in the hidden layer is determined here after a long simulation and training process to reach the best performance. The mean square error MSE is indicator for the quality of estimated data from targeted output. Best result of MSE is 0 and Training was stopped when the mean square error MSE between the actual input and the desired output generated for the test pattern stopped improved. The equation of MSE as in equation:

\[ MSE = \sum_{i=1}^{n} (out_{ANNi} - output_{targeti})^2 \]  \hspace{1cm} (64)

\( n \) represent the number data

The outputs have been termed as A, B, C indicating the faulted phase, and G1, G2 indicating the grounded phase in the first and the second fault respectively. Any one of the outputs A, B, C approaching 1 indicates a fault in that phase, and if G1 or G2 is taken 1 indicates a fault related to ground. The combination of the neurons in the target of output layer classifies the phase situation according to table (3). Once the fault is classified, the relevant ANNs for fault location are activated.

### Fig. 7: The Architecture Back Propagation Neural Network.

### Fig. 8: Detailed Structure of the Simultaneous Fault Classification.

8. The structure of the proposed diagram

A program was written in MATLAB environment for the detection and classification. The input data was calculated by a Newton-Raphson load flow program and considered as the initials values. The proposed method is described as follows:

**Subroutine 1: simultaneous fault analysis and detection**

1. Input data of power transmission system including all the line data, bus data a, G&T data, input number of buses , and location of two bus bar fault i and j

2. Run the load flow program to calculate the initial values of currents and voltages and store the current and voltage before fault

3. Formulate Z, Y bus matrices for all three sequence networks (Z0, Z1, Z2, Y0, Y1, Y2)

4. Input types of faults if:
   a) Series-series connection (Z-type faults)
   b) Parallel-parallel connection (Y-type faults)
   c) Series-parallel connection (H-type faults)

5. Form fault port matrices for all sequence network and open circuit voltage for positive sequence network is calculated.

6. Solve boundary (conditions) the voltage and current

7. Bus voltages and currents of the buses affected by occurrence of the fault are calculated.

8. The next fault analysis if yes goes to step 4 else go to step 8

9. Store the line current fault and voltage for each bus bar

10. Compare fault current and voltage with pre-fault current and voltage for each bus bar.

11. Detect the fault

12. End

Fig.7 shows the flow chart of simultaneous fault and detection fault
Subroutine 2: simultaneous fault classification by neural network

The structure of subroutine simultaneous fault classification is as follows:

Step 1: Input and output data
- Input to the neural network are ten inputs: three phase currents, voltages, and ground current and voltage for each fault.
- The outputs are associated with the five fault categories.

Step 2: Assemble and preprocess the training data for single and modular ANN-based fault classification

Step 3: Training Process

The behavior of the selected ANN depends on numerous parameters, such as the number of hidden layers, the number of hidden neurons, transfer functions, initial weights and biases, training rule and training parameters. In some cases, choosing one of these parameters wrongly may lead to overfitting or other kinds of problems.

The design and development of the backpropagation with supervised learning BP network as a fault classifier.

Step 4: Test and evaluate

In order to prove the effectiveness of the fault classification technique by using the suggest fault classification based on ANN, a number of fault cases were tested under different parameter variations.

The test and Evaluate is used to judge the overall performance of the finally developed trained neural network. If the test data set reaches up to the minimum value of mean square error at any significantly different iteration than the validation set, it means that the neural network will not be able to provide satisfactory performance and needs to be re-architecture. For the task of training the neural networks for different stages, sequential feeding of input and output pair has been adopted. In order to obtain a large training set for efficient performance, each of the six ten kinds of faults has been simulated at different locations along the considered transmission line.

Fig. 9 shows the flow chart of simultaneous fault classification by neural network.

Subroutine 4: Fault location by neural network

Step 1: Start

Step 2: Input & output
- The magnitudes of three phase currents were used as input of the neural network.
- The input variables have to be normalized in order to fit into ANN input range.

Step 3: Assemble and preprocess the training data for single and modular ANN-based fault location

Step 4: Training Process

The data for training was obtained by M-file Matlab. The neural network toolbox from Matlab was used to create ANN diagram, train it and obtain the weight and bias as output.

The magnitudes of three phases current were used as input of the neural network. It should be mentioned that the input variables have to be normalized in order to fit into ANN input range. The output of the ANN fault locator is the estimation of fault location in Km. The output is scaled to distance of fault from bus in Km.

In the post process, the fault location procedures the output of ANN processing stage is location of occurred fault. The output of ANN is scaled to distance of fault from bus in Km.

The mean square error MSE is indicator for the quality of estimated data from targeted output and best result when MSE value is equal to zero.

Fig. 11: Shows the Flow Chart of Simultaneous fault Classification by Neural Network.
The process of training validation and testing are performed using suitable number of hidden layer. The transfer function of hidden layer and output layer respectively sigmoid and linear function.

Step 5: Test of performances
Once the ANNs training procedure is entirely carried out, all networks of the fault locator are tested under different fault scenarios using different fault conditions which are not presented during the training process. All fault types with different fault location in the transmission line are simulated in order to evaluate the performances of the proposed fault location scheme. The criterion for evaluating the performance of the proposed neural fault locator is based on the following equation.

$$\text{Absolute Error} (\%) = \frac{|\text{estimated distance} - \text{actual distance}|}{\text{length of line}} \times 100\%$$ (65)

Fig. (12) Shows the flow chart of simultaneous fault location by neural network

9. Case study
To verification of the proposed program accuracy and methodology are an important task in order to create a reliable tool for calculation, the program was applied on the IEEE 11-bus test system. The system consists of 11 bus and 14 transmission line. The parameter of the system in per-unit and the single line diagram of this system is shown in “Fig. 11,” and its data are explained in the appendix (A).

Table-4 shows Power Flow Solution by Newton-Raphson program.

Table 4: Power Flow Solution by Newton-Raphson Method

<table>
<thead>
<tr>
<th>No.</th>
<th>Mag.</th>
<th>Degree</th>
<th>MW</th>
<th>Mvar</th>
<th>MW</th>
<th>Mvar</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1.04</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>240.01</td>
<td>211.39</td>
</tr>
<tr>
<td>2</td>
<td>1.028</td>
<td>-0.772</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>3</td>
<td>1.004</td>
<td>-2.26</td>
<td>150</td>
<td>120</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>4</td>
<td>1.024</td>
<td>-0.587</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>5</td>
<td>1.021</td>
<td>-1.413</td>
<td>120</td>
<td>60</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>6</td>
<td>1</td>
<td>-2.588</td>
<td>140</td>
<td>90</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>7</td>
<td>1</td>
<td>-0.425</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>8</td>
<td>0.993</td>
<td>-2.765</td>
<td>110</td>
<td>90</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>9</td>
<td>0.99</td>
<td>-3.174</td>
<td>80</td>
<td>50</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>10</td>
<td>1.035</td>
<td>0.278</td>
<td>0</td>
<td>200</td>
<td>147.65</td>
<td>0</td>
</tr>
<tr>
<td>11</td>
<td>1.03</td>
<td>0.447</td>
<td>0</td>
<td>0</td>
<td>160</td>
<td>92.906</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td>600</td>
<td>410</td>
<td>600.01</td>
<td>0</td>
</tr>
</tbody>
</table>

When two faults occur on bus-bar to make sure the accuracy of the program, fault on first bus-bar three phase on bus-bar (6) and single line to ground (b-g) on transmission line (4-9). The single line diagram of simultaneous fault of transmission lines is shown in “Fig. 12,”.
### Table 5: Fault Current on Fault Location At Bus (6) and Transmission Line (4-9) [Imaginary Bus 12].

<table>
<thead>
<tr>
<th>Bus</th>
<th>Voltage before fault</th>
<th>Current before fault</th>
<th>Angle before fault</th>
<th>Voltage after fault</th>
<th>Current after fault</th>
<th>Angle after fault</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>2.134e-10</td>
<td>0.01542</td>
<td>90.977</td>
<td>1.028</td>
<td>1.024</td>
<td>1.004</td>
</tr>
<tr>
<td>12</td>
<td>0.1432</td>
<td>42.0544</td>
<td>4.0339</td>
<td>-87.1906</td>
<td>4.0339</td>
<td>552.8094</td>
</tr>
</tbody>
</table>

### Table 6: Comparison of Voltages for Simultaneous Faults on Bus 6 and Transmission Line (4-9).

<table>
<thead>
<tr>
<th>Bus</th>
<th>Voltage before fault</th>
<th>Current before fault</th>
<th>Angle before fault</th>
<th>Voltage after fault</th>
<th>Current after fault</th>
<th>Angle after fault</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>1.04</td>
<td>0.71853</td>
<td>-2.519</td>
<td>0.688382</td>
<td>-121.153</td>
<td>0.719024</td>
</tr>
<tr>
<td>12</td>
<td>1.028</td>
<td>0.612864</td>
<td>-2.10765</td>
<td>0.563863</td>
<td>-120.398</td>
<td>0.613757</td>
</tr>
<tr>
<td>1</td>
<td>1.004</td>
<td>1.171138</td>
<td>0.324218</td>
<td>-117.086</td>
<td>0.442826</td>
<td>121.9973</td>
</tr>
<tr>
<td>2</td>
<td>1.024</td>
<td>0.236988</td>
<td>0.470355</td>
<td>-120.121</td>
<td>0.661081</td>
<td>118.4076</td>
</tr>
<tr>
<td>5</td>
<td>1.02</td>
<td>0.575135</td>
<td>-119.115</td>
<td>0.633071</td>
<td>121.8791</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>1.02</td>
<td>0.604689</td>
<td>-0.47502</td>
<td>0.68294</td>
<td>112.398</td>
<td>0.713552</td>
</tr>
<tr>
<td>7</td>
<td>1.021</td>
<td>0.713232</td>
<td>-1.08183</td>
<td>0.634654</td>
<td>112.398</td>
<td>0.713552</td>
</tr>
<tr>
<td>9</td>
<td>0.993</td>
<td>0.54547</td>
<td>4.518935</td>
<td>0.242535</td>
<td>-113.302</td>
<td>0.452269</td>
</tr>
<tr>
<td>10</td>
<td>0.935</td>
<td>0.800076</td>
<td>-0.50339</td>
<td>0.650666</td>
<td>-121.058</td>
<td>0.800506</td>
</tr>
<tr>
<td>11</td>
<td>1.03</td>
<td>0.880257</td>
<td>0.7703</td>
<td>121.277</td>
<td>0.802735</td>
<td>120.0104</td>
</tr>
<tr>
<td>12</td>
<td>1.00</td>
<td>0.622702</td>
<td>5.80E-17</td>
<td>83.6029</td>
<td>0.622702</td>
<td>111.5564</td>
</tr>
</tbody>
</table>

### Table 7: Comparison of Currents of a Symmetrical Fault on Bus (6) and Unsymmetrical Fault on Transmission Line (4-9).

<table>
<thead>
<tr>
<th>Bus</th>
<th>Current before fault</th>
<th>Line current before fault</th>
<th>Line current after fault at bus 6 and transmission line (4-9)</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>0.3076</td>
<td>-138.62</td>
<td>32.8094</td>
</tr>
<tr>
<td>12</td>
<td>0.1192</td>
<td>-136.05</td>
<td>42.0544</td>
</tr>
<tr>
<td>1</td>
<td>0.0947</td>
<td>-142.71</td>
<td>97.2922</td>
</tr>
<tr>
<td>2</td>
<td>0.094</td>
<td>-137.77</td>
<td>97.2922</td>
</tr>
<tr>
<td>3</td>
<td>0.0892</td>
<td>-35.378</td>
<td>97.2922</td>
</tr>
<tr>
<td>4</td>
<td>0.0166</td>
<td>-117.06</td>
<td>97.2922</td>
</tr>
<tr>
<td>5</td>
<td>0.0706</td>
<td>-145.01</td>
<td>97.2922</td>
</tr>
<tr>
<td>6</td>
<td>0.0804</td>
<td>-141.934</td>
<td>97.2922</td>
</tr>
<tr>
<td>7</td>
<td>0.0706</td>
<td>-145.01</td>
<td>97.2922</td>
</tr>
<tr>
<td>8</td>
<td>0.0804</td>
<td>-141.934</td>
<td>97.2922</td>
</tr>
<tr>
<td>9</td>
<td>0.0706</td>
<td>-145.01</td>
<td>97.2922</td>
</tr>
<tr>
<td>10</td>
<td>0.2402</td>
<td>36.165</td>
<td>97.2922</td>
</tr>
<tr>
<td>11</td>
<td>0.1429</td>
<td>-143.68</td>
<td>97.2922</td>
</tr>
<tr>
<td>12</td>
<td>0.1796</td>
<td>-145.01</td>
<td>97.2922</td>
</tr>
<tr>
<td>13</td>
<td>0.0154</td>
<td>-145.01</td>
<td>97.2922</td>
</tr>
</tbody>
</table>
10. Discussion of results

Fig. (14) Shows the voltage profile achieved. The bus voltage (6,12) before simultaneous fault was (1.028 , 0.993) p. u. respectively and after simultaneous fault three phase fault on bus 6, and b-g fault on bus 12 the buses voltage (6,12) is reduced down to (Va = 0.0464, Vb = 0.0927, Vc = 0.0464) p.u. and (Va= 0.6227, Vb =5.8E-17, Vc = 0.6227) p.u. respectively.

Fig. (15) Shows the line current achieved before simultaneous fault by N.R. and after simultaneous fault by the proposed method as shown in the table (7). We observed an increase in the line current value whenever fault location near from power supply because transmission lines impedance is low as shown in lines (1-2), (4-12), and (4-10).

Fig. 16 shows the fault bus current with time. We observed fault current at bus 6 is approximately symmetrical phase and fault current at bus 12 thus fulfilling the conditions of fault, phase B is increased while current of phase A and C approximately equal to zero thus fulfilling the conditions of fault.

Detection simultaneous faults according the fault current magnitude may be any-where from 10 to 30 times the full-load or rated current of the equipment and the voltage magnitude is reduced down to 60% -70% of the normal value. Classification simultaneous faults according fault conditions. Simultaneous fault detection , classification fault A-B-C-G on bus (6) and (B-G ) on transmission line (L4-9).

If the detected simultaneous fault on bus bar therefore simultaneous fault location on bus bar and if the fault location in transmission line calculated estimated location and error . The actual location on transmission line (L4-6) is 0.5. The estimation location (m1) is 0.5. The error of fault location (er1) is 0.0035.

Fig. 15: Results Given by Matlab Program by Proposed Method.

Fig. 16: Voltage Profile for the 11- Bus System.

Fig. 17: Line Current for the 11- Bus System.
11. Conclusions

The problem of simultaneous fault detection, classification and location in power system great importance for the economics and power quality of the power systems. It provides the essential continuity of service for reliable transmission. The importance of accurate fault location is increasing for fast repair and power system restoration. In this work, a conventional method using current and voltage values comparisons has been presented. The obtained results show the effectiveness and the accuracy of this method for simultaneous fault detection, classification and location.

References