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Synchronized Fault-Location Scheme For Multi Section Compound Transmission System Without Using Line Parameters

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ABSTRACT:

Locating faults in transmission lines helps to reduce maintenance time ΩΩ and it depends on voltage and current wave forms obtained during the fault at relay location. In this thesis fault location technique for one and two terminal multi section compound transmission lines which combine overhead line with underground power cables using phase synchronized measurement and compare results one end and two end (Takagi method) with differentfault resistances (0Ω, 5Ω, 10Ω, 30Ω, 50Ω) and grounding system Y_g and isolated system Y and compare with them, find fault location for single line model, single line with load and single terminal multisession. Also evaluated and discussed to estimate the fault location using ground system for neutral source with isolated system Y and their effects for different types of faults by using MATLAB.

Keywords: Locating faults, single line model, synchronized measurement, Takagi method and matrix method.

INTRODUCTION:

Electricity produced by a power plant is delivered to load centers and electricity consumers through transmission lines held by huge transmission towers. During normal operation, a power system is in a balanced condition. Abnormal scenarios occur due to faults. Faults in a power system can be created by natural events such as falling of a tree, wind, and an ice storm damaging a transmission line, and sometimes by mechanical failure of transformers and other equipment in the system. A power system can be analyzed by calculating system voltages and currents under normal and abnormal scenarios [1]. A fault is define as flow of a large current which could cause equipment damage. If the current is very large, it might lead to interruption of power in the network. Moreover, voltage level will change, which can affect equipment insulation. Voltage below its minimum level could sometimes cause failure to equipment. It is important to study a power system under fault conditions in order to provide system protection. Analysis of Faulted Power System by Paul Anderson and Power System Analysis by A.Nagoor Kani in fault studies and calculations. Background The purpose of this research is to provide the overview of different methods to calculate the fault distance on a transmission line. Different methods based on two principles – impedance theory and traveling-wave theory. On a test system to calculate a fault distance under different types of faults. A comparative analysis was performed to compare the calculation errors in the implemented methods. In order to understand how to calculate the fault distance on a transmission line, the following topics need to be explained. Fault on the transmission line needs to be restored as quickly as possible. The sooner it is restored, the less the risk of power outage, damage of equipment of grid Many algorithms have been developed to calculate the fault distance on the transmission line. This thesis gives the general overview of fault location calculation on transmission line using impedance based method transmission line model, its sequence components, symmetrical components for fault analysis, impedance measurements based approach for transmission line fault location, change current and voltage at point fault can detected by impedance measured where get minimum value for impedance This

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thesis compares and evaluates different methods for classification of fault type.

Sequence Network for Single Phase to Ground Fault

Assuming that fault current (I_f) occurred on the phase a with fault impedance (Z_f). The voltages and currents at the point of fault are $V_a = Z_f I_a, I_b = 0, I_c = 0$

Voltage equation similar to equation (1.1) is

$$= V_a = V_a^0 + V_a^+ + V_a^-$$

$$= Z_f I_a$$

Since fault current in the phase b and the phase c is zero, equation (1.6) will be

$$\begin{bmatrix} I_a^0 \\ I_b^0 \\ I_c^0 \end{bmatrix} = \frac{1}{3}\begin{bmatrix} 1 & 1 & 1 \\ 1 & \propto & \propto^2 \\ 1 & \propto^2 & \propto \end{bmatrix}\begin{bmatrix} I_a = I_f \\ I_b = 0 \\ I_c = 0 \end{bmatrix}$$

$$I_a^0 = I_a^+ = I_a^- = \frac{If}{3} \qquad (1.14)$$

It implies that the sequence current are equal and sequence network must be connected inseries. The sequence voltage add to $3Z_f I_a^+$

$$I_a^0 = I_a^+ = I_a^- = \frac{V_f}{z_{0+}z_1+z_2+3z_f} \qquad (1.15)$$

Where,

z_0,$z_1 z_2$are a zero, a positive and a negative sequence impedance.

Equation (1.15) is used to find out sequence fault voltage.

One-Ended fault location algorithm

The majority of one-end fault-location algorithm is based on calculation of fault loop composed to identify fault type, similar to the distance relay One-ended impedance methods of fault location are a standard feature in most numerical relays. The methods use a simple algorithm, communication channel and remote data are not required. The impact of fault resistance on one-end impedance measurement is a key factor in deriving the majority of one- end fault-location algorithm. Fault locators calculate the fault location from the apparent impedance seen by looking from one end of the line [4] Fault types usually coincide by the phase to ground voltages and current in each phase, it is also possible to locate phase to phase faults by the zero-sequence impedance (Z_{L0}).

The majority of all one-ended fault location is based on a "fault loop" composite for identified the fault type. The following formulas calculate the apparent impedance from the feeding bus bar (S) for distance relays [2], [4].

$$Z_s = \frac{V_s}{I_s} \qquad (2.1)$$

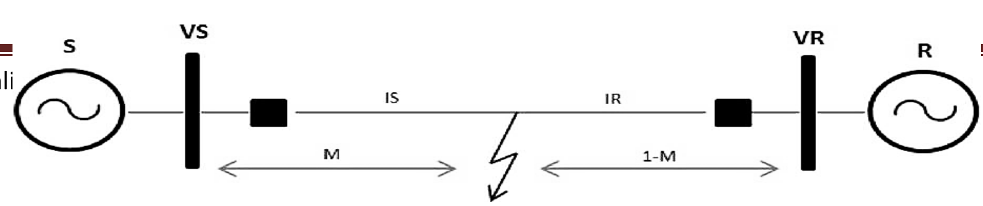
Fault calculation is laid down by the fault impedance with compensation for fault resistance drop. For determined fault where fault resistance ($R_f = 0$) is the apparent impedance equal to the positive sequence impedance (Z_{L1}) of the line segment by distance (m) from the measuring point until the fault according equation (2.1).

$$Z_s = m * Z_{L1} \qquad (2.2)$$

If not taken account to the positive sequence line impedance at resistive fault, the calculation will probable estimate wrong distance to fault.The other important aspect of this fault locator algorithm is the use of the pre-fault current in order to establish the variation of line current at fault. The first equation will return here as positive-sequence impedance equation(2.2). A voltage is the sum of the drop in the line to the fault point.[3].

$$Vs = m * Z_{L1} * I_s * R_f * I_f \qquad (2.3)$$

Figure 1: Single transmission line model



Single line (positive-sequence impedance equation)		
Fault type	Fault loop voltage: V_{sp}	Fault loop current: I_{sp}
A-ground	V_{sa}	$I_{sa} + k * I_0$
B-ground	V_{sb}	$I_{sb} + k * I_0$
C-ground	V_{sc}	$I_{sc} + k * I_0$
a-b or a-b-g	$V_{sa} - V_{sb}$	$I_{sa} - I_{sb}$
b-c or b-c-g	$V_{sb} - V_{sc}$	$I_{sb} - I_{sc}$
c-a or c-a-g	$V_{sc} - V_{sa}$	$I_{sc} - I_{sa}$
a-b-c	$V_{sa} - V_{sb}, V_{sb} - V_{sc}, V_{sc} - V_{sa}$	$I_{sa} - I_{sb}, I_{sb} - I_{sc}, I_{sc} - I_{sa}$

Table 1: Standard calculation on single line with positive-sequence impedance method

For a fault between two phases from table 2.1 the impedance can be obtained from the substations voltage and current in the involved phases. The difference between the two-phase voltages is divided by the difference between phases current. For a three-phase short circuit the voltage and current in any pair of phases can be used for distance to fault calculation.[3]

Reactance Based Algorithm

Simple reactance method, algorithms reported in [3],[4] extend simple reactance method by making assumptions to eliminate effect of remote infeed and fault resistance. One-ended impedance methods of fault location are standard feature in most numerical relay. The reactance fault location algorithms depend on accurate values of the positive (Z_{L1}) and zero -sequence impedance (Z_{L0}) to determine locations of faults on the transmission line. The positive and zero-sequence impedance of the transmission line can be verified when a fault location relay is installed at each end of the transmission line. The positive-sequence impedance has verified that it can be used to check the values of the zero-sequence impedance of the line as used by each relay. The method also uses the value of voltage drop from one side bus bar of the line, and the value of current depend of type of fault and symmetrical components. Transmission line impedance (Z) is typically dominated by the reactive components (X) and the fault impedance is typically dominated by the resistive components (R).

$V_s = m * Z_{L1} * I_s * R_f * I_f$ (2.4)

The current flowing through (R_f) is the sum of the local source (I_s) and the remote source (I_r).

$I_f = I_s + I_r$ (2.5)

$I_s = I + k * 3 * I_0$ (2.6)

Where:

I_0 = zero -sequence current

$$k = \frac{Z_{L0} - Z_{L1}}{3Z_{L0}}$$

The simple reactance method divides all terms by (I_s).

$\frac{V_s}{I_s} = \frac{m*Z_{L1}*I_s}{I_s} + \frac{R_f*I_f}{I_s}$ (2.7)

Imaginary components of each term mitigate the fault resistance.

$Im\left(\frac{V_s}{I_s}\right) = Im(m * Z_{L1}) + im\left(\frac{I_f}{I_s} * R_f\right)$ (2.8)

Both (I_S) and (I_R) have the same angle and the imaginary part of $im\left(\frac{I_f}{I_s} * R_f\right)$is zero in a homogenous system.

$$m = \frac{Im\left(\frac{V_s}{I_s}\right)}{ImZ_{L1}} \qquad (2.9)$$

For this equation (V_s) is the phase-to ground voltage for given fault, (Is) is the compensated phase current for a phases-to-phases faults and equals phase current difference for a phases-to-phases faults. These methods calculate an estimated fault location in the transmission system.

In a non-homogenous system (I_S) and (I_R) will have a different angle and the imaginary part will show up in the fault as an error term.

$$Im\left\{\frac{|I_f|}{|I_s|}\angle(\delta - \alpha) * R_f\right\} \qquad (2.10)$$

Inducing of the simple reactance method has some drawbacks as impact by load and introduces error in fault resistance in non-homogenous system.

Takagi method

Takagi impedance based algorithm, with uses of pre-fault and fault data [3],[4] use pre-fault and fault data to reducing the effect of load flow and minimizing the effect of fault resistance.

Fault location algorithm by Takagi method calculates the reactance of faulty line using one-terminal voltage and current data of the transmission line. When a fault occurs on a transmission line the data of pre-fault current are stored immediately and the fault phases are selected. The Takagi method introduces superimposed current (I_{sup}) to eliminate the effect of power flow. This method assume constant current load model and require both pre-fault and post -fault data. The key to success of the Takagi method is that the angle of (I_s) is the same as the angle of (I_f). In an ideal homogeneous system, these angles will be identical. As the angle increases, the errors in fault location also increase.

$$Im\left(\frac{V_s}{I_{sup}^*}\right) = m * Im\left(Z_{L1} * I_s * I_{sup}^*\right) + Im\left(R_f + I_f + I_{sup}^*\right) \qquad (2.11)$$

$$I_{sup} = I_f - I_{pre} \qquad (2.12)$$

If complex number (I_f) and (I_{sup}^*) have the same angle as (R_f) in a homogenous system will a multiplication of (I_{sup}^*) take the imaginary part of the equation and eliminate (I_f) according equation (2.13).

$$m = \frac{Im(V_s * I_{sup}^*)}{Im\left(Z_{L1} * I_s * I_{sup}^*\right)} \qquad (2.13)$$

Takagi method, one-terminal fault method, simply assumes that the three sequences network distribution factors are equal can lead to undesirable error because the zero-sequence current (I_0) is not known as reliably as the positive-sequence current (I_1). In reality, the fault current is not uniformly distributed when a ground faults occurs. Takagi methods can be improved by applying the 3/2 factor in deriving superposition current to compensated for the removal unreliable zero-sequence current [3].

$$I_{sup} = \left(3/2\right)\left(I_f - I_{pre}\right) \qquad (2.14)$$

Modified Takagi method

Modified Takagi method eliminates the need for pre-fault data and uses the zero sequence current (I_0) term or negative sequence current (I_2) for ground faults [3]

The zero-sequence Takagi method, which is suitable for single-phase-to-ground faults, has an advantage that does not require pre-fault current measurements. The expression for this algorithm is:

$$m = \frac{Im(V_s * 3I_0^*)}{Im\left(Z_{L1} * I_s * 3I_0^*\right)} \qquad (2.15)$$

The algorithm is developed with the assumption that the zero sequence system is homogeneous. If this assumption is not fulfilled, the fault location become very sensitive to an angle difference between S and R side and the method can be very inaccurate. In order to reduce errors due to non-homogenous

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zero-sequence, the modified Takagi allows angle correction if the user knows the system source, the zero-sequence current (I_0) can be adjusted by angle T to improve the fault location for a transmission line. The algorithm minimizes/eliminates the effects of; fault resistance, impact by load and the line charging current.

The angle correction (T) can be calculated by using the zero sequence fault current (I_{f0}), if the source impedance zero-sequence impedance and is known [10], these values can be estimated using fault recorders.

$$\frac{I_f}{3*I_0} = \frac{ZR_0+(1-m)Z_0}{ZS_0+ZR_0+Z_0} = A\angle T \qquad (2.16)$$

$$m = \frac{Im(V_S*3I_0^* * e^{-iT})}{Im(Z_{L1}*I_S*3I_0^* * e^{-iT})} \qquad (2.17)$$

Formalization for Fault Locator

Fig. 3.1 illustrates the single line diagram of the Compound transmission line. According to the equivalent circuit shown in Fig. 3.2 for the faulted circuit, the three-phase voltages to the fault point are computed from both ends in the form:

Figure. 2:Fault on the underground power cable section.

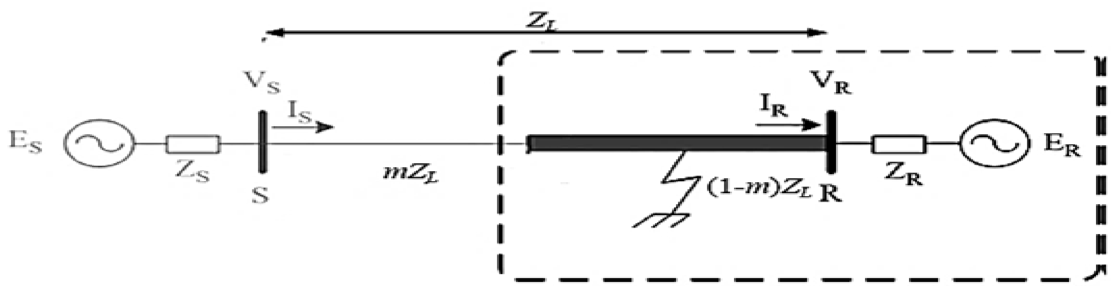
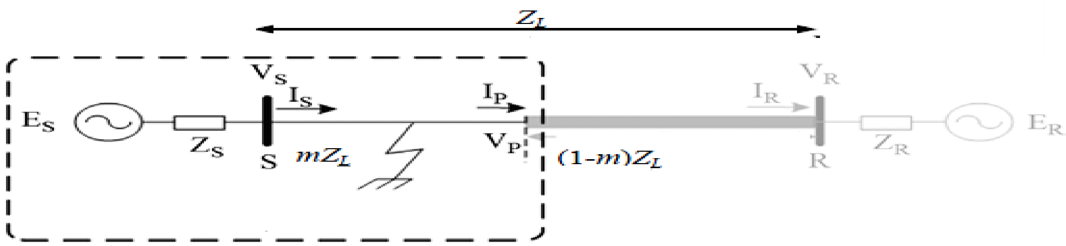


Figure 3:Fault on the overhead line section.



$[Vs]_{abc} - [V_R]_{abc} = m[Z_L]_{abc} [Is]_{abc} - (1\text{-}m) [Z_L]_{abc} [I_R]_{abc}$ (3.1)

Where m is the per unit fault distance of the line length. $[Z_L]_{abc}$ is the total line impedance. $[Is]_{abc}$, $[I_R]_{abc}$, $[Vs]_{abc}$ and $[V_R]_{abc}$ are the three-phase currents[6] and voltages at the sending and receiving ends respectively. When the measured data at both line ends is unsynchronized, then equation (3.1) is represented as:

$[Vs]_{abc} - ([V_R]_{abc} e^{j\delta}) = m[Z_L]_{abc} [Is]_{abc} - (1\text{-}m) [Z_L]_{abc} ([I_R]_{abc} e^{j\delta})$ (3.2)

Where $e^{j\delta}$ is designated for the unknown synchronizing angle. Correctly identifying $e^{j\delta}$ accurately determines the fault distance. Solving the locator model with unsynchronized data represented by equation (3.2) is a challenge due to its sophistication and the increased number of unknowns. On the other hand, if the synchronization angle $e^{j\delta}$ is determined,equation (3.2) can be solved in order to estimate the unknown fault distance independent of the associated line parameters. Then, computing the unknown synchronization angle first is essential to be facilitate estimating the correct fault distance.

When the synchronizing angle is known, the estimated fault distance [6] can be computed as follows.

$$[\Delta V]_{abc} - [Z_L]_{abc} [I_R]_{abc} = m[Z_L]_{abc} [\sum I]_{abc} \quad (3.3)$$

Where

$[\Delta V]_{abc} = [Vs]_{abc} - [V_R]_{abc}$ and $[\sum I]_{abc} = [Is]_{abc} - [I_R]_{abc}$.

Applying the Symmetrical Transformation, equation (3.1) was rewritten as,

$$[\Delta V]_{012} - [Z_L]_{012} [I_R]_{012} = m [Z_L]_{012} [\sum I]_{012} \quad (3.4)$$

Where

$[\Delta V]_{abc} = [Q] [\Delta V]_{012}$ and [Q] is the transformation matrix.

Using the positive sequence components, the formula for the first circuit can be written as,

$$(\Delta V1) + (Z_{L1}) (I_{R1}) = m (Z_{L1}) (\sum I_1) \quad (3.5)$$

Then, (ΔV1) can be formulized as,

$$(\Delta V1) = m (Z_{L1}) (\sum I_1) - (Z_{L1}) (I_{R1}) \quad (3.6)$$

Considering the phasor measurements at instant t = t1, then equation (3.6) was rewritten as,

$$(\Delta V1_{(t1))} = m (Z_{L1}) (\sum I_1)(t_{1)) - (Z_{L1}) (I_{R1)} (t_{1))} \quad (3.7)$$

Preceding the above equation for 4 successive samples with constant time interval, a total of 4 consecutive equations can be formed as follows.

$$\begin{bmatrix} (\mathbf{\Delta V1(t4)}) \\ (\mathbf{\Delta V1(t3)}) \\ (\mathbf{\Delta V1(t2)}) \\ (\mathbf{\Delta V1\ (t1)}) \end{bmatrix} = \begin{bmatrix} (\mathbf{\sum I1(t4)}) & (\mathbf{I(t4)}) \\ (\mathbf{\sum I1(t3)}) & (\mathbf{IR1(t3)}) \\ (\mathbf{\sum I1(t2)}) & (\mathbf{IR1(t2)}) \\ (\mathbf{\sum I1(t1)}) & (\mathbf{IR1(t1)}) \end{bmatrix} \begin{bmatrix} \mathbf{m(ZL1)} \\ \mathbf{(ZL1)} \end{bmatrix} \quad (3.8)$$

Equation (3.8) can be then rewritten as,

$$[Vn] = [In] \begin{bmatrix} \mathbf{m(ZL1)} \\ \mathbf{(ZL1)} \end{bmatrix} \quad (3.9)$$

Equation (3.9) should be solved for computing the ratio between both unknowns m (Z_{L1}) and (Z_{L1}) rather than computing the values of these unknowns. Hence, this ratio can be computed even if fewer numbers of equations are available. Thus, solving equation (3.8) yields,

$$\begin{bmatrix} \mathbf{m(ZL1)} \\ \mathbf{(ZL1)} \end{bmatrix} = [In]\text{-}1\ [Vn] \quad (3.10)$$

Then the local fault distance Lf of the line length L is computed as,

$$Lf = m*L = \frac{\mathbf{m(ZL1)}}{\mathbf{(ZL1)}} * L \quad (3.11)$$

In order to compute the associated unknown synchronizing angle, equation (3.5) can be arranged as follows,

$$(Vs) - (V_R) = m (Z_{L1}) (I_{S1}) + m (Z_{L1}) (I_{R1}) - (Z_{L1}) (I_{R1}) \quad (3.12)$$

Assuming the receiving end measured quantities are unsynchronized, a phase difference between the sending end and the receiving end measurements is represented by an arbitrary angle δ. Then, the phase difference can be represented mathematically by multiplying the receiving end data by $e^{j\delta}$. Then, equation (3.13) is rewritten as,

$$(Vs) - (V_R)\, e^{j\delta} = m (Z_{L1}) (I_{S1}) + m (Z_{L1}) (I_{R1})\, e^{j\delta} - (Z_{L1}) (I_{R1})\, e^{j\delta} \quad (3.13)$$

To compensate for the phase difference between measurements, the receiving end data is shifted intentionally by an angle θ. When the assumed variable angle θ equals the negative value of the unknown phase difference angle δ, the misalignment angle between the local and remote terminal measurements is estimated. To provide a compensation procedure of the misalignment, the receiving end data in equation (3.13) is multiplied by $e^{j\theta}$as follows.

$(Vs) – ((V_R)\ e^{j\delta}\ ))\ e^{j\theta} = m\ (Z_{L1})\ (I_{S1}) + (m\ (Z_{L1})\ (I_{R1})\ e^{j\delta})\ e^{j\theta}$
$- ((Z_{L1})\ (I_{R1})\ e^{j\delta}\ )\ e^{j\theta}$ (3.14)
$(Vs) – (V_R)\ e^{j\delta+j\theta} = m\ (Z_{L1})\ (I_{S1}) + m\ (Z_{L1})\ (I_{R1})\ e^{j\delta+j\theta}$
$- (Z_{L1})\ (I_{R1})\ e^{j\delta+j\theta}$ (3.15)
$(Vs) – (V_R)\ e^{j\delta+j\theta} = m\ (Z_{L1})\ (I_{S1}) + (m-1)\ (Z_{L1})\ (I_{R1})\ e^{j\delta+j\theta}$ (3.16)
Rearranging equation (3.16) yielded,
$(Vs) – (V_R)\ e^{j(\delta+\theta)} = m\ k_1 + (m-1)\ k_{2*} e^{j(\delta+\theta)}$ (3.17)Where, $k_1 = (Z_{L1})\ (I_{S1})$
$k_2 = (Z_{L1})\ (I_{R1})$
Then, equation (3.16) was rewritten as,
$(Vs)–(V_R)(\cos(\delta+\theta)+j\ \sin(\delta+\theta))=mk_1+(m-1)k_2(\cos(\delta+\theta)+j\ \sin(\delta+\theta))$ (3.18)
$[(Vs) – (V_R)\ \cos(\delta + \theta)] + j[(V_R)\ \sin(\delta + \theta)] = [\ mk_1 + (m – 1)k_2 \cos(\delta + \theta)]$
$+ j[(m – 1)\ k_2 \sin(\delta + \theta)]$ (3.19)
Separating both real and imaginary parts ofequation (3.19) yielded,
$[(Vs) – (V_R)\ \cos(\delta + \theta)] = mk_1+ (m – 1)\ k_2 \cos(\delta + \theta)]$ (3.20)
By differentiating the above equation with respect to θ and rearrangement, the following equation is obtained.

$(V_R)\ \sin(\delta + \theta) = \frac{\partial m}{\partial \theta}\ k_1 + \frac{\partial m}{\partial \theta} k_2 \cos(\delta + \theta) - (m – 1)\ k_2 \sin(\delta + \theta)$ (3.21)
$(V_R)\ \sin(\delta + \theta) + (m – 1)\ k_2 \sin(\delta + \theta) = \frac{\partial m}{\partial \theta}\ k_1 + \frac{\partial m}{\partial \theta} k_2 \cos(\delta + \theta)$ (3.22)
$\frac{\partial m}{\partial \theta} = \frac{(VR)\ \sin(\delta+\theta) + (m-1)\ K2\sin(\delta+\theta)}{K1+K2\cos(\delta+\theta)}$ (3.23)

As noted from equation (3.23), at δ = -θ, the computed derivative part ($\frac{\partial m}{\partial \theta}$) is equal to zero. Thus, the unknown synchronized angle by characterizing the fault distance along the entire range of the synchronizing angle. Then, the unknown synchronizing angle can be estimated by pinpointing the minimum value of the profiled characteristic [6]. Below Flow chart shows a schematic of the overall procedure of the proposed fault location technique. It is assumed that the transmission lines have been equipped with communication facilities to help in collecting the required measurements for the proposed technique. Recently, fiber optic communication links are commonly utilized. The proposed technique uses a two-layer approach to estimate the fault location. In the inner layer the fault location is estimated using the synchronized-based model. In the outer layer, the measurements are shifted intentionally by multiplying it with an angle that changes y fixed step of 1 for specific range from -180 to180. At each step, the measurements are passed to the inner layer to calculate the corresponding fault location using the synchronized data representation (as described by equation 3. 1 to 3. 12 Then, the variation of the unknown fault distance can be profiled as a function of the synchronization angle along the entire range of the angle θ, then, the minimum estimated fault distance can pinpoint the actual synchronization angle as well as the corresponding actual fault distance m. The advantage of this concept is that the fault distance is estimated without needing to the sophistications of numerical solutions. Only, the fault distance vector is calculated over a variation in the angle $^{\theta}$ (from -180^0 to $+180^0$) and then the minimum calculated distance is the correct one. Different test cases were prepared covering a variety of situations that may significantly affect the technique accuracy including line loading, fault resistance, and line un-transposition … etc. The voltage and current measurements were collected with sampling frequency of 1.6 MHz. As the proposed fault locator is based on fundamental phasors, the recursive Discrete Fourier Transform (DFT) is utilized to extract those phasors. Then, the fault location technique was executed as described in the preceding section. For each test case, the resulted estimation error is expressed as a percentage of the total line length L as,

$Lf\% = \frac{Lfactual - Lfcomputed}{L} *100\%$ (3.25)

Where Lf-actual, Lf-computed, and L are the actual fault distance, computed fault distance and the total transmission line length, respectively

Figure3.3 explain find fault location in case unsynchronized where take input data for sending end and receiving end for two ended as equation (3.1) and(3.2)In the inner layer the fault location is estimated using the synchronized-based model. In the outer layer, the measurements are shifted intentionally by multiplying it with an angle that changes y fixed step of 1^{θ} for specific range from -180^{θ} to180^{θ}. At each step, the measurements are passed to the inner layer to calculate the corresponding fault location using the synchronized data representationwheree$e^{j\delta}$ is designated for the unknown synchronizing angle. Correctly identifying $e^{j\delta}$accurately determines the fault distance. Solving the locator model with unsynchronized data represented by equation (3.2) is a challenge due to its sophistication and the increased number of unknowns [6]. On the other hand, if the synchronization angle $e^{j\delta}$is determined, after that calculated error by Lf% = $\frac{\text{Lfactual}-\text{Lfcomputed}}{\text{L}}$ *100%

Fault Location Technique

Two-Terminal Line (Synchronized Data):

This section describes the principles of the fault location technique using the three-phase voltage and current phasors for both ends of the line to compute the fault location. Consider the system depicted by Figure 3.4.

TERMINAL 1 TERMINAL2

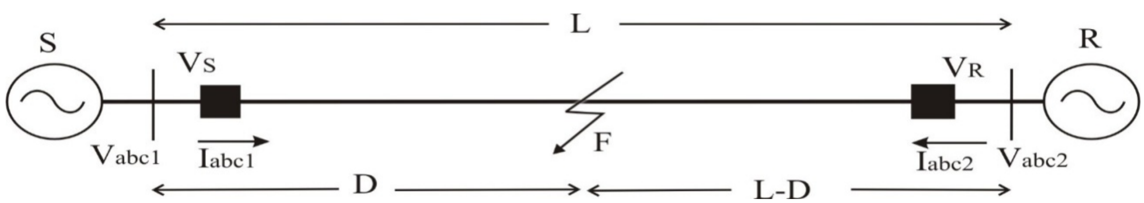


Figure 4: Two-Terminal Line

Assuming that the phasors of the three-phase currents and voltages at buses 1 and 2 are synchronously obtained, the three-phase voltage vectors at bus 1 and 2 can be represented in terms of the three-phase current vectors as shown in equations(2) and (3) [7].

$V_{abc1} = VF_{abc} + DZ_{abc}I_{abc1}$ (3.26)

$V_{abc2} = VF_{abc} + (L-D)Z_{abc}I_{abc2}$ (3.27)

From 3.26 and 3.27

$V_{abc1} - V_{abc2} + LZ_{abc}I_{abc2} = DZ_{abc}[I_{abc1} + I_{abc2}]$ (3.28)

Where

Z_{abc} is the three-phase series impedance of line per mile.

VF_{abc} is the voltage vector at the fault.

Equation (3.28) can be rewritten as

$$\begin{bmatrix} Y_a \\ Y_b \\ Y_c \end{bmatrix} = \begin{bmatrix} M_a \\ M_b \\ M_c \end{bmatrix} \text{ D or Y = MD} \quad (3.29)$$

Where

$Y_j = V_{j1} - V_{j2} + L\sum_{i=a,b,c} Z_{ji} I_{i2}$ (3.30)

$M_j = \sum_{i=a,b,c} Z_{ji}(I_{i1} + I_{i2})$ (3.31)

j = a,b,c

Equation (3.29) represents three complex equations or six real equations in one unknown, the solution for D can be then obtained using the least-squares estimates as

$D = (M^{+}M)^{-1}M^{+}Y$ (3.32)

Where M^+ is the conjugate transpose of M.It should be noted that this procedure is independent of fault type or fault resistance, using the computed value of D, the fault boundary [7] conditions VF_{abc} and IF_{abc} can be obtained as follows

$$VF_{abc} = V_{abc1} - DZ_{abc}I_{abc1} \quad (3.33)$$

$$IF_{abc} = I_{abc1} + I_{abc2} \quad (3.34)$$

Using the voltage and current vectors at the fault, the fault type may also be identified, the availability of advanced communication systems in conjunction with digital relays would allow the implementation of the described method to determine the fault location. However, in some cases synchronization error may be unavoidable. In this case the synchronization error needs to be considered in the fault location process. This is described in the next subsection

Unsynchronized Data

If the voltage and current phasors at terminal 2 are not synchronized relative to the data at terminal 1, the voltage equations can be modified as shown in equations (3.35) and(3.36)[7].

$$V_{abc1} = VF_{abc} + DZ_{abc}I_{abc1} \quad (3.35)$$

$$V_{abc2}e^{j\delta} = VF_{abc} + (L - D)Z_{abc}I_{abc2}e^{j\delta} \quad (3.36)$$

Where $V_{abc2}e^{j\delta}$ and $I_{abc2}e^{j\delta}$ represent the synchronized phasors with δ asthe unknown angle.
From 3.35 and 3.36

$$V_{abc1} - V_{abc2}e^{j\delta} = DZ_{abc}I_{abc1} - LZ_{abc}I_{abc2}e^{j\delta} + DZ_{abc}I_{abc2}e^{j\delta} \quad (3.37)$$

Rearranging equation 13 in terms of the unknowns (D and$e^{j\delta}$) leads to

$$\frac{V_{j1}}{V_{j2}} = M1_jD + M2_je^{j\delta} + M3_jDe^{j\delta} \quad (3.38)$$

Where

$$M1_j = \frac{1}{V_{j2}}\sum_{i=a,b,c} Z_{ji}l_{i1}$$

$$M2_j = 1 - \frac{L}{V_{j2}}\sum_{i=a,b,c} Z_{ji}l_{i2}$$

$$M3_j = \frac{1}{V_{j2}}\sum_{i=a,b,c} Z_{ji}l_{i1}$$

RESULTS:

This fault location is simulated result using synchronous measurement voltage and current depend on impedance (Z) use impedance method and tested for various faults oftype and different resistances fault for three line model [5].

Table 2: Parameters of transmission lines

Line	Length (KM)	Type	Parameter
1	5	u/g	R=0.024 L=0.256*10-3 C=457.6*10-9 R_0=0.036 L_0=0.332*10-3 C_0=457.6*10-9
2	5	u/g	R=0.016 L=0.268*10-3 C=456.9*10-9 R_0=0.059 L_0=0.206*10-3 C_0=456.9*10-9
3	20	O/H	R=0.038 L=0.896*10-3 C=13.11*10 -9 R_0=0.248 L_0=2.686*10-3 C_0=7.12*10-9
4	20	O/H	R=0.024 L=0.898*10-3 C=13.4*10-9 R_0=0.380 L_0=3.148*10-3C_0=7.11*10-9
5	20	O/H	R=0.024 L=0.903*10-3 C=12.6*10-9 R_0=0.362 L_0=3.329*10-3 C_0=6.7*10-9
6	20	O/H	R=0.024 L=0.896*10-3C=13.1*10-9 R_0=0.248 L_0=2.686*10-3 C_0=7.1210-9

In table 4.1 shows parameters for 6 lines different transmissionnonhomogeneousline because impedance is not uniform in transmission line in table4.1 we see that fouroverhead transmission line and two underground cable,each line consists from zero sequence and positive sequence for R,L,C parameters.

X_L=2*pi*f*L, X_C=1/2*pi*f*C=R+j(X_L-X_C)

$Z_{S1} = 0.238 + j\,5.72 Z_{R1} = 0.238 + j\,6.19$

$$E_S = 1\angle 10 \;\; E_R = 1\angle 0$$

System model

Network has nominal voltage phase to phase RMS voltage 138 kV is composed transmission line overhead line and underground cable for three different models and six lines different length and different parameter overhead and underground lines for 50Hz.

Single line without load model

Figure 4.1showsThe total length of the transmission line is 90 km with sixsectionsdifferent underground and overhead transmission line as shown in figure4.1 model for line transmission line has six block with two sourcephase to phase RMS voltage 138kV, 50Hz[10]Block1 has parameter with length 5km, length L_1=5km, L_2=5km, L_3=20km, L_4=20km, L_5=20km, L_6=20km figure 4.1shows also block for measurement along transmission line with two sourcephase to phase RMS voltage 138 kV can be put actual voltage at any point on transmission line.

Single line with load model

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Figure 4.2 shows single line model has sixsection, two cable underground and four overhead line different length and different parameters with two source phase to phase RMS voltage 138kV, 50Hz length L_1=5km, L_2=5km, L_3=20km, L_4=20km, L_5=20km, L_6=20km figure 4.2 shows also block for measurement along transmission line with two sourcephase to phase RMS voltage 138 kVcan be put actual voltage at any point on lineFigure 4.2 shows single line with load model has five transformers 132/33kV these transformers have different capacity and different load in figure 4.2 shows measuring fault where can change this measuring at any point in transmission line using different types fault as ABC, AN, BC, BCN figure 4.2 represented to single line with load model where length the five lines 90 km with two sources. This model different from single line without loadwhere consists from different transformers and different loads where occur fault location these transformers will fed point fault location and terminal fault current because transformer has high reactance while in single line without load current is very small and not load at normal condition.

Figure 5: Single Line without Load Model

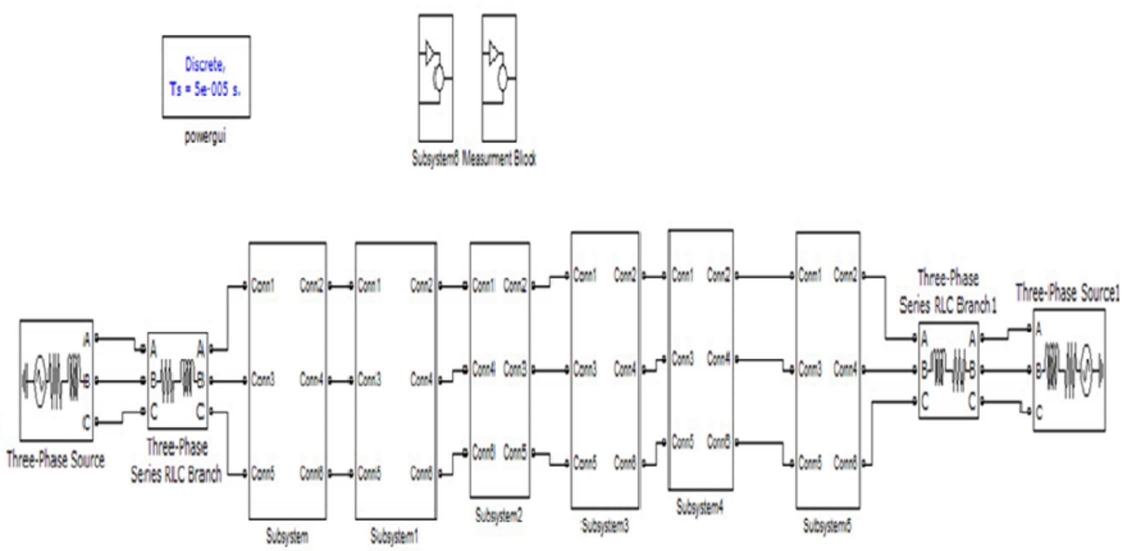

Figure 6: Single Line with Load

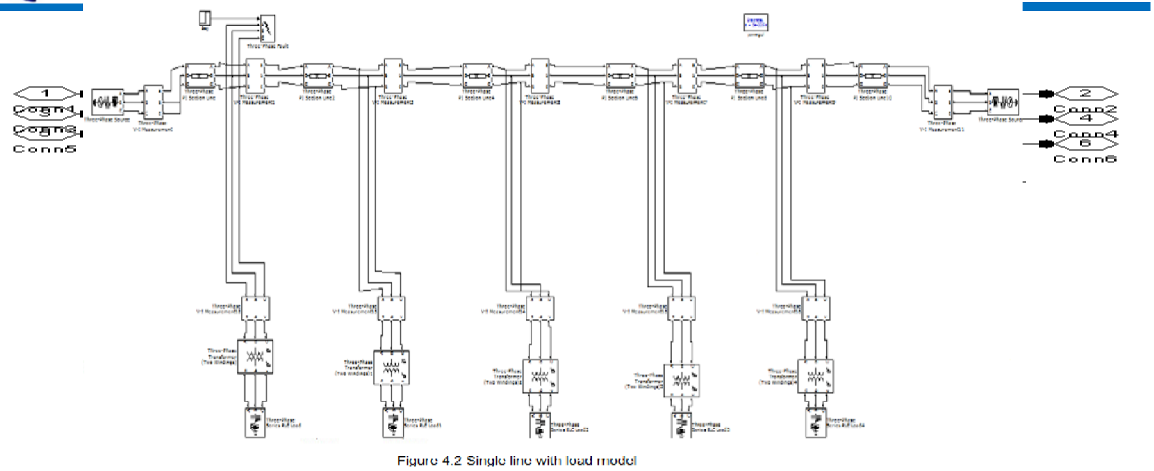

Figure 7: Component for single line with load

Figure 7shows three phase pi section lines has parameter for one part where consist box has frequency, length line with parameter for line positive sequence and zero sequence for resistance, reactance and capacitance with measured and load consists from power transformer three phase transformer two windings 138/33kV with load RLC three phases in transmission line has different capacity transformer each transformer two winding with different load.

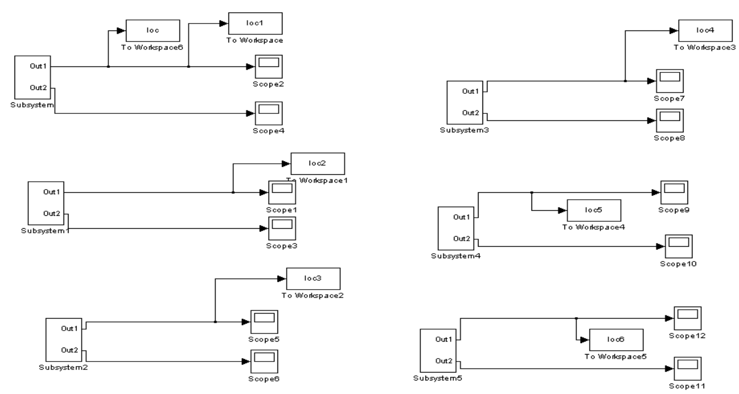

Figure 8:Measurements for single line

Figure4.4 shows measurement for single line transmission line in figure 4.4 shows six block for current and voltage Measurement circuit for transmission line has six part each section part this part has two scope one for measured voltage and another for measured current.

1Fault Location at 10km Single line without load by use Takagi method

In the table 4.2 fault resistance 0.001 ohms and different type fault, ABC, AN, BC, BCN actual fault occur at 10 km shows measured location and error from result error very acceptable and accuracy in table 4.2 we can see that different value for fault type for% errorAN=0.0030and forBC=0.0226 some swing in calculation but all value is agree with value expected her in table 4.2 fault location at 10km %error is different from fault location at 70 km and depend on resistance fault value where increased resistance fault will increase voltage and decrease current.

Table 3: Resistance fault at 0.001ohms at 10km

Type Fault	Measured Location	Actual Location	%Error
ABC	10.0103	10	0.0114
AN	10.0227	10	0.0030
BC	10.0204	10	0.0226

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BCN	10.0174	10	0.0195

In the table 4.3fault resistance 5 ohms and different type fault, ABC, AN, BC, BCN actual fault occur at 10 km as shown in table 4.3 measured location and error from result error veryacceptable and accuracy shows different value for fault type for% error AN=0.0059and forBC=0.0453 some increased in values because increased resistance fault and some swing in calculation but all value is agree with value expected.in table 4.3 fault location at 10km %error is different from fault location at 70 km and depend on resistance fault value where increased resistance fault will increase voltage and decrease current and depend on type of model.

Table 4:Resistance fault at 5 ohms at 10km

Type Fault	Measured Location	Actual Location	%Error
ABC	10.0205	10	0.0228
AN	10.0053	10	0.0059
BC	10.0408	10	0.0453
BCN	10.0547	10	0.0386

In the table 5 fault resistance10ohms and different type fault,ABC, AN, BC, BCN actual fault occur at 10 km in table 5 we can see that measured location and error from result error very acceptable and accuracy in the table 5, we can see that different value for fault type for %error AN=0.0080and for BC=0.0679 some increased in values because increased fault resistance and some swing in calculation but all value is agree with value expected.

Table 5: Resistance fault at 10 Ohms at 10km

Type Fault	Measured Location	Actual Location	%Error
ABC	10.0308	10	0.0342
AN	10.0080	10	0.0080
BC	10.0611	10	0.0679
BCN	10.0621	10	0.0570

In the table 6 fault resistance 30 ohms and different type fault, ABC, AN, BC, BCN actual fault occur at 10 km shows measured location and error from result error very acceptable and accuracy the different value for fault type for% error AN=0.0118and forBC=0.0906 some increased in values because increased fault resistance some swing in calculation but all value is agree with value expected.

Table 6: Resistance fault at 30 ohms at 10km

Type Fault	Measured Location	Actual Location	%Error
ABC	10.0411	10	0.0456
AN	10.0106	10	0.0118
BC	10.0815	10	0.0906
BCN	10.0684	10	0.0771

In thetable 4.6 fault resistance 50 ohms and different type fault ,ABC,AN,BC,BCN actual fault occur at 10 km in the table 4.6 we can see that measured location and error from result error veryacceptable and accuracy the different value for fault type for %error AN=0.0148and forBC=0.5200 some increased in

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values because increased fault resistance some swing in calculation but all value is agree with value expected where increases error with increases fault resistance in table 4.6,we can see that some different from table4.2 for resistance fault at 0.0001 ohms at 10km where error increased wherever increased fault resistance and these result by use neutral grounding for source Y_g grounded system.

Table 7: Resistance fault at 50 ohms at 10km

Type Fault	Measured Location	Actual Location	%Error
ABC	10.0513	10	0.0570
AN	10.0132	10	0.0148
BC	9.8153	10	0.5200
BCN	10.0668	10	0.0664

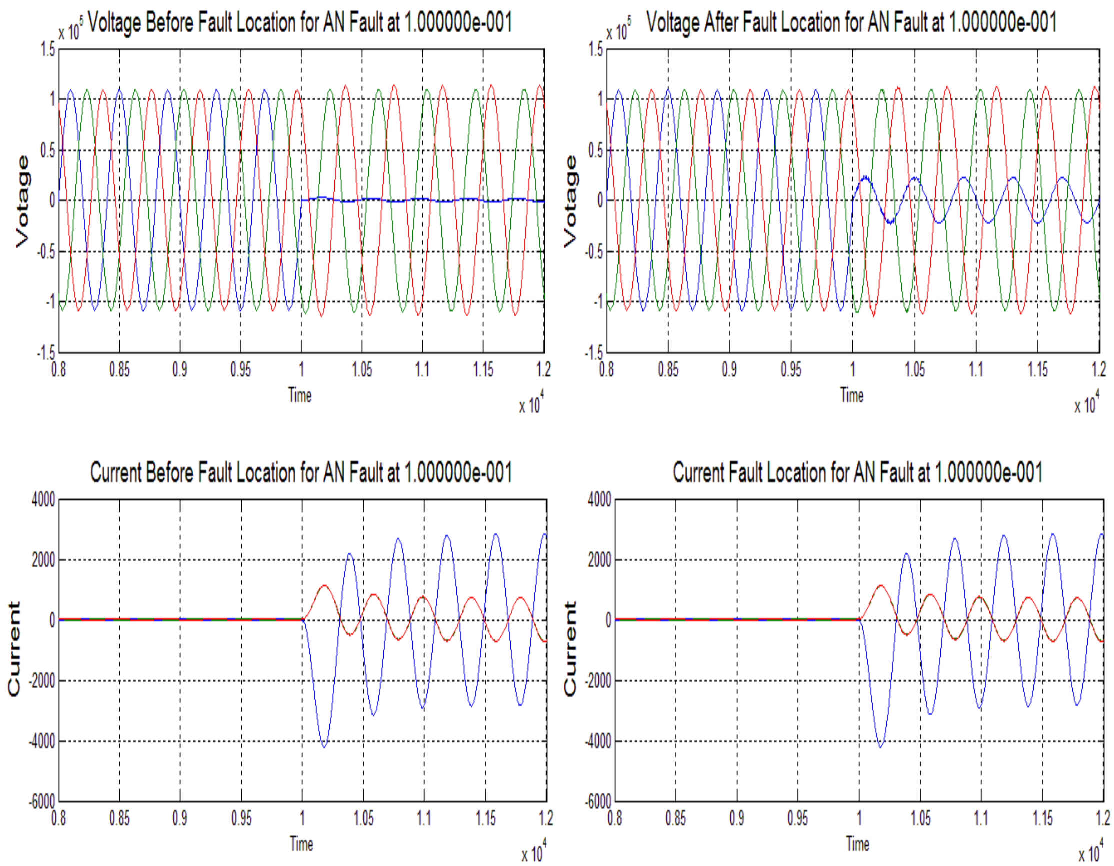

Figure 9: wave form for Voltage and Current for AN fault at 0.001 ohms at 10km.

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Figure 9 shows the voltage before fault location for AN fault at 0.001 ohmsall phases normal A,B,C and phase A is normal before fault and for amplitude 113kV sine wave result from source phase to phase RMS 138kVwere $V_{m=}138*\sqrt{2}/\sqrt{3} = 113kV$ for sample time 12000 sample in figure 4.6shows voltage after fault location for AN fault at location4(50km) The change voltage at AN fault is zero for current before fault at AN fault at 0.001 ohms has value is stable and normal because not load but after occur fault location at 10 km increased current for phase A between 2000Ato 3000A represented to ground fault current $I_{A=}I_F$ by use neutral source by Y_g the neutral is grounded either directly or through resistance or reactance the neutral grounding provide return path to zero sequence current advantage for this grounding eliminated arcing and voltage of healthy phases normal value $V_B=V_{PHASE=}113kV,V_C=V_{PHASE=}113kV$ they do not increase to1.732times normal value as in case of ungrounded system. While faulty phase $V_A=0$ these condition are clear at point fault location 5(70km) and this very important for design all equipment and current for healthy phases $I_{B=0}$, $I_{C=0}$ but ground fault current $I_{A=}I_F$ is high and sufficient to operate over current relay as protection and not use over voltage under voltage as protection and avoid arcing ground.

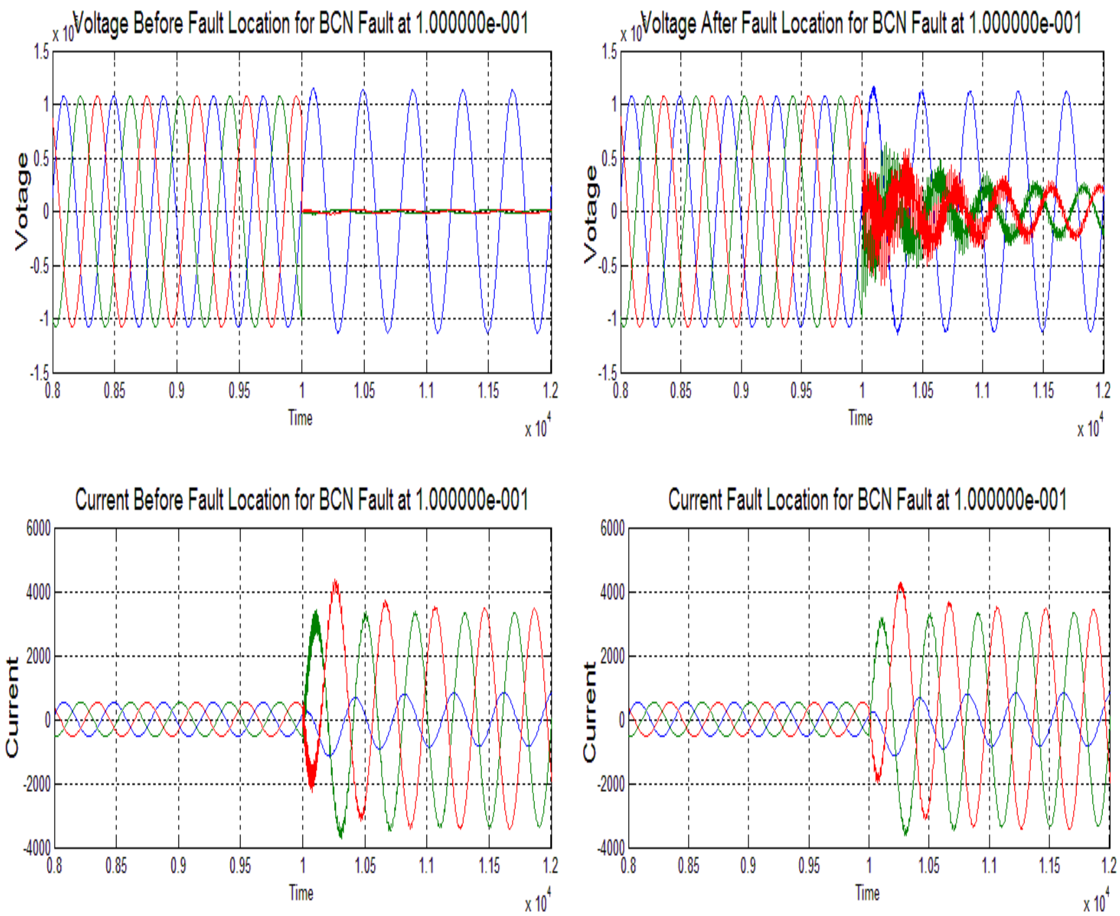

Figure 10: Wave form for voltage and current for BCN fault at 0.001 ohms at 10km.

Figure 10 shows the voltage before fault location for BCN fault at 0.001 ohms all phases normal A,B,C and phases BC is normal before fault at location4(50km) and for amplitude 113kV sine wave result from source phase to phase RMS 138kVwere $V_{m=}138*\sqrt{2}/\sqrt{3} = 113kV$ for sample time 12000 sample in figure 4.8shows voltage after fault location for BCN fault at location4(50km) The

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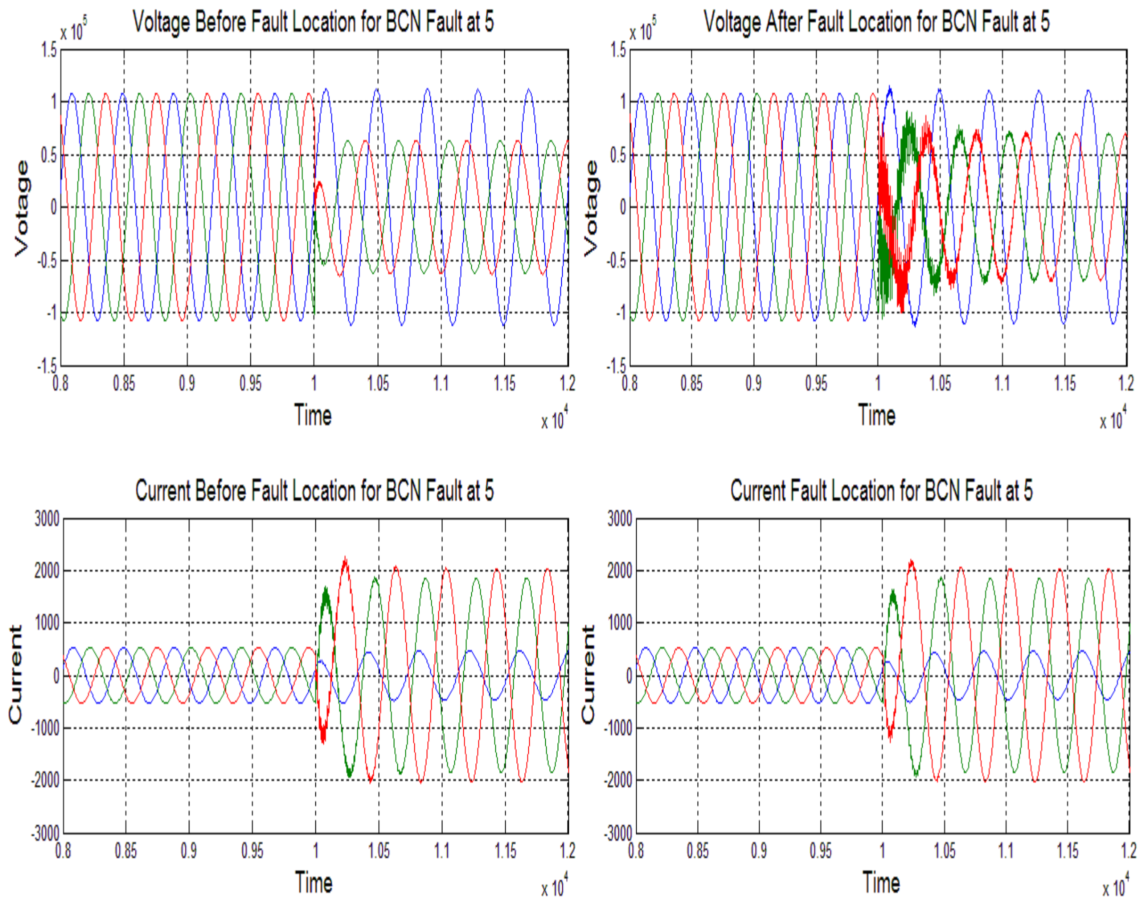
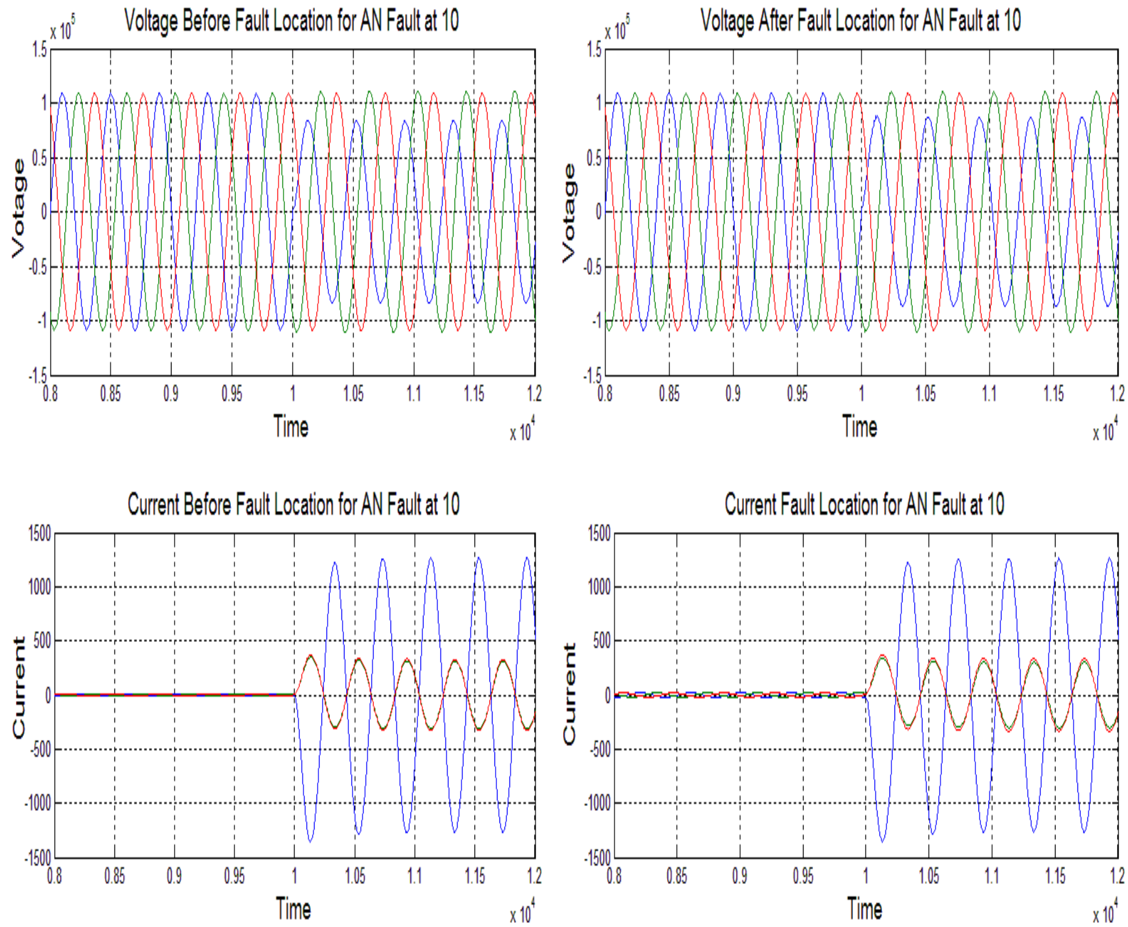
change voltage phases BC is zero but for phase A=V_{PHASE} for current before fault at ABC at 0.001 ohms has value is stable and normal because not load but after occur fault location at 10 km increased current for phases BC 3000A represented to ground fault current by use neutral source by Y_g the neutral is grounded either directly or through resistance or reactance the neutral grounding provide return path to zero sequence current advantage for this grounding eliminated arcing and voltage of healthy phases normal value $V_A=V_{PHASE=}$113kV, $V_B=V_{C=}$0they do not increase to1.732times normal value as in case of ungrounded system these condition are clear at point fault location 5(70km) and this very important for design all equipment and current for healthy phases $I_{A=0}$.and use over current relay as protection and for



detection fault.

Figure 11: Wave form for voltage and current for BCN fault at5 ohms at 10km

Figure 11 shows the voltage before fault location for BCN fault at5ohms all phases normal A,B,C and phases BC is normal before fault at location4(50km) and for amplitude 113kV sine wave result from source phase to phase RMS 138kVwere $V_{m=}138*\sqrt{2}/\sqrt{3} = 113kV$ for sample time 12000 sample in figure 4.8shows voltage after fault location for BCN fault at location4(50km) The change voltage phases BC is zero but for phase A=V_{PHASE} for current before fault at ABC at5 ohms has value is stable and normal because not load but after occur fault location at 10 km increased current for phases BC between 1500A to 2000A represented to ground fault current by use neutral source by Y_g the neutral is grounded either directly or through resistance or reactance the neutral grounding provide return path to zero sequence current advantage for this grounding eliminated arcing and voltage of healthy phases normal value $V_A=V_{PHASE=}$113KV, $V_B=V_{C=}$ 0they do not increase to1.732times normal value as in case of ungrounded system these condition are clear at point fault location 5(70km) and this very important for design all equipment and current for healthy phases $I_{A=0}$ while current faulty phases is high and use over



current relay as protection and for detection fault.

Figure 12: Wave form for voltage and current for ANfault at 10ohms at 10km

Figure 12 shows the voltage before fault location for AN fault at 10ohms all phases normal A,B,C and phase A is normal before fault and for amplitude 113kV sine wave result from source phase to phase RMS 138KVwere $V_{m=}138*\sqrt{2}/\sqrt{3} = 113kV$ for sample time 12000 sample in figure 4.9shows voltage after fault location for AN fault at location4(50km) The change voltage at AN fault is zero for current before fault at AN fault at 10 ohm has value is stable and normal because not load but after occur fault location at 10 km increased current for phase A between 1200A represented to ground fault current $I_{A=}I_F$ by use neutral source by Y_g the neutral is grounded either directly or through resistance or reactance the neutral grounding provide return path to zero sequence current advantage for this grounding eliminated arcing and voltage of healthy phases normal value $V_B=V_{PHASE=}113kV$, $V_C=V_{PHASE=}113kV$ they do not increase to1.732times normal value as in case of ungrounded system. While faulty phase $V_A=0$ these condition are clear at point fault location 5(70km)but here some value for voltage V_A to find fault resistance 10 ohms and this very important for design all equipment and current for healthy phases $I_{B=0}$, $I_{C=0}$ but fault current ground $I_{A=}I_F$ is high and sufficient to operate over current relay as protection and not use over voltage under voltage as protection and avoid arcing ground figure 4.9shows decreasefault current ground $I_{A=}I_F$ where 1200A for resistance fault 10 ohms while for resistance fault 5ohms in figure 4.6 shows 2000A to3000A by effect increase resistance fault.

Fault Location at 70km Single line without load by use Takagi method (y_g)

In table 4.7 fault resistance 0.001 ohms and different type fault, ABC, AN, BC, BCN actual fault occur at 70 km in table 4.7shows measured location and error from result error very acceptable and accuracy in table 4.7, we can see that different value for fault type for %error AN=6.8e-5and forBC=0.0075 some swing in calculation but all value is agree with value expected.

Table 8:Fault resistance 0.001ohmsat 70kmfault location

Type Fault	Measured Location	Actual Location	Error%
ABC	70.0065	70	0.0072
AN	70.0001	70	6.8e-5
BC	70.0068	70	0.0075
BCN	70.0065	70	0.0072

In table 9 fault resistance 5 ohms and different type fault ,ABC,AN,BC,BCN actual fault occur at 70 km shows measured location and error from result error very acceptable and accuracy in table4.8,we can see that different value for fault type for% error AN=1.3e-5and forBC=0.0150 some swing in calculation but all value is agree with value expected

Table 9: Fault resistance 5 Ohmsat 70km fault location

Type Fault	Measured Location	Actual Location	%Error
ABC	70.00130	70	0.0145
AN	70.0001	70	1.3e-4
BC	70.0135	70	0.0150
BCN	70.0130	70	0.0143

In the table 10 fault resistance 10ohms and different type fault, ABC, AN, BC, BCN actual fault occur at 70 km shows measured location and error from result error very acceptable and accuracy in table4.9, we can see that different value for fault type for% error AN=2.04e-4and forBC=0.0225 some swing in calculation but all value is agree with value expected.

Table 10: Fault resistance 10 Ohmsat 70km fault location

Type Fault	Measured Location	Actual Location	%Error
ABC	70.0195	70	0.0217
AN	70.002	70	2.04e-4
BC	70.0203	70	0.0225
BCN	70.0195	70	0.0217

In the table 11 fault resistance 30ohms and different type fault, ABC, AN, BC, BCN actual fault occur at 70 km shows measured location and error from result error very acceptable and accuracy in table4.10, we can see that different value for fault type for %error AN=2.7e-4and forBC=0.0300 some swing in calculation but all value is agree with value expected.

Table 4.10: Fault resistance 30 Ohms at70kmfault location

Type Fault	Measured Location	Actual Location	%Error
ABC	70.0261	70	0.0190
AN	70.0002	70	2.7e-4
BC	70.0270	70	0.0300
BCN	70.0261	70	0.0290

In the table 12 fault resistance 50ohms and different type fault,ABC,AN,BC,BCN actual fault occur at 70 km measured location and error from result error very acceptable and accuracy in table 4.11, we can see that different value for fault type for% error AN=3.4e-4and forBC=0.0375 some swing in calculation but all value is agree with value expected and increase fault resistance then increase %error for different type fault at 70km.

Type Fault	Measured Location	Actual Location	%Error
ABC	70.0326	70	0.0362
AN	70.0003	70	3.4e-4
BC	70.0336	70	0.0375
BCN	70.0321	70	0.0362

Table 12: Fault resistance 50 Ohms at 70kmfault location

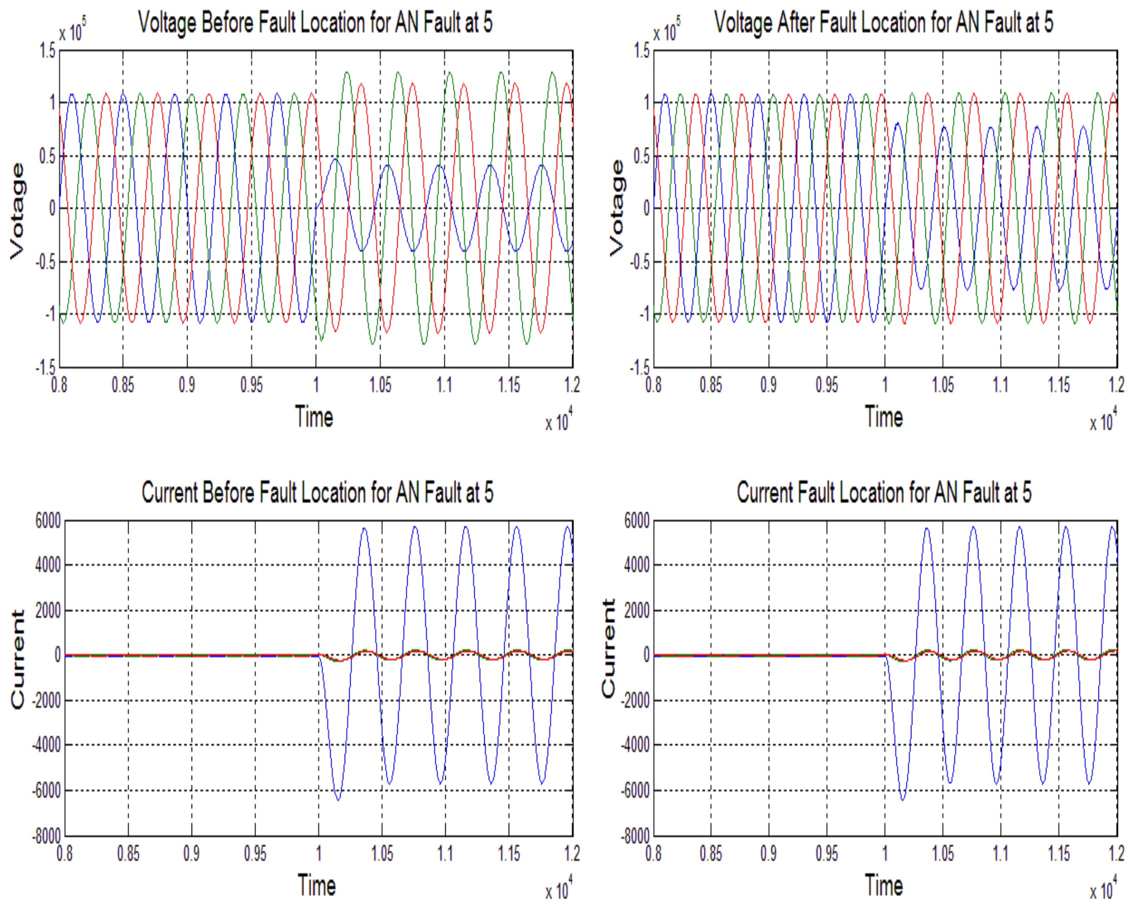


Figure 13: Wave form for voltage and current for AN fault at 5Ohms at 70km.

Figure 13 shows the voltage before fault location for AN fault at 5 ohms before and after fault location at location4(50km) and 6(90km) while point fault location at location 5(70km) all phases normal A,B,C and phase A is normal before fault and for amplitude 113kV sine wave result from source phase to phase RMS 138kVwere $V_{m=}138*\sqrt{2}/\sqrt{3} = 113$kV for sample time 12000 sample in figure 4.10shows voltage after fault location for AN fault at location4(50km) The change voltage at AN fault is not zero

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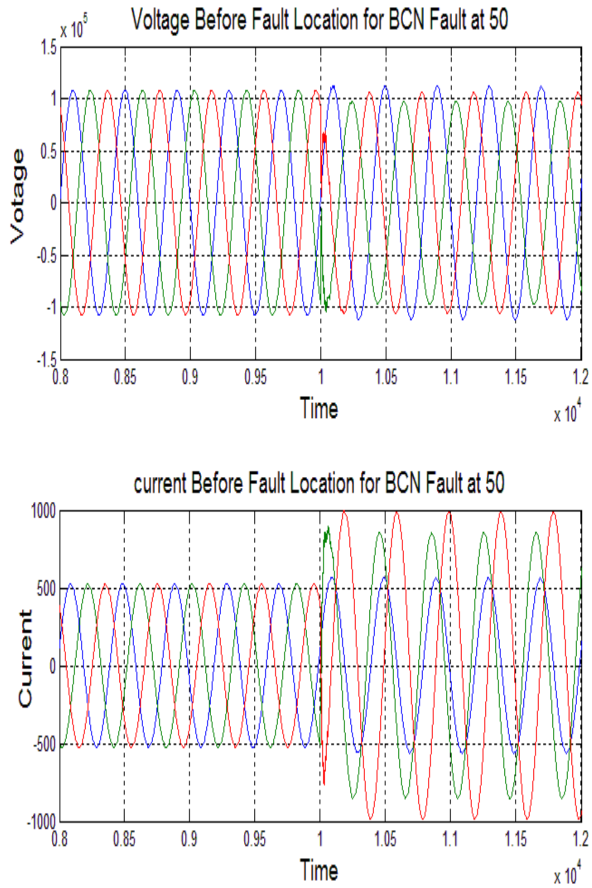
because resistance fault 5ohmswill increase voltage for AN for current before fault at AN fault at 5 ohms has value is stable and normal because not load but after occur fault location at 70 km increased current for phase A6000A represented to ground fault current $I_{A=}I_F$ by use neutral source by Y_g the neutral is grounded either directly or through resistance or reactance the neutral grounding provide return path to zero sequence current advantage for this grounding eliminated arcing and voltage of healthy phases normal value V_B=$V_{PHASE=}$113kV, V_C=$V_{PHASE=}$113kV they do not increase to1.732times normal value as in case of ungrounded system. While faulty phase V_A=0 these condition are clear at point fault location 5(70km)at ideal case resistance fault =0but here some value for voltage V_A to find fault resistance 5 ohm and this very important for design all equipment and current for healthy phases $I_{B=0}$, $I_{C=0}$ but fault current ground $I_{A=}I_F$ is high and sufficient to operate over current relay as protection and not use over voltage under voltage as protection and avoid arcing ground figure 4.10shows increasefault current ground $I_{A=}I_F$



where 6000A for resistance fault 5 fault location for 70km

Figure 14: wave form for voltage and current for BCNfault at 50 ohms at 70km.

Figure 14 shows the voltage before fault location for BCN fault at50 ohms all phases normal A,B,C and phases BC is normal before fault at location4(50km) and for amplitude 113kV sine wave result from source phase to phase RMS 138kVwere $V_{m=}138*\sqrt{2}/\sqrt{3} = 113$kV for sample time 12000 sample in figure 4.11shows voltage after fault location for BCN fault at location4(50km) The change voltage phases BC is not zero because find resistance fault but for phase A=V_{PHASE} for current before fault at ABC at 50 ohm has value is stable and normal but after occur fault location at 70 km increased current for phases BC 1000A represented to ground fault current by use neutral source by Y_g the neutral is grounded either directly or through resistance or reactance the neutral grounding provide return path to zero sequence current advantage for this grounding eliminated arcing and voltage of healthy phases normal value V_A=$V_{PHASE=}$113kVthey do not increase 1.732times normal value as in case of ungrounded system these condition are clear at point fault location 5(70km).

Fault Location at 70km Single line with load by use Takagi method

In table 15 fault resistance 0.001ohms and different type fault,ABC,AN,BC,BCN actual fault occur at 70 km in table 15 measured location and error from result error very acceptable and accuracy in table4.12 we can see thatdifferent value for fault type for% error AN=0.0032and forBC=0.0036 some swing in calculation but all value is agree with value expected formethod.

Type Fault	Measured Location	Actual Location	%Error
ABC	70.0001	70	0.00015
AN	70.0031	70	0.0032
BC	70.0003	70	0.0036
BCN	70.002	70	0.00027

Table 15: Resistance fault at 0.001ohms for Takagi method

In table 16 fault resistance 5ohms and different type fault, ABC, AN, BC, BCN actual fault occur at 70 km shows measured location and error from result error very acceptable and accuracy in table 4.13 we can see that different value for fault type for %error AN=0.0069and forBC=0.0069 some swing in calculation but all value is agree with value expected for Takagi method in fig4.13 any increased in fault resistance will

Increase error fault location

Table 16: Resistance fault at 5 ohms for Takagi method

Type Fault	Measured Location	Actual Location	%Error
ABC	70.0006	70	0.00052
AN	70.00063	70	0.0069
BC	70.0006	70	0.0069
BCN	70.0005	70	0.00054

Intable 16 fault resistance 10 ohms and different type fault, ABC, AN, BC, BCN actual fault occur at 70 km shows measured location and error from result error very acceptable and accuracy in table 4.14 different value for fault type for %error AN=0.0104 and forBC=0.0104 some swing in calculation but all value is agree with value expected for Takagi method in table 4.14 any increased in fault resistance will increase %error fault location for different type fault.

Type Fault	Measured Location	Actual Location	%Error
ABC	70.0010	70	0.0012
AN	70.0094	70	0.0104
BC	70.0094	70	0.0104
BCN	70.0007	70	0.0008

Table 17: Resistance fault at 10ohms for Takagi method

Type Fault	Measured Location	Actual Location	%Error

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ABC	70.0014	70	0.0016
AN	70.0125	70	0.0139
BC	70.0125	70	0.0139
BCN	70.0010	70	0.0011

Intable 17 fault resistance 30 ohms and different type fault ,ABC,AN,BC,BCN actual fault occur at 70 km measured location and error from result error very acceptable and accuracy the different value for fault type for% error AN=0.0139 and forBC=0.0139 some swing in calculation but all value is acceptable.

. Table 18: Resistance fault at 30 ohms for Takagi method

Table 19: Resistance fault at 50 ohmsfor Takagi method

Intable 19 fault resistance 50ohmsand different type fault ,ABC,AN,BC,BCN actual fault occur at 70 km measured location and error from result error very acceptable and accuracy the different value for fault type for% error AN=0.0173 and forBC=0.0173 some swing in calculation but all value is acceptable.

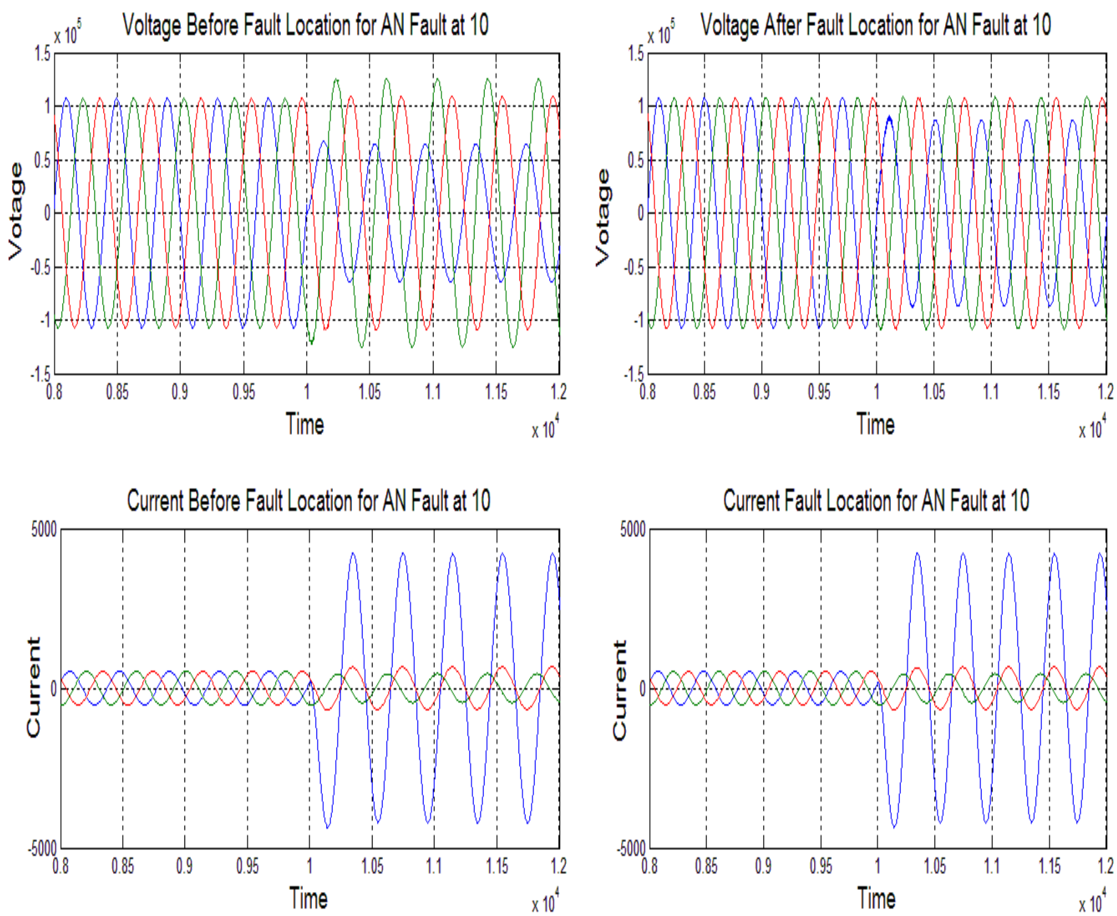


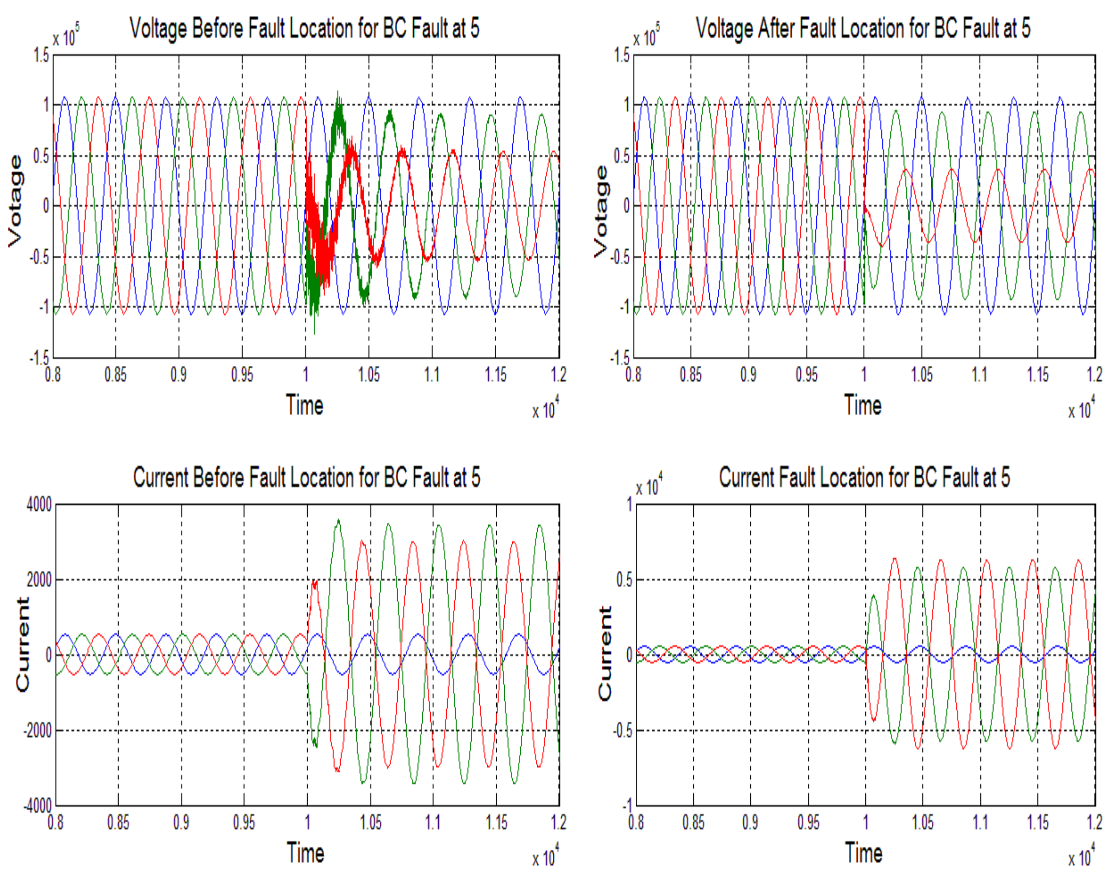
Figure 13: Wave form for voltage and current for ANfault at 10ohms at 70Km.

Figure 13 shows the voltage before fault location for AN fault at 10 ohms all phases normal A,B,C and phase A is normal before fault and for amplitude 113kV sine wave result from source phase to phase RMS 138kVwere $V_{m=}138 *\sqrt{2}/\sqrt{3} =$ 113kV for sample time 12000 sample in figure 4.12shows voltage after fault location for AN fault at location4(50km) The change voltage at AN fault is zero for current before fault at AN fault at 10 ohms has value is stable and normalbut after occur fault location at 70 km increased current for phase A 4000A represented to ground fault current $I_{A=}I_F$ by use neutral source by Y_g the neutral is grounded either directly or through resistance or reactance the neutral grounding provide return path to zero sequence current advantage for this grounding eliminated arcing and voltage of healthy phases normal value V_B=$V_{PHASE=}$113kV, V_C=$V_{PHASE=}$113kV they do not increase to1.732times normal value as in case of ungrounded system. While faulty phase V_A=0 these condition are clear at point fault location 5(70km)but here some value for voltage V_A to find fault resistance 10 ohms and this very important for design all equipment and current for healthy phase is very small current because find resistance fault 10 ohms but fault current ground $I_{A=}I_F$ is high and sufficient to operate over current relay as protection and not use over voltage under voltage as protection and avoid arcing ground figure 4.12showsincreasefault current ground $I_{A=}I_F$ where4000A for resistance fault 10 ohmsat fault 70km while for resistance fault 10 ohms in figure 4.9 shows 1200A by effectlong distance fault location.

Type Fault	Measured Location	Actual Location	%Error
ABC	70.0017	70	0.0019
AN	70.0156	70	0.0173
BC	70.0156	70	0.0173
BCN	70.0012	70	0.0014

Figure 14 shows the voltage before fault location for BC fault at5 Ohms at location4(50km) all phases normal and phase BC is normal before fault and for amplitude 113kv and voltage for $V_{A=}V_{PHASE}$ as shown in figure 15 but after occur fault location .

Figure 14: Wave form for voltage and current for BC fault at 5 Ohms at 70km



Double circuit line by use Takagi method

Table 20: Resistance fault at 0.001ohms double circuit line

Type Fault	Measured Location	Actual Location	%Error
ABC	70.0865	70	0.0961
AN	70.003	70	0.0037
BC	70.0063	70	0.007
BCN	70.003	70	0.0037

In table 20 fault resistance 0.001ohms and different type fault, ABC, AN, BC, BCN actual fault occur at different distance shows measured location and error from result error very acceptable and accuracy also in table 20 we can seethat different value for fault type for %error AN=0.0037 for distance 70km and forBC=0.007 for 70km fault location some swing in calculation but all value is agree with value expected.

Table 21: Resistance fault at 5 ohm double circuit line

Type Fault	Measured Location	Actual Location	%Error
ABC	70.1724	70	0.193
AN	70.06	70	0.0071
BC	70.012	70	0.013
BCN	70.006	70	0.0073

In table 21 fault resistance 5ohm and different type fault ,ABC,AN,BC,BCN actual fault occur at different distance notes measured location and error from result error very acceptable and accuracy also in table 21 we can see that different value for fault type for%error AN=0.0071 for distance 70km and forBC=0.013 for 70km fault location

Table 22: Resistance fault at 10ohms double circuit line

Type Fault	Measured Location	Actual Location	%Error
ABC	70.2594	70	0.288
AN	70.009	70	0.0110
BC	70.0188	70	0.0209
BCN	70.009	70	0.011

In table 22 fault resistance 10ohms and different type fault ,ABC,AN,BC,BCN actual fault occur at different distance shows measured location and error from result error very acceptable and accuracy in table 4.19, we can see different value for fault type for %error AN=0.0110 for distance 70km and for BC=0.0209 for 70km fault. Location some swing in calculation but all value is agree with value expected. Intable4.20 fault resistance 30ohms and different type fault, ABC, AN, BC, BCN actual fault occur at different distance shows measured location and error from result error very acceptable and accuracy different value for fault type for %error AN=0.0147 for distance 70km and forBC=0.0278 for 70km fault location some swing in calculation but all value is agree with value expected.

Figure 15: wave form for voltage and current for BCN fault at 0.001hms at 70kmfor double line

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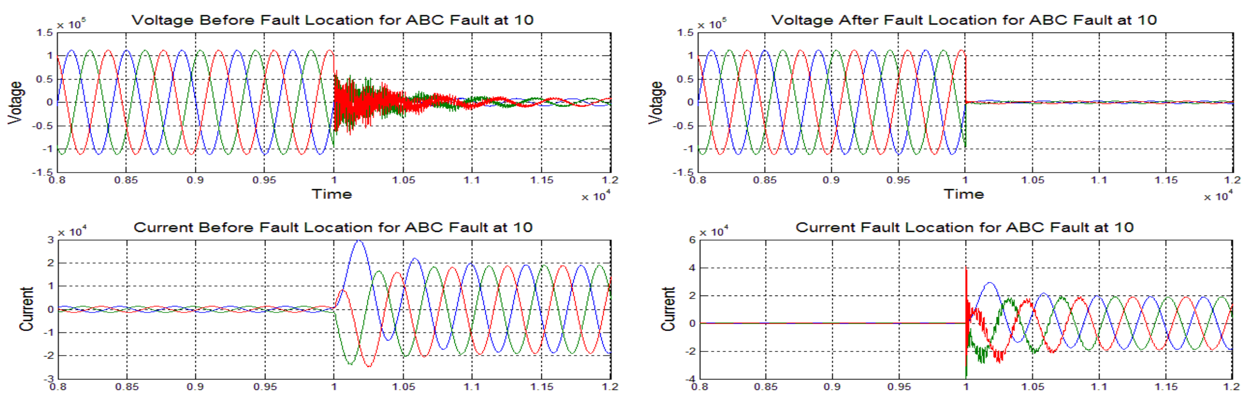
FFigure 15 shows the voltage before fault location for BCN fault at 0.001 ohms all phases normal A,B,C and phases BC is normal before fault at location4(50km) and for amplitude 113kV sine wave result from source phase to phase RMS 138kVwere $V_{m=}138*\sqrt{2}/\sqrt{3} = 113$kV for sample time 12000 sample in figure 4.14shows voltage after fault location for BCN fault at location4(50km) The change voltage phases BC is zero but for phase $A=V_{PHASE}$ for current before fault at ABC at 0.001 ohms has value is stable and normal because not load but after occur fault location at 70 km increased current for phases BC between 12000A represented to ground fault current is very high because small resistance fault 0.001ohms and long distance fault location 70km and effect double line with transformers and load by use neutral source by Y_g the neutral grounded. either directly or through resistance or reactance of healthy phases normal value $V_A=V_{PHASE=}113$kV, $V_B=V_{C=}$ 0they do not increase to1.732times normal value as in case of ungrounded system these condition are clear at point fault location 5(70km) and this very important for design all equipment and current for healthy phase $I_{A=0}$.and use over current relay as protection and for detection fault.

Figure 4.15: wave form for voltage and current for ABC fault at 10hm at 70Km for double line

Figure4.15 shows the voltage before fault location for ABC fault at 10ohms all phases normal and phase ABC is normal before fault occur and for amplitude 113kVsine wave and after fault occur three phases =0while for current before fault occur is normal but after fault occur at location4 (50km) high increase as protection over current is good for this case.

Simulation and result by use neutral source Y (isolated system) (Takagi Method)

Y:The three voltage sources are connected in Y to an internal floating neutral or called isolated neutral system the neutral is not connected to the ground where the potential of fault for single line to ground fault equal to ground voltage =0 and voltage for healthy phases will increase to V_{LIN} that meaning by ($\sqrt{3}$)For isolated system or ungrounded system the neutral is not connected to the ground the voltage of the neutral is not fixed and may float freely if occur fault at single line to ground fault then healthy phases will increase to line voltage which cause insulator



breakdown in this case not use earth fault protection and use over current relay in ideal case $V_{A=}0$, $V_{B=}$ $V_{C=}V_{LINE}$ if fault occur at phase AN.

Type Fault	Measured Location	Actual Location	%Error
ABC	70.0065	70	0.0072
AN	70.0001	70	6813e-5
BC	70.0068	70	0.0075
BCN	70.0065	70	0.0072

Table 23: Fault resistance 0.001ohmsat 70kmfault location with Y source

In the table 4.43 the fault resistance 0.001ohms and different type fault ABC, AN, BC, BCN actual fault occur at 70 km as shown in table 4:43 the measured location and error from result error very acceptable and accuracy the different value for fault type for %error AN=681e-5 and for BC=0.0075 some swing in calculation but all value is agree with value expected in the table we can see values are very small these values don't depend on type source neutral either grounded system or isolated system.

Table 24: Fault resistance 5 Ohmsat 70km fault locationwith Y source

Type Fault	Measured Location	Actual Location	%Error
ABC	70.0130	70	0.0145
AN	70.0001	70	1.362e-4
BC	70.0135	70	0.0150
BCN	70.0130	70	0.0145

I

n the table 24 fault resistance 5ohms and different type fault,ABC,AN,BC,BCN actual fault occur at 70 km the measured location and error from result error very acceptable and accuracy in table 4.44we can seethat different value for fault type for% error AN=1.36e-4and for BC=0.0150 some swing in calculation but all value is agree with value expected with small increased by effect increase fault resistance.

Table 25: Fault resistance 10 Ohm at 70km fault locationwith Y source

Type Fault	Measured Location	Actual Location	%Error
ABC	70.0195	70	0.0217
AN	70.0002	70	2.0439e-4
BC	70.0203	70	0.0225
BCN	70.0195	70	0.0217

In the table 25 fault resistance 10 ohms and different type fault,ABC,AN,BC,BCN actual fault occur at 70 km notes measured location and error from result error very acceptable and accuracy in table 4.45 we can see that different value for fault typefor% error AN=2.0439e-4and for BC=0.0225 some swing in calculation but all value is agree with value expected.

Table 26: Fault resistance 30 Ohmsat70kmfault locationwith Y source

Type Fault	Measured Location	Actual Location	%Error
ABC	70.0261	70	0.0290
AN	70.0002	70	2.725e-4
BC	70.0270	70	0.0300
BCN	70.0261	70	0.0290

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In the table 26 fault resistance 30ohms and different type fault ,ABC,AN,BC,BCN actual fault occur at 70 km in table4.46 measured location and error from result error very acceptable and accuracy also see different value for fault type for AN=2.725e-4and for BC=0.0300 some swing in calculation but all value is agree with value expected.in the table 4.46 we can see values are very small these values don't depend on type source neutral either grounded system or isolated system.

Table 27: Fault resistance 50 Ohms at 70kmfault location with Y source

Type Fault	Measured Location	Actual Location	%Error
ABC	70.0326	70	0.0362
AN	70.0003	70	3.4066e-4
BC	70.0338	70	0.0375
BCN	70.0322	70	0.0362

In the table 27fault resistance 50ohms and different type fault,ABC,AN,BC,BCN actual fault occur at 70 km in table 27,we can see that measured location and error from result error very acceptable and accuracy also see different value for fault type for A %error=3.40e-4.

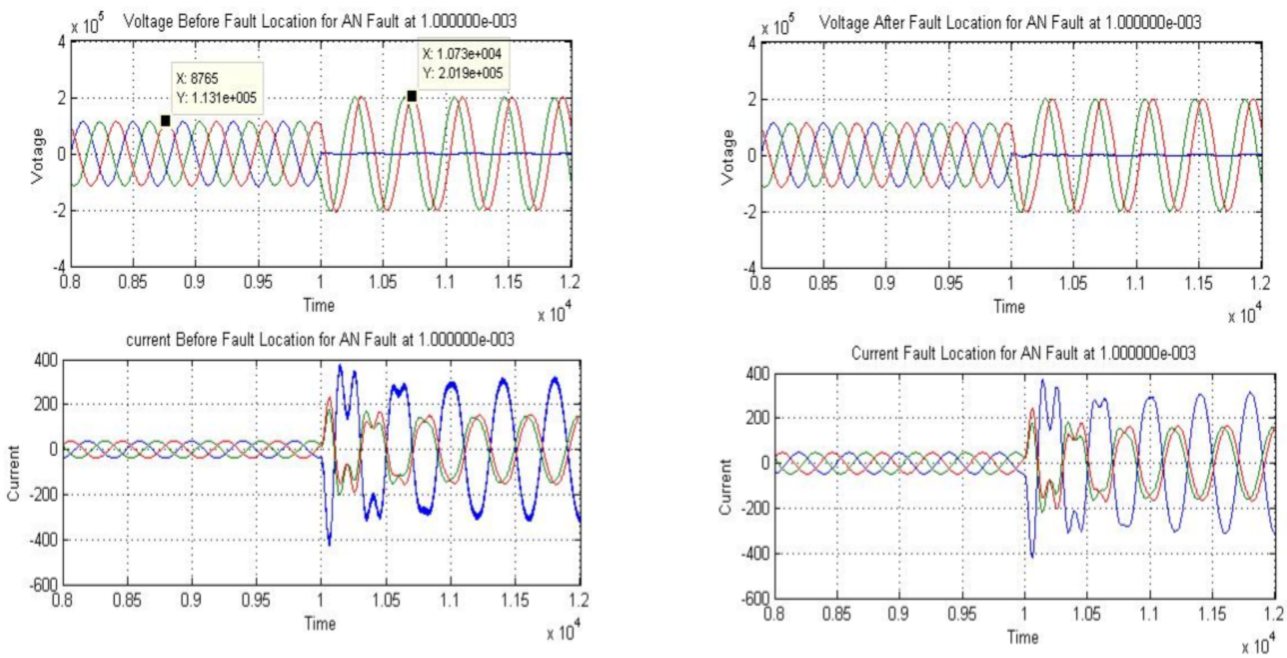

Figure 16: Wave form for voltage and current for AN fault at 0.001 ohms at 70km

Figure 16 shows the voltage before fault location for AN fault at 0.001 Ohms all phases normal andphase ABC is normal before fault and for amplitude 113kv for1200 sample time , and voltage after occur fault location for AN fault the change voltage at phase A is zero and for another phases B,C will increased to 201kv by 1.732*113kV this at location 50km before fault location and for after current is same while current before fault at AN fault at 0.001 Ohms has value is stable but after occur fault location at 70 km increased current about 300A and oscillation three phases.The voltage before fault location for AN fault at 0.001 ohms figure 4.31 shows voltage after fault at location at 70 km increased current for phase A represented to ground fault current this case use neutral source by Y the neutral is not grounded directly or through resistance or reactance the neutral is not connected healthy phases normal value

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$V_B=V_{LINE}$, $V_C=V_{LINE}$ they do increase 1.732times normal value. While faulty phase $V_A=0$ then voltage increased at healthy phases used over voltage relay as detecting fault and protection.

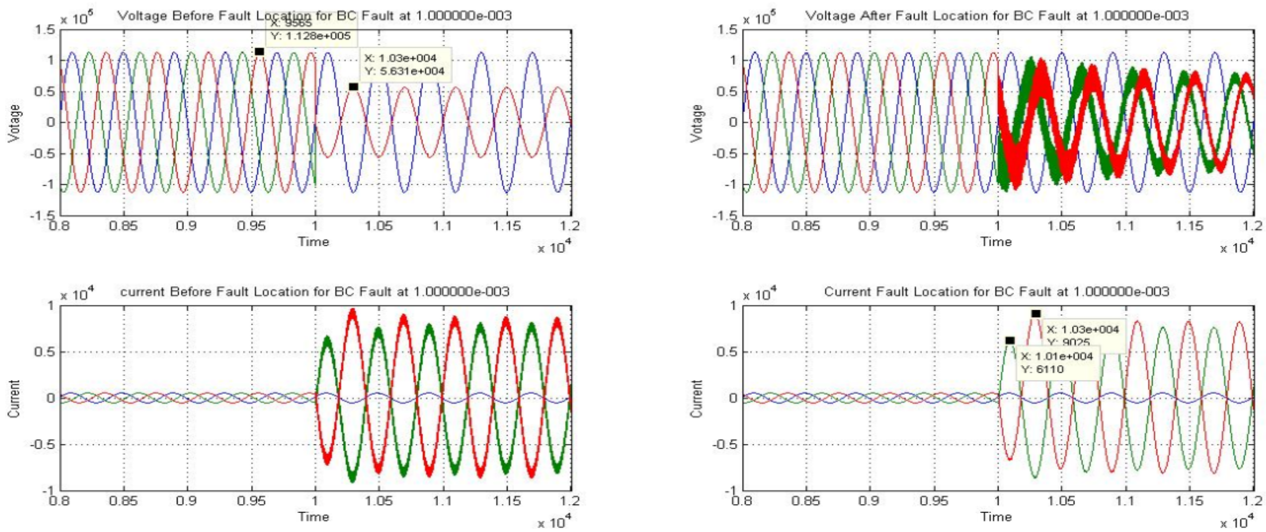

Figure 17: Wave form for voltage and current for BC fault at 0.001 Ohms at 70Km

Figure 17 shows the voltage before fault location for BC fault at 0.001 Ohms all phases normal and phase BC is normal before fault and for amplitude 113kV, and voltage after fault location for BC fault the change voltage at BC fault is oscillation between 113kV for phase A=113kV while for another phases B,C is dropped this dropped depend on resistance fault value and distance fault location and resistance value in neutral source for current before fault at BC fault at 0.001 ohms hasvalue is stable but after occur fault location at 70 km increased where fault phase to phase is high current.

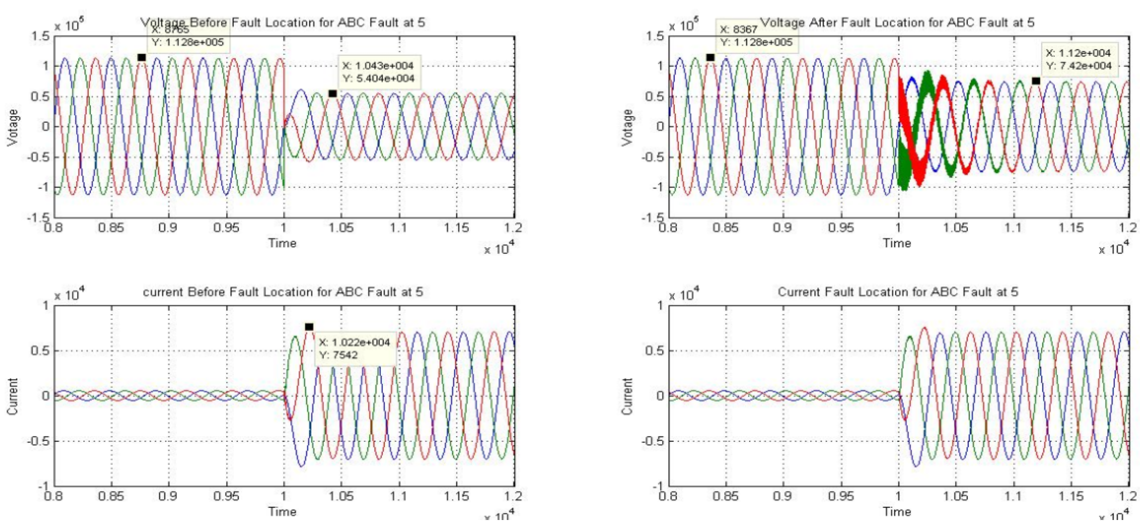

Figure 18: Wave form for voltage and current for ABC fault at 5 Ohms at 70km

Figure 18 shows the voltage before fault location for ABC fault at 5 ohms all phases normal and phase ABC is normal before fault and for amplitude 113kv for sample time 12000 sample, and voltage after fault location for ABC fault figure 4.33shows the change voltage at ABC fault is decrease to 54kV for three phases, while after fault at 90km change voltage to 74kVwith oscillation , for current before fault at ABC fault at 5 ohms has value is stable but after occur fault location at 70 km increased current about 7542A and increase for three phases where three phase fault is high current and use over current relay for detection fault as protection where three phase fault not increase voltage while current increase.

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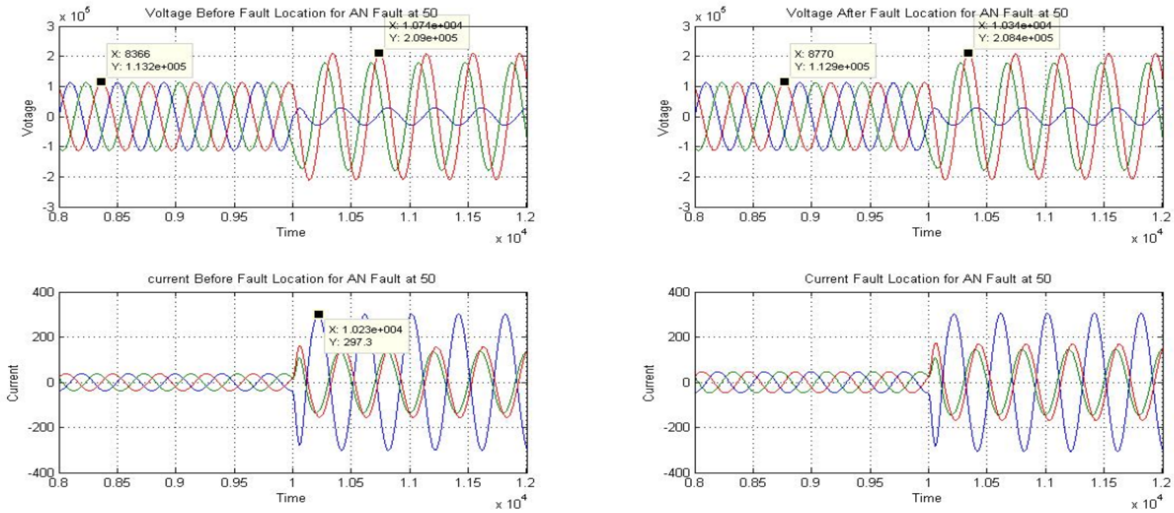
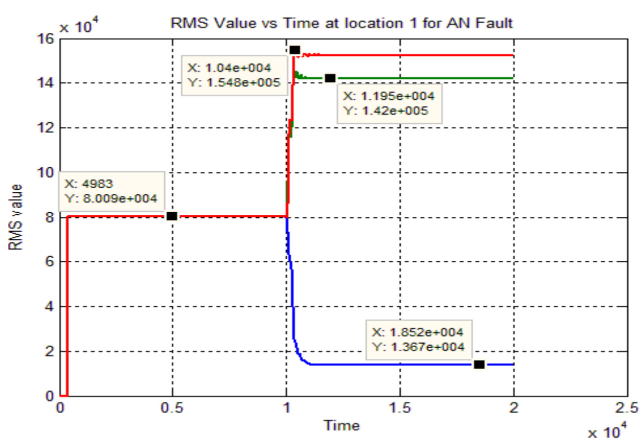


Figure 19: Wave form for voltage and current for AN fault at 50Ohms at 70km

Figure 19 shows the voltage before fault location for AN fault at 50Ohms all phases normal and phase A is normal before fault and for amplitude 113kv for sample time 12000 sample, and voltage after fault location at 50km for AN fault figure 4.34shows voltage at AN fault isnearzero at location4(50km) for resistance fault50ohm and for another phases B, C will increased to 209kVby 1.732*113kV and for current before fault at AN fault at 50Ohms has value is stable but after occur fault location at 70 km increased current about 297Aneutral source by Y the neutral is not grounded directly or through resistance or reactance for healthy phases normal value V_B=V_{LINE},V_C=V_{LINE} they do increase 1.732times normal value. While faulty phase V_A=0 and this very important for design all equipment and current for healthy phases is small but ground fault current is high and sufficient to operate over current relay as protection and use over voltage under as protection and avoid arcing ground Va=0,Vb=V_{LINE},Vc=$V_{LINE=}$1.732*V_{PHASE} in point fault location .

Simulation and result by use neutral source Y (isolated system) by use RMS (Takaji Method)



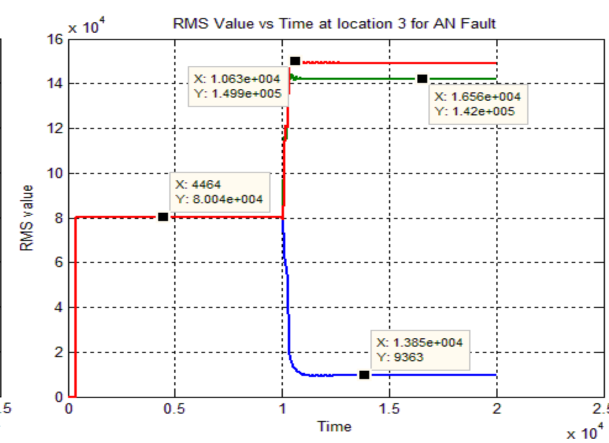


Figure 20: voltage at location 1(5km) effect from AN fault at location 5(70km) with single line without load

Figure 21:voltage at location 3(30km) effect from AN fault at location 5(70km) with single line without load

Figure 20 shows fault type single phase ground AN is dropped to 17kV while another phases B, Cchange to phase=154kV and phase C=142kVthat meaning 80KV by $\sqrt{3}$ that mean $V_{A=}0$ and $V_{B=}V_{LINE}$,$Vc=V_{LINE}$ for ideal case ungrounded system or called isolated system fault location and device measuring 65km therefor no dropped to zero and start from zero to 1secand where fault occur.Figure 4.35 shows the voltage at location 1(5) effect from fault AN at location 5(70km) for single line without loadfor damage equipment insulationwhere root mean square voltage =Vm/√2=80kVfor sine wave in figure 21 we can see that138kVphase to phase RMS, that mean$V_{m=}138*\sqrt{2}/\sqrt{3} =$ 113kV then R.M.S=113/√2=80kVas phase voltage RMS in line voltageRMS 80*.$\sqrt{3}$ =138kV In figure 4.35 we can see that grounded source Y for neutral source that meaning no impedance in neutral isolated system and for current I_A=fault current I_B=0,Ic=0at point fault location and we can use for detection fault earth fault relay as protection. Figure 4.36 shows fault type single phase ground AN is dropped to 9.363kV while another phases B, C change to phase B=149kV and phase C=142kVthat meaning 80KV by $\sqrt{3}$ that mean $V_{A=}0$ and $V_{B=}V_{LINE}$,$Vc=V_{LINE}$ for ideal case ungrounded system or called isolated system fault location and device measuring 40km therefor no dropped to zero and start from zero to 1secand where fault occur.Figure 4.36 shows the voltage at location 3(30) effect from fault AN at location 5(70km) for single line without load for damage equipment insulation may be occurwhere root mean square voltage =Vm/√2=80kVfor sine wave in figure 4.36we can see that138kVphase to phase RMS, that mean$V_{m=}138*\sqrt{2}/\sqrt{3} =$ 113kV then R.M.S=113/√2=80kVas phase voltage RMS in line voltageRMS 80*.$\sqrt{3}$=138kV In figure 4.36 we can see that grounded source Y for neutral source that meaning no impedance in neutral isolated system and for current I_A=fault current I_B=0,Ic=0at point fault location and we can use for detection fault by use earth fault relay as protection.

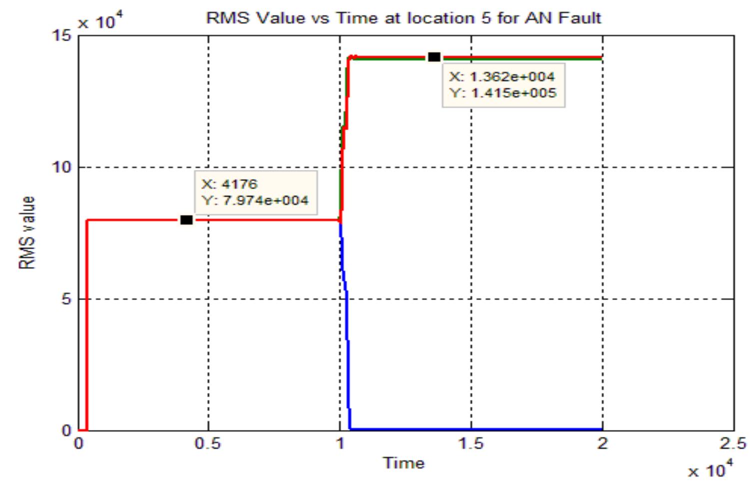


Figure 22: voltage at location 5(70km) effect from AN fault at location5 (70km) with single line without load

Figure 22 shows fault type single phase ground AN is dropped to zero while another phases B, C change to phase B=141kV and phase C=141kVthat meaning 80kV by $\sqrt{3}$ that mean $V_{A=}0$ and $V_{B=}V_{LINE}$,$Vc=V_{LINE}$ for ideal case ungrounded system or called isolated system fault location and device measuring 0km therefor dropped to zero and start from zero to 1sec as time and where fault occur.Figure 4.37 shows the voltage at location 5(70) effect from fault AN at location 5(70km) for single line without load for damage equipment insulation may be occur if equipment's are design as voltage phasewhere root mean square voltage =Vm/√2=80kVfor sine wave in figure 4.38we can see that138KVphase to phase RMS, that mean$V_{m=}138*\sqrt{2}/\sqrt{3} =$ 113kV then R.M.S=113/√2=80kVas phase voltage RMS in line voltage RMS 80*.$\sqrt{3}$ =138kV In figure 4.38 we can see that grounded source Y for neutral source that meaning no impedance in neutral isolated system and for current I_A=fault current ground I_B=0,Ic=0at point fault location5(70) and we can use for detection fault by use earth fault relay as protection.

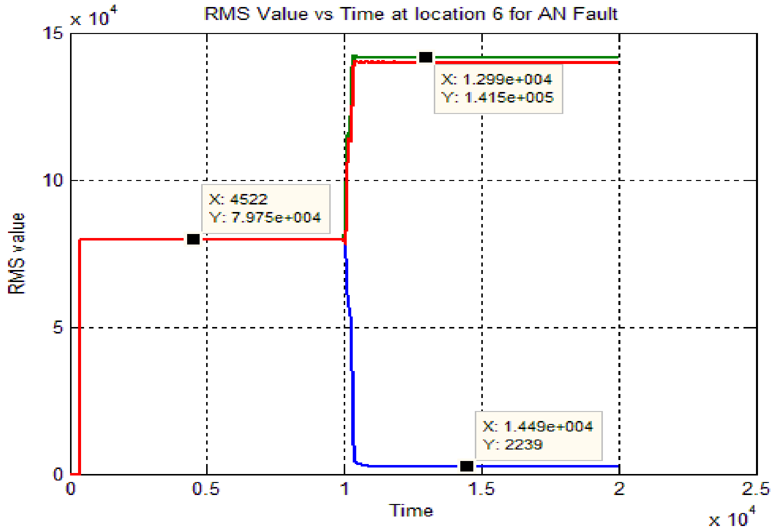


Figure 23: voltage at location 6(90km)effect from AN fault at block 5(70km) with single line without load

Figure 23 shows fault type single phase ground AN is dropped to zero while another phases B, C change to phase B=141.5kV and phase C=142kVthat meaning 80kV by $\sqrt{3}$ that mean $V_{A=}0$ and $V_{B=}V_{LINE}$,Vc=V_{LINE} for ideal case ungrounded system or called isolated system fault location and device measuring 20km after location fault therefor dropped to 2.239kV and start from zero to 1sec as time and where fault occur.Figure 4.38 shows the voltage at location 6(90) effect from fault AN at location 5(70km) for single line without load for damage equipment insulation may be occur if equipment's are design as voltage phasewhere root mean square voltage =Vm/√2=80kV for sine wave in figure 4.38we can see that138KVphase to phase RMS, that mean$V_{m=}138*\sqrt{2}/\sqrt{3} =$ 113kV then R.M.S=113/√2=80kVas phase voltage RMS in line voltage RMS 80*.$\sqrt{3}$ =138kV In figure 4.38 we can see that grounded source Y for neutral source that meaning no impedance in neutral isolated system and for current I_A=fault current ground I_B=0,Ic=0at point fault location5(70) and we can use for detection fault by use earth fault relay as protection.

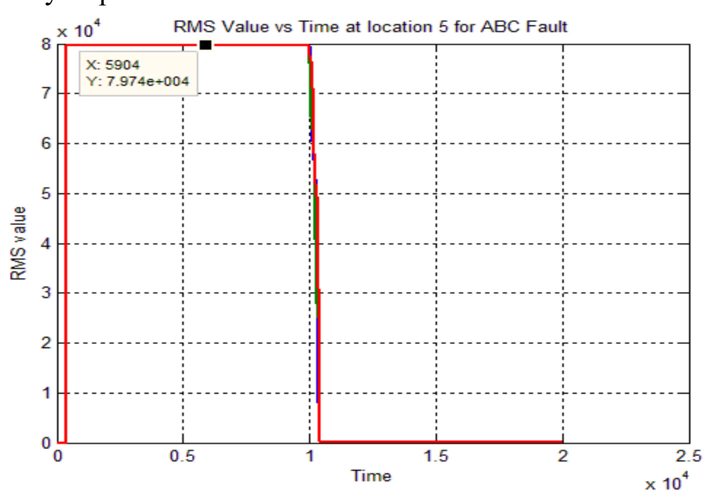


Figure 24: voltage at location 5(70km) effect from fault ABC at location 5(70km) for single line without load

figure 24 shows dropped voltage RMS for two phases ABC to 0 , where fault occurred atlocation70kmwhere root mean square voltage =Vm/√2=80kVfor sine wave.in three phase short circuit current will be very high$V_{m=}138*\sqrt{2}/\sqrt{3}$ = 113kV then R.M.S=113/√2=80KVas phase voltage RMS in line voltage RMS 80*.$\sqrt{3}$ =138kVas voltage RMS line In figure 4.39 we can see that grounded source Y for neutral source that meaning no impedance in neutral isolated system.

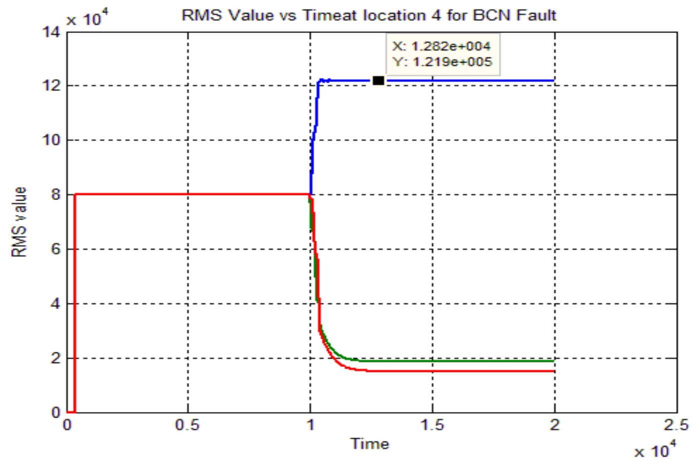


Figure 25: Voltage at location 4(50km) effect from fault BCN at location5 (70km) for single line without load

Figure 25 shows fault type single phase ground BCN is dropped to 2.000kV while another phase Aincrease to 121.9kVmeaning 80KV by $\sqrt{3}$ for ideal case ungrounded system or called isolated system fault location and device measuring 20km.Figure 4.40 shows the voltage at location 4(50) effect from fault BCN at location 5(70km) for single line without load for damage equipment insulation may be occur if equipment's are design as voltage phasewhere root mean square voltage =Vm/√2=80kVfor sine wave in figure 4.41we can see that138KVphase to phase RMS, that mean$V_{m=}138*\sqrt{2}/\sqrt{3}$ = 113kV then R.M.S=113/√2=80kVas phase voltage RMS in line voltage RMS 80*.$\sqrt{3}$ =138kV In figure 4.40 we can see that grounded source Y for neutral source that meaning no impedance in neutral isolated system and for current I_A=0 and another phase high current at point fault location5(70) and we can use for detection fault by use earth fault relay or over current or both as protection.

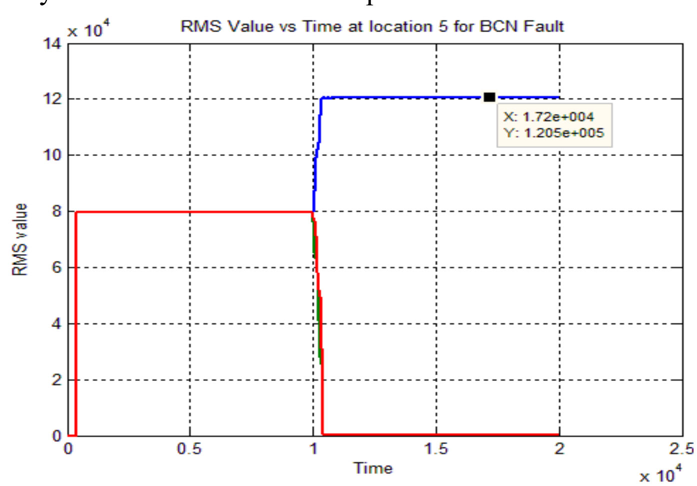


Figure 26: Voltage at location 5(70km) effect from fault BCN at location5 (70km) for single line without load

Figure 26 shows fault type single phase ground BCN is dropped to 2.000kV while another phase Aincrease to 121kVmeaning 80kV by $\sqrt{3}$ for ideal case ungrounded system or called isolated system fault location and device measuring 20km.Figure 4.41 shows the voltage at location 5(70) effect from fault BCN at location 5(70km) for single line without load for damage equipment insulation may be occur if equipment's are design as voltage phasewhere root mean square voltage =Vm/√2=80kVfor sine wave in figure 4.42we can see that138KVphase to phase RMS, that mean$V_{m=}138*\sqrt{2}/\sqrt{3} = 113$kV then R.M.S=113/√2=80kVas phase voltage RMS in line voltage RMS 80*.$\sqrt{3}$=138kV In figure 4.41we can see that grounded source Y for neutral source that meaning no impedance in neutral isolated system and for current I_A=0 and another phase high current at point fault location5(70) and we can use for detection fault by use earth fault relay or over current or both as protection.

CONCLUSION:

This thesis compares and evaluates different methods for classification of fault types and calculation of distance to faults. The purpose of this thesis is to examine the applications of conventional one-side and two-side based fault location methods for transmission line. Different type of algorithm will be verified in Simulink and be implemented to the transmission line analyses of different known fault cases. Implemented the selected algorithms in MATLAB and Simulink for verification of fault distance and fault location methods accuracy in different cases studies. On the contrary, all two-side algorithms present a high fault margin at real tested fault situation. Two-side methods provide fault location estimation with acceptable error. But in reality, two-sided algorithms are more accurate than one-sided algorithms, compare two method by using impedance method depend on minimum impedanceand impedance method by using y_{bus}this method is accuracy and better , and result for one side(Takagi method) about 0.5%while for two side method(matrix method) and 3.3% .

- Where increase length for transmission line will increased error and increase fault current at point fault location
- Used y_{bus} method for simulation gives small error
- Accuracy of Takagi method is 0.5% and for matrix method 3.3%for unhomogenies system.

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