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# Implementation of Novosel Simple Impedance Algorithm for fault location

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**ABSTRACT**

Accurate determination of fault location is needed to clear the fault for maintaining the continuity of electrical energy. This paper presents the location of line to ground fault in transmission line using Novosel simple impedance method. The proposed algorithm utilizes the currents and voltages of both ends of transmission line with phasor angles when the fault occurs. The data generated on both ends of transmission line are unsynchronized data. To make the both end data synchronize Newton Raphson method is used for finding synchronize angle. Simulation results indicate that this method achieves more accurate in locating the fault.

***Keywords:*** Fault analysis, Transmission line, Newton Raphson method.

## 1. INTRODUCTION

A ccuracy in fault location helps to reduce the faults which occur in long transmission lines. Fault location usually deals with transmission lines because these are exposed directly to the environment. Power produced in the powerplants is delivered to the customers using transmission lines. In transmission lines faults can be classified as two types: 1)Physical Faults. 2)Mechanical Faults [1]-[2].

Physical faults mainly involves variation in temparature, wind pressure, Lightning. To avoid these faults the strength of the transmission lines should be increased. Mechanical faults are generally classified as shuntfaults,seriesfaults and combination of both. Shunt faults occurs when there is a insulation breakdown between phases or to earth. Seriesfaults occurs when there is a broken conductor. Arcing faults comes under combination of both.

This Paper mainly deals with Line-Ground fault location. Faults which occur mainly are Tripping faults. Tripping faults comes under Line-Ground faults[4]. Different algorithms came in to existence for the fault location namely Impedance Method, Traveling waveMethod . Impedance method uses the phasor values of voltage and current for fault locating. If these values are obtained from both the terminals( i.efrom both sending and receiving end) it is known as two terminal method otherwise it is known as single terminal method. Data which is obtained from these terninals may be synchronized or unsynchronized data[2]. Synchronized data can be obtained from GPS or PMU. But unsynchronized data is transformed to synchronized data by reducing the synchronization error. An electrical pulse is made to travel along the transmission line. The time taken for the pulse to return back gives the fault location .This method is named as Traveling wave method[1].

This paper is framed in such a way that it consists of Methodology in section II. Section III presents the algorithm which is used to locate the fault. Section IV for Simulation and results. Finally, section V for conclusions.

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## 2. METHODOLOGY

.Novosel Simple Impedance Method uses the data from both sides. The main objective of this method is to detect and locate the fault and only single line to ground fault is considered .Only positive sequence of currents and voltages from both the terminals of faulted line is used for locating the fault. In this method, fault impedance is neglected.

This algorithm follows the work done by[3]. In a real time system the data obtained from the two ends will be an unsynchronized data. Communication of unsynchronized data is expensive usually data is transmitted from the both ends by using relays. Unsynchronized data is rectified by introducing an synchronizing angle(ä).Fig1 gives an idea for the implementation of Novosel method it uses iteration method to find the angle(ä). Newton Raphson Method is selected for iteration. Va,Vb,Ia,Ib are the voltages&currents at both ends of the transmission line.

The main advantage is there is no mutual coupling effect which is predominant in parallel transmission lines. System parameters and change in network configurations will not affect the propagation. This method is useful when the transmission lines are branched . For both transposed and untransposed lines this method is applicable.

Assumptions made in this method are fault resistance is set to be zero and the fault type, load currents doesn’t have any affect on this method.

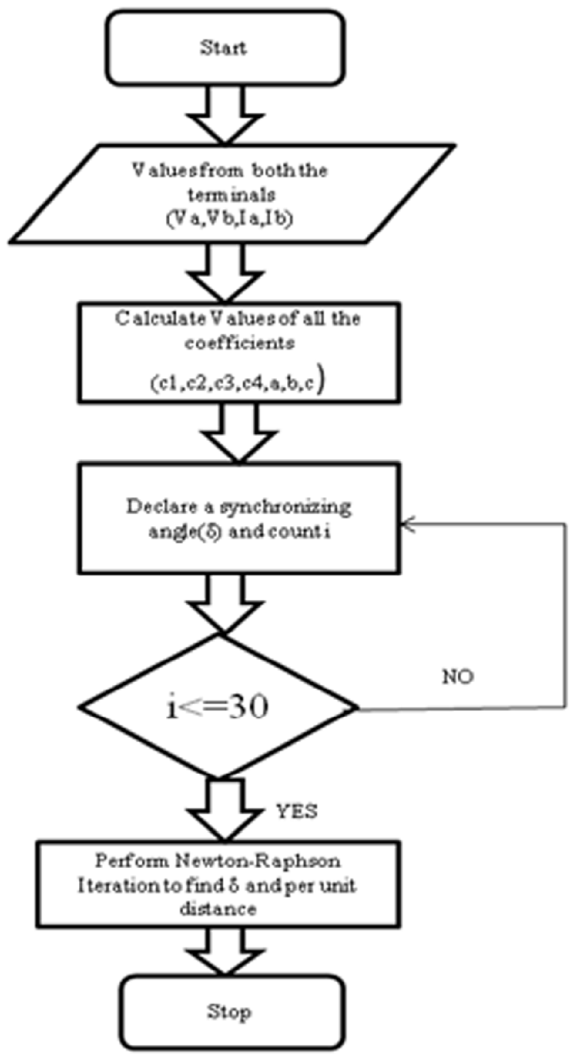


**Figure 1: Block diagram of Novosel simple impedance method.**

Va,Vb : Voltages at both ends of transmission lines.

Ia, Ib : currents at both ends of transmission lines.

## 3. FAULT LOCATION ALGORITHM

Fig. 2. gives us an simple idea of two bus system.Let ‘n’ be the distance at which fault created[3].

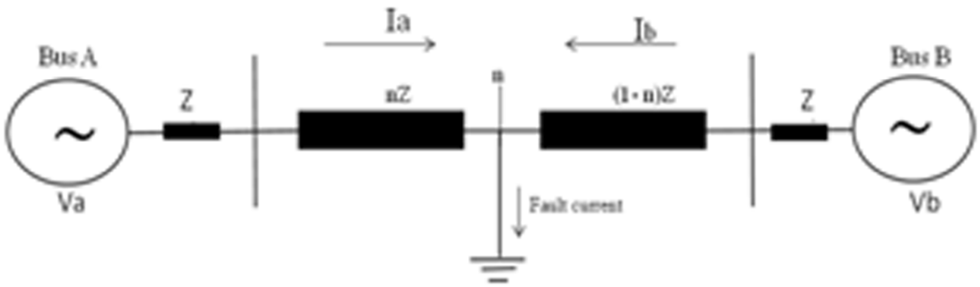


**Figure 2: Simple two bus system**

By applying Kirchhoff’s voltage to Fig2. Two loops are obtained when there is a fault occurred at a distance of ‘n’ from any bus. Let’s assume fault is occurred at a distance ‘n’ from Bus A . So from Bus B fault is occurred at a distance of (1-n). Z be the source impedances of both the buses and Ia, Ib are the currents passing through them[1].

$$(V_f) = V_a - (n * z * I_a) \tag{1}$$

$$(V_f) = V_b - ((1 - n) * z * I_b) \tag{2}$$

$$Z = R + JX \tag{3}$$

By considering the phasor angles associated with voltages and currents.

$$(V_a) = V_a < (\alpha + \delta) \tag{4}$$

$$(V_b) = V_b < \beta \tag{5}$$

$$(I_a) = I_a < (\gamma + \delta) \tag{6}$$

$$(I_b) = I_b < \theta \tag{7}$$

Measured angles = $\beta$, $\alpha$, $\gamma$, $\theta$

By equating 1 & 2, formulating the above equations using complex representation of $e^{j\delta}$

We obtained

$$(V_a)e^{j\delta} - V_b + Z(I_b) = n * z * (I_a e^{j\delta} + I_b) \tag{8}$$

$\delta$ can be expressed as cos $\delta$ + $j$ sin $\delta$

By equating real and Imaginary components equation (8) can be written as

$$\text{Re}\,(V_a)\sin\delta + Im(V_a)\cos\delta - Im(V_b) + C_4 = n(C_1 \sin\delta + C_2 \cos\delta + C_4) \tag{9}$$

$$\text{Re}\,(V_a)\cos\delta + Im(V_a)\sin\delta - Re(V_b) + C_3 = n(C_1 \cos\delta + C_2 \sin\delta + C_3) \tag{10}$$

where coefficients are:

$$C_1 = R * Re(I_a) - X * Im(I_a) \tag{11}$$

$$C_2 = R * Im(I_a) + X * Re(I_a) \tag{12}$$

$$C_3 = R * Re(I_b) - X * Im(I_b) \tag{13}$$

$$C_4 = R * Im(I_b) + X * Re(I_b) \tag{14}$$

can be obtained by dividing the equations 9 and 10, by removing the unwanted terms the following equation is obtained:

$$a * \sin\delta + b * \cos\delta + c = 0 \tag{15}$$

where

$$a = -C_3\, Re(V_a) - C_4\, Im(V_a) - C_1\, Re(V_b) - C_2\, Im(V_b) + (C_1 C_3) + (C_2 C_4) \tag{16}$$

$$b = -C_4\, Re(V_a) - C_3\, Im(V_a) - C_2\, Re(V_b) + C_1\, Im(V_b) + (C_2 C_3) + (C_1 C_4) \tag{17}$$

$$c = -C_2\, Re(V_a) - C_1\, Im(V_a) - C_4\, Re(V_b) + C_3\, Im(V_b) \tag{18}$$

Synchronization angle(can be obtained by Newton Raphson Iterative method which says:

$$\delta_{k+1} = \delta_k - \frac{F(\delta_k)}{\hat{F}(\delta_k)} \tag{19}$$

$$F(\delta_k) = b * \sin\delta + a * \cos\delta + c \tag{20}$$

$$F(\delta_k) = b * \cos\delta - a * \sin\delta \tag{21}$$

δ value is initially guessed to start iteration. In this method 30 is set as tolerance. This can be adjusted according to our tolerance band (i.e smaller difference between $\delta_k$ and $\delta_{k+1}$). Once δ value is obtained it is substituted either in equation 9 or 10 to calculate distance '*n*'.

$$n = \frac{\mathrm{Re}(V_a) * \sin\delta + \mathrm{Im}(V_a)\cos\delta - \mathrm{Im}(V_b) + C_4}{C_1 * \sin\delta + C_2\cos\delta + C_4} \tag{21}$$

The same algorithm is applied for 9 Bus system . Using ETAP software a 9 bus system is simulated and short circuit analysis is done. The fault is created in between any two buses. Based on the current magnitudes and direction the transmission line which is effected by the fault is detected. When the fault occurs on transmission line either of the three conditions may exist:

a) sending end current and receiving end current may differ in magnitudes.

b) sending end current and receiving end current directions are opposite.

c) Both of the above conditions.

By the above conditions transmission line which is effected by fault is known. Then both buses data is transferred to algorithm and remaining buses datas are neglected to find the fault distance. Using Matlab , code is generated for both nine bus and two bus system.

## 4. SIMULATION AND RESULTS

Nine bus Anderson system is simulated and fault analysis is done in ETAP.

By considering the fault in transmission line 6 (between bus 7 and bus 8).

From the Fig 4 the current through the transmission line from both ends are having different magnitude and opposite in direction. So fault is detected and data from the bus 7 and bus 8 are considered for the fault distance calculation.

Two bus system simulation is done in MATLAB Simulink .

Algorithm is tested for the above two bus system and error is 3% approximately.

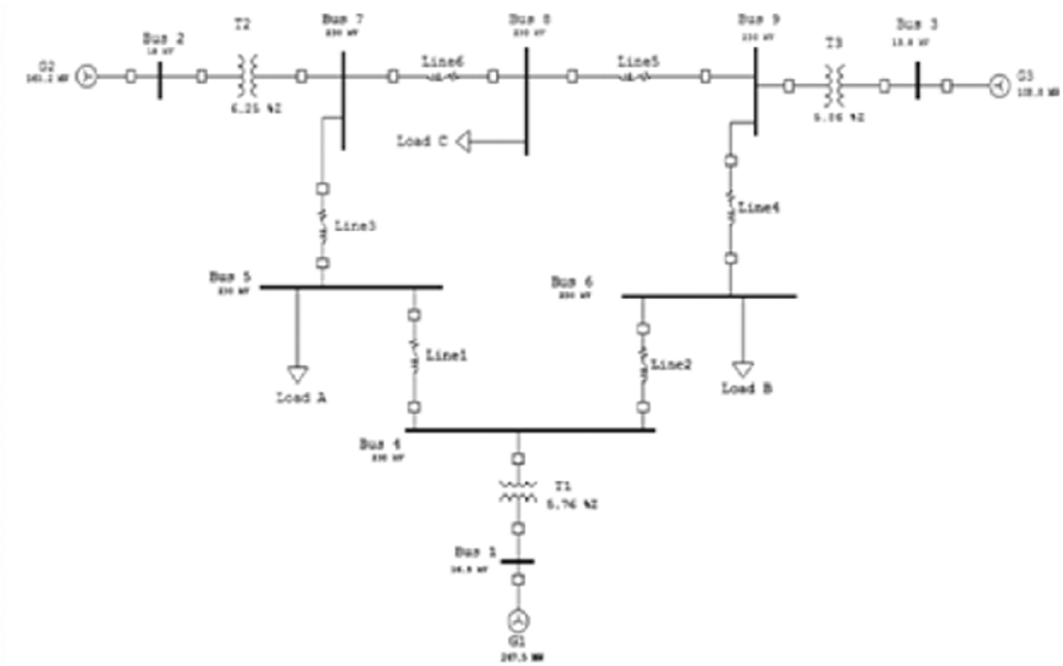


**Figure 3: Nine bus Anderson system in ETAP.**

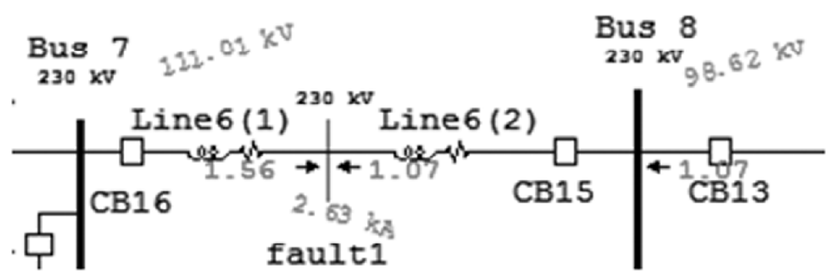


**Figure 4: Faulted line between bus 7 and bus 8**

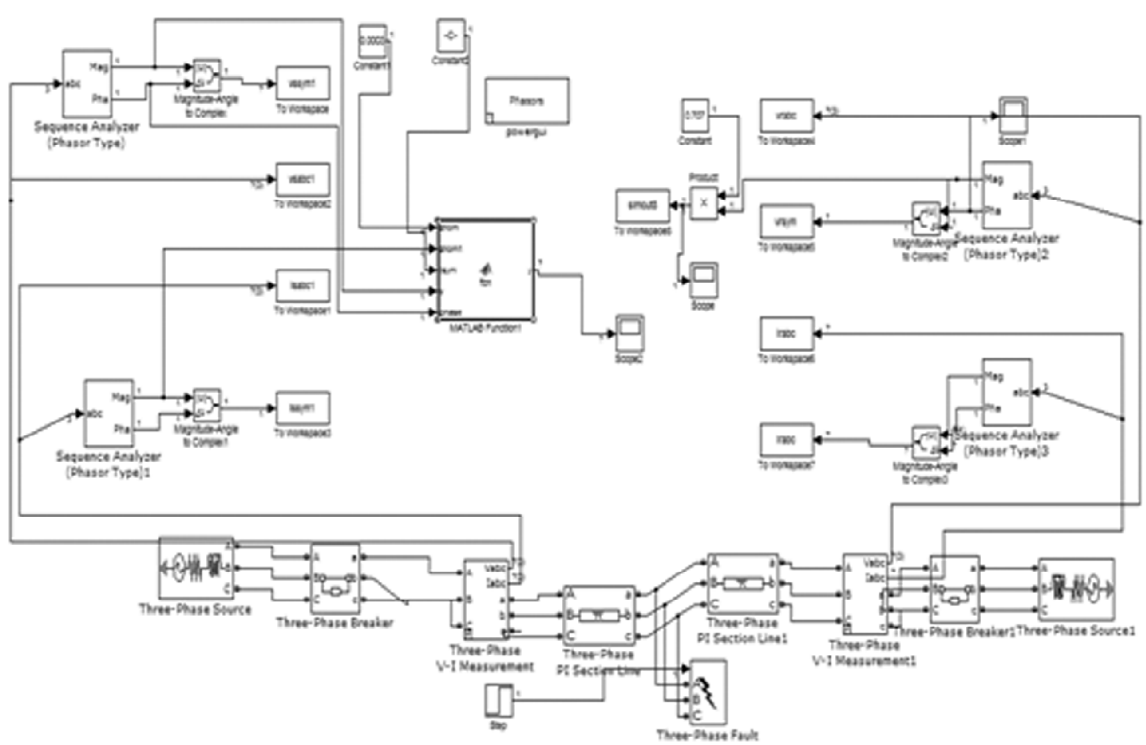


**Figure 5: Two bus system in MATLAB Simulink**

**Table 1**
**Sample data for nine bus system.**

| | 60km from bus 7 | | | | 80km from bus 7 | | | |
|---|---|---|---|---|---|---|---|---|
| | Bus 7 | | Bus 8 | | Bus 7 | | Bus 8 | |
| | Mag(%) | Ang | Mag(%) | Ang | Mag(%) | Ang | Mag(%) | Ang |
| Va | 20.49 | 4.0 | 7.7 | 3.5 | 25.1 | 3.6 | 4.14 | 3.9 |
| Vb | 81.94 | -129 | 76.3 | -127 | 83.6 | -129 | 74.27 | -126 |
| Vc | 118.8 | 114.7 | 119 | 111.7 | 118 | 115 | 118.9 | 110.5 |
| Ia | 1.69 | -71.5 | 1.00 | -71 | 1.578 | -71.6 | 1.054 | -71.2 |
| Ib | 0.03 | 103.5 | 0.03 | -76.5 | 0.009 | 94.2 | 0.009 | -85.8 |
| Ic | 0.029 | 104 | 0.029 | -76 | 0.009 | 91.9 | 0.009 | -88.1 |

**Table 2**
**Results for nine bus system.**

| Fault b/w / Distance | Bus 4 & Bus 5 | Bus 4 & Bus 6 | Bus 5 & Bus 7 | Bus 6 & Bus 9 | Bus 7 & Bus 8 | Bus 8 & Bus 9 |
|---|---|---|---|---|---|---|
| 10Km | 9.685 | 9.784 | 10.22 | 10.798 | 9.652 | 9.856 |
| 20Km | 19.223 | 19.833 | 20.813 | 21.46 | 19.684 | 19.75 |
| 30Km | 29.486 | 29.4 | 31.25 | 30.786 | 29.7 | 29.83 |
| 40Km | 38.765 | 38.826 | 40.946 | 41.488 | 38.756 | 38.841 |
| 50Km | 48.889 | 48.786 | 51.269 | 50.624 | 48.705 | 48.496 |
| 60Km | 58.686 | 58.75 | 60.859 | 61.459 | 58.9435 | 58.778 |
| 70Km | 69.685 | 69.89 | 70.582 | 70.898 | 69.456 | 69.803 |
| 80Km | 79.754 | 79.687 | 80.664 | 80.798 | 79.489 | 79.432 |
| 90Km | 88.15 | 88.88 | 91.03 | 90.923 | 89.000 | 88.4 |

**Tabel 3**
**Results for two bus system.**

| Fault b/w / Distance | Bus 1 & Bus 2 |
|---|---|
| 10Km | 9.7 |
| 20Km | 19.563 |
| 30Km | 29.785 |
| 40Km | 38.675 |
| 50Km | 48.76 |
| 60Km | 59.06 |
| 70Km | 69.456 |
| 80Km | 79.678 |
| 90Km | 89.134 |

In the Table 1 (100%) = 230V (voltage) and angle is measured in degrees.

For executing the algorithm all the data are converted to per unit.

The length of the each transmission line is 100Km.

Tabel 2 represents the obtained fault distance .

Suppose fault occurred between bus 4 and bus 5 at a distance of 10km from bus 4. From this algorithm the distance obtained is 9.685Km from bus 4. The error is 315meters

## 5. CONCLUSION

This methods provides more accurate fault distance and Algorithm can be improvised by introducing programmable relays , circuit breakers , PMU"s and GPS. These are used for data acquisition from both the ends whenever the fault occurs without the manual interruption. It is applicable for both transposed and untransposed transmission lines. The error obtained can be reduced by setting a tolerance value which gives accurate synchronising angle. This method can also be used for remaining faults like LLG, LLL, LL etc..

The algorithm considers only line impedances but it will neglect fault impedance. This algorithm is implemented for nine bus system in ETAP and two bus system in MATLAB simulunk. This method is a two terminal algorithm and considers positive sequence components only because positive sequence components respond to all type of faults.

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