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OPERATION AND REVIEW OF DIFFERENT METHODS OF FAULT IDENTIFICATION IN POWER SYSTEM

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Abstract:-*A methodology is presented to detect high- impedance faults in radial distribution feeders by means of fault identification methods reasoning. The proposed technique is based on the analysis of the feeder responses to impulse waves which are periodically injected at the feeder inlet. Secondary substations are usually equipped with short-circuit detectors only indicating that an over-current has occurred for a given line. In case of a fault, further information about type and location is required to recover an assured grid operation as fast as possible. Conventional algorithms for fault detection used in high voltage grids are not well suited because of the high uncertainties regarding current and voltage measurement in secondary substations.*

INTRODUCTION

Electrical power systems are more frequently operated close to their technical limits due to the increase of renewable energy systems and distributed generation. Therefore they become more prone to fault occurrences. Especially the medium voltage grid is affected since it experiences the most significant changes. Therefore fault detection; identification and localization are of great concern for the distribution grid operators. Fault identification and localization mainly includes the following aspects: type, direction, and distance. It is generally independent from protective relaying. The purpose is not to protect assets through a short-term generation of a trip signal to de energize a faulted section as fast as possible. The objective is to supply the grid operator with information about the fault prior to an on-site investigation. Transmission lines are most prone to occurrence of fault. Fault detection, direction estimation and faulty phase selection play a critical role in the protection for a transmission line. Accurate and fast fault detection and classification under a variety of fault conditions are important requirements of any protective relaying scheme.

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Secondary substations are often equipped with short-circuit detectors only indicating that a fault has occurred for the given line since reset. In case of a fault the operator will check these indications to identify and locate the fault, but any further information as well as a timeline of the events are not available.

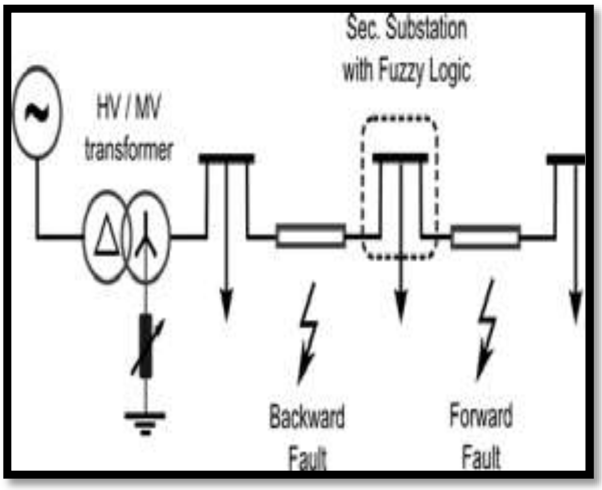

Fig.1.1: Scheme of a radial medium voltage feeder with the proposed fuzzy logic to detect fault type and direction

II. FAULT LOCATION TECHNIQUES

This section presents the basics of fault analysis and fault locators. Distance relays are analyzed with respect to their effectiveness in fault location detection and a comparison is made with conventional fault locators using numerical algorithms. A comprehensive review of all of the different methods of fault location on power systems is presented in this chapter. The advantages and disadvantages of each method of fault location detection and techniques for deriving them is discussed, as is the need for special measures to ensure the accuracy of the results obtained from the fault locators under certain network topologies or fault conditions.

Fault Analysis

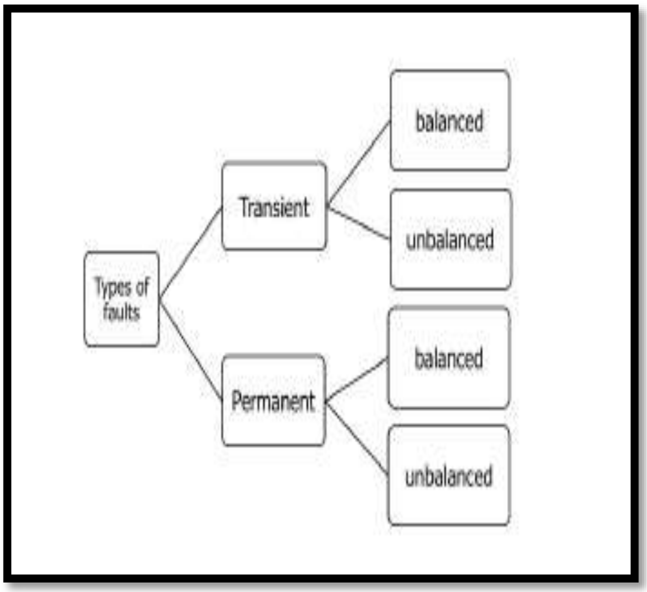

Figure 2.1: Classification of fault types in electrical power systems

A fault is an interruption to the normal flow of current in a circuit. Large currents flow across the lines in a faulted condition, which results not only in financial losses to the suppliers and inconvenience to the customers, but also in severe cases, a complete shutdown of the grid supply. According to the Nordic Grid report of the year 2013 and the data presented in IEEE journal, the most common to occur type of fault in electrical transmission lines remains to be the line to ground fault, but the most severe faults are still of three phase nature.
The Table 2.1 summarizes the same:

Type of fault	Nature	Percentage occurrence
Single Line-to-ground-SLG	unbalanced	85%
Line-to-Line-LL	unbalanced	8%
Double Line-to-ground-LLG	unbalanced	5%
Triple Line-LLL	balanced	2%

Table 2.1: Statistics for fault types on transmission lines

There are broadly two types of faults in transmission lines – transient and permanent faults, as is shown in Figure 2.1. A transient fault is no longer present if power is disconnected for a short time and then restored. Many faults in overhead power lines are transient in nature and power system protection devices operate to isolate the area of the fault, clear the fault and then the power-line can be returned to service. Typical examples of transient faults include:

- momentary tree, bird or animal contact
- lightning strike
- conductor clashes

A permanent fault can cause lasting damage to the transmission lines. To counter a permanent fault, the line first has to be isolated and then correction has to be made to the line. Some examples of the fault of permanent nature are:

- direct lightning stroke on line

- man-made damage
- mechanical damage due to environment and age

A symmetrical or balanced fault on a line affects each of its three phases equally. In transmission line faults, roughly 3-5% is symmetric in nature as seen in Table 2.1. This is in contrast to an asymmetrical or unbalanced fault, where the three phases are not affected equally. Common types of asymmetric faults and their causes are:

• **Line-to-ground** fault (Figure 2.2) - a short circuit between one line and ground, often caused by physical contact, for example due to lightning or other storm damage.

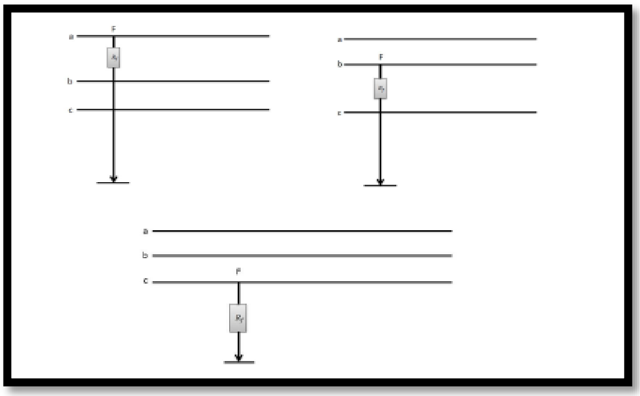

Figure 2.2: Single line to ground Fault

• **Line-to-line** fault (Figure 2.3) - a short circuit between lines, caused by ionization of air, or when lines come into physical contact, for example due to a broken insulator.

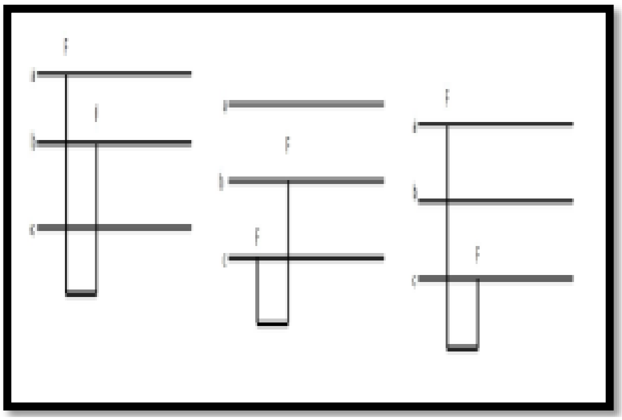

Figure 2.3: Line to Line Fault

• **Double line-to-ground** fault (Figure 2.4) - two lines come into contact with the ground and each other, commonly due to storm damage.

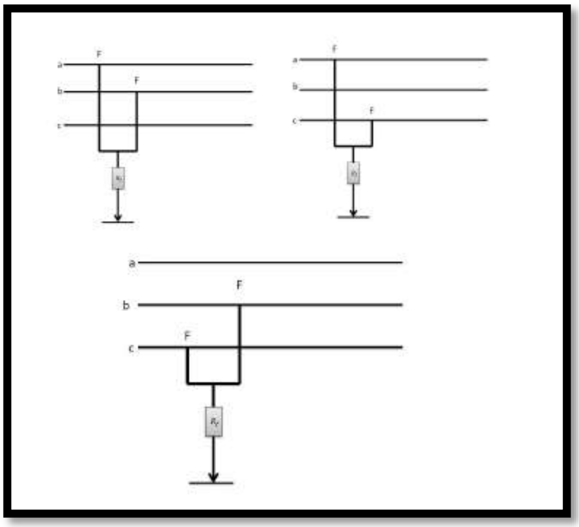

Figure 2.4: Double line to ground Fault

III. Techniques of fault Identification

- **Method of Novosel**

The method is based on the idea of fault location applied for short transmission lines, with all loads, including tapped lines, represented by a lumped-parameter impedance model placed behind the fault. This way of compensating for tapped loads is accurate as tapped load impedances are much larger than feeder impedance. The fault type is considered by including the adequate voltages and currents. Unlike other methods using only local data, this method is not affected if the fault current at a fault locator is not in phase with current at the fault. In conclusion, immunity to effects of load current and fault resistance is achieved.

Technique of Das

This technique that uses the fundamental frequency voltages and currents measured at a line terminal before and during the fault. The fault location technique is described by considering a single-phase-to-ground fault on a radial system, shown in Figure 2.5. The selected system consists of an equivalent source G , the line between nodes M and N and laterals. Loads are tapped at several nodes and conductors of different types are used on this circuit. The fault location technique consists of six steps.

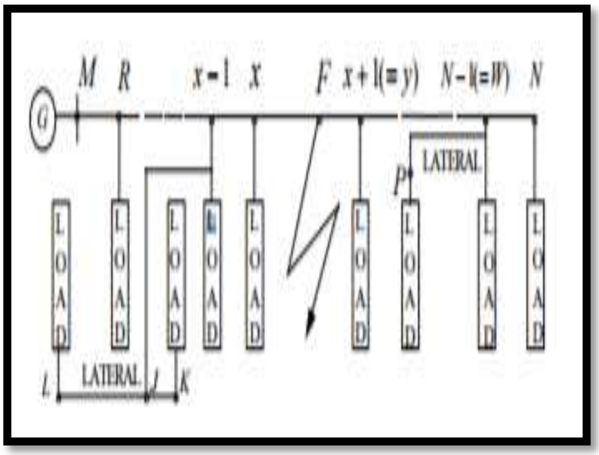

Figure 2.5 the single line diagram of a radial line experiencing a fault at F

A. Apparent Faulted Section

A preliminary estimate of the location of the fault is made, say between nodes x and x + 1=(y). Line parameters, the type of fault and phasors of the sequence voltages and currents are used to obtain this estimate.

B. Equivalent Radial System

All laterals between node M and the apparent location of the fault are ignored and the loads on a lateral are considered to be present at the node to which the lateral is connected.

C. Load Modelling

The effects of the loads are considered by compensating for their currents. Static response type models are used for all loads up to node x and also for a consolidated load at the remote end.

D. Voltages and Currents at the Fault and Remote End

The sequence voltages and currents at node F during the fault are estimated by assuming that all loads beyond node x are consolidated into a single load at N , as in Figure 3.1.

F. Converting Multiple Estimates to Single Estimate

The fault location technique could provide multiple estimates if the line has 'laterals'. The number of estimates, for a fault, depends on the system configuration and the location of the fault. Software-based fault indicators, like those commercially available, are developed for this purpose. They detect downstream faults irrespective of their location. Information from the fault indicators is combined with multiple estimates, to arrive at a single estimate for the location of a fault.

ONE-END FAULT LOCATION ALGORITHMS

One-end fault location algorithms usually use variables from the sending end. Fig. 4.1 is a basic circuit for fault location. Sending end voltage can be defined as;

$$V_S = I_S(mZ_L) + I_f R_f \quad \text{..... (1)}$$

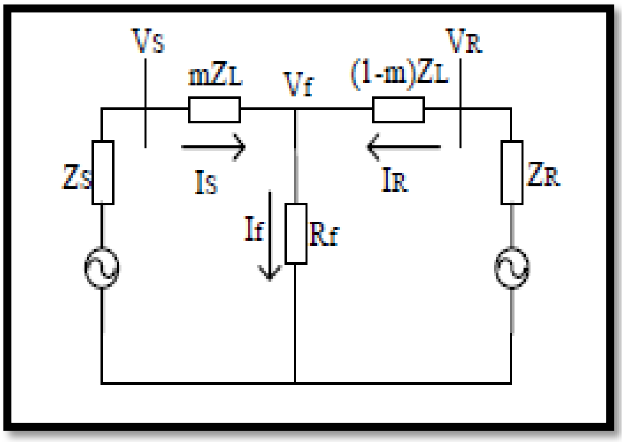

Figure 4.1 Circuit representation of line fault

Where,
m: distance to fault location,
Rf: fault resistance,
If: fault current,
ZL: line impedance,
VS and *IS*: voltage and current at the sending end bus respectively.
As given in Fig. 4.1,
VR and IR are voltage and current at the receiving end bus respectively and Vf is the fault voltage.

A. Simple Reactance Method

This method compares the measured line impedance (ZL) and calculated impedance (VS/IS) to find the fault location. Accuracy of this method depends on the angle of IS being equal to the angle of If.
The simple form of the distance to the fault can be obtained as given in Eq. (2) where the fault resistance is ignored in Eq. (1), dividing this equation by IS and saving the imaginary part;

$$m = Im(V_S/I_S)/Im(Z_L) \quad \text{..... (2)}$$

B. Takagi Method

The Takagi method requires additionally pre-fault current values. This method improves simple reactance method by reducing the effect of load flow and minimizing the effect of fault resistance. Superposition current (Isup) can be described as follows;

$$Isup = I - Ipre = If/d \quad \text{..... (3)}$$

Where, *I*: fault current and *Ipre*: pre-fault current.
If the source and line have the same impedance, d becomes a real number. Accuracy of this method depends on this assumption.
Through Eq. (3) and Eq. (1);

$$V_S = I_S(mZ_L) + I_{sup} dR_f \quad (4)$$

$$V_{Sr} = mR_L I_{Sr} - mX_L I_{Si} + I_{supr} dR_f \quad (5)$$

$$V_{Si} = mX_L I_{Sr} + mR_L I_{Si} + I_{supi} dR_f \quad (6)$$

By multiplying Eq. (5) with *Isupi*and Eq. (6) with *Isupr*and subtract Eq. (6) from Eq. (5);

$$m = a/(b-c) \quad (7)$$

where;

$$a = V_{Sr}I_{supi} - V_{Si}I_{supr} \quad (8)$$

$$b = R(I_{Sr}I_{supi} - I_{Si}I_{supr}) \quad (9)$$

$$c = X(I_{Sr}I_{supr} + I_{Si}I_{supi}) \quad (10)$$

C. Modified Takagi Method

Modified Takagi method replaces superposition current with zero sequence current of sending end.
This method is limited with ground faults since zero sequence current exists for ground faults. Then, the fault distance is calculated as follows:

$$m = Im(3V_S I_0^* e^{-jT}) / Im(3Z_L I_S I_0^* e^{-jT}) \quad (11)$$

where, I_{0S}: zero sequence current and T: angle between I_{0S} and I_f.

TWO-END FAULT LOCATION ALGORITHMS

Two-end fault location algorithms calculate fault location from the impedance seen from both end of the line. Because of accurately detecting fault location, these algorithms usually better than one-end fault location algorithms. Two-end fault location algorithms take *Vf*as a reference point.

A. Basic Two-End Method

This method is fundamental for the other two-end fault location methods.

$$V_f = V_S - I_S m Z_L \quad (12)$$

$$V_f = V_R - I_R(1-m)Z_L \quad (13)$$

Fault location can be calculated with Eq. (12) and Eq. (13);

$$m = (V_S - V_R + Z_L I_R)/(Z_L(I_S + I_R)) \quad (14)$$

B. Symmetrical Fault Method

This method calculates the fault resistance with high accuracy for symmetrical faults and doesn't require line parameters for detecting fault location. Accuracy of this method depends on the fault type.
Voltage equations of VS, VR and Vf can be derived from the circuitry given in Fig. 2 where D is the line length, l is the distance from the fault point and z is the line impedance.

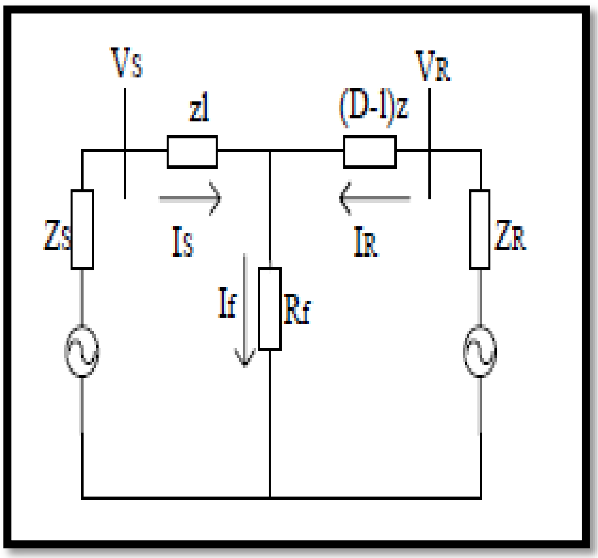

Figure 4.2 Circuit representation of line fault for symmetrical fault method

EVALUATION OF ALGORITHMS

The single line diagram of an 8 bus system that fault location algorithms are tested is shown in Fig. 4.3. The system consists of 3 synchronous generators, 2 external grids, 6 transformers and 2 asynchronous motors.

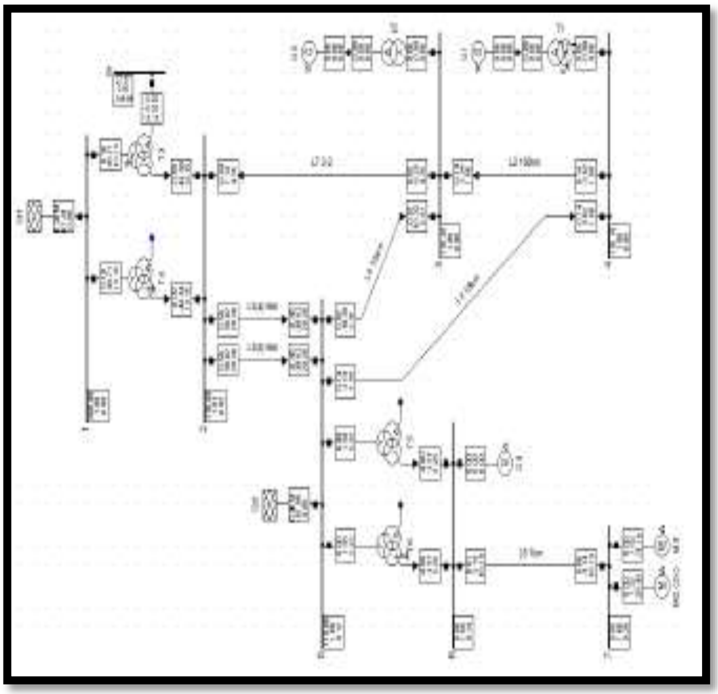

Figure 4.3 Test transmission system.

Fault location algorithms are tested at line L2 in Fig. 4.3, between bus 3 (sending end) and bus 4 (receiving end).

V. MODELLING AND SIMULATION

<u>Conventional Method For Fault Location:</u>

For detection and location of fault on overhead transmission line I used the simulation model in which 400km long transmission line are also used. One source, one transformer, and three loads are also used in this simulation model.

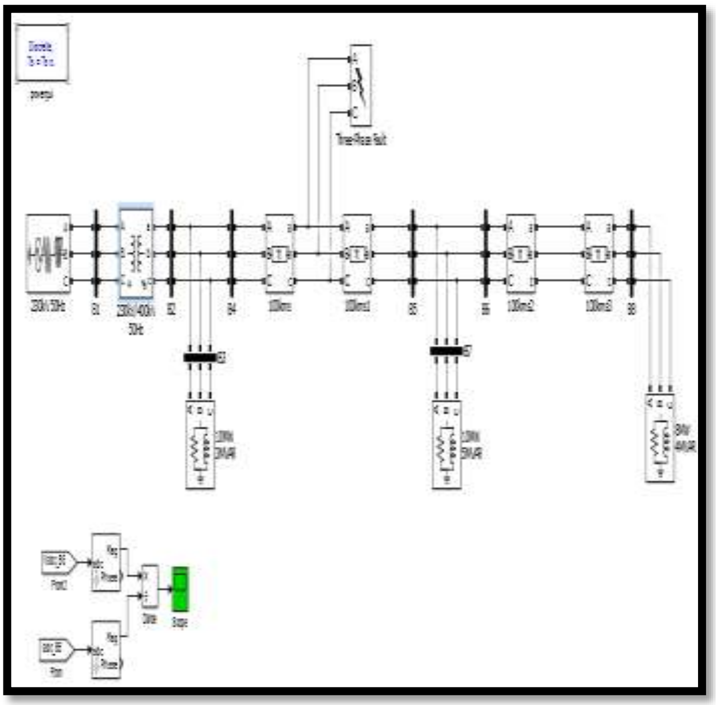

Figure: 5.1: Simulation Model of 4oo KV, 400 Km Transmission Line

Waveform for Different Fault:

[1] Single Line to Ground Fault for Phase A:

When we create the single line to ground fault on Phase A from the 100km from the generating source by a fault creator the graph also show below. Here the fault voltage is increased up to 6.28 per unit in positive as well as negative direction. As same we have also create the waveform for remaining phases.

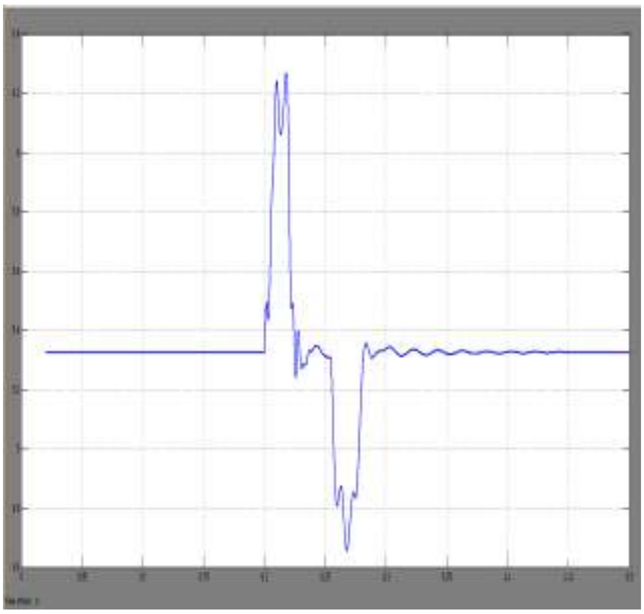

Figure: 5.1: Waveform of Phase A-G Fault.

[2] Double Line to Ground Fault between Phase A and B:

By creating the double line to ground fault Between Phase A and Phase B, 100km from the source .We have see the graph. When the fault is creating the voltage magnitude from bus 5 is increase to 7.5per unit and decrease to 3.8 per unit. Here we can also obtain the output waveform for remaining phase as for Phase C consider.

Figure: 5.2: Waveform for Double Line to Ground Fault Between Phase A-B-G

[3] Line to Line Fault between Phase A and B:

Here By creating a line To line fault between Phase A and Phase B, from the 100km, the Graph will also show. When the Fault is creating the Voltage magnitude is also obtain from bus 5 the fault Voltage is Increased up to 6.6 in per unit and decreased to 4.52 per unit. Here We Can Also obtain the output waveform For the Reaming Conductor as C Phase.

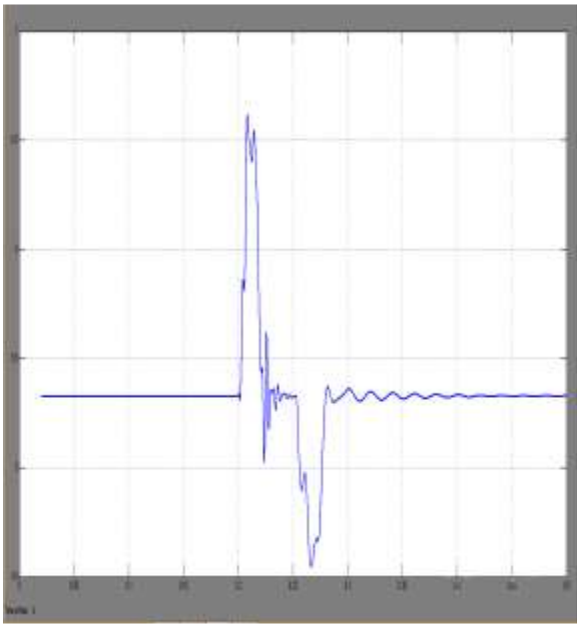

Figure: 5.3: Waveform for Line to Line Fault Between Phase A-B

[4] Symmetrical Fault:

Here we have also see that the output waveform for unsymmetrical fault. But now, we see that the symmetrical fault between the all the Phases. By creating the fault on the transmission line the fault voltage is increased up to 10.8 per unit and decreased to 0.8 per unit.

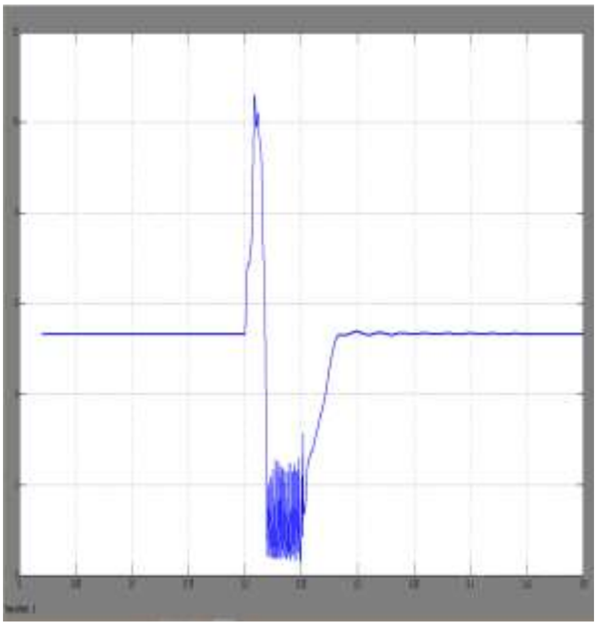

Figure: 5.4: Waveform For Symmetrical Fault

CONCLUSION

I used MATLAB software for analysis and design of Detection and Identification and Location of fault by impedance method. Considering the best features of MATLAB software I use 400km transmission line with one source and three load system in Simulink model. The symmetrical fault method gives better results except for asymmetrical faults with a fault resistance in two-end fault location algorithms. Basic two-end method has the best results at asymmetrical fault with a fault resistance. Both of these methods have acceptable accuracy for any fault, but if the fault type is predetermined and the suitable two-end fault location method is chosen, then the fault location estimation error is minimized. Considering the protection of transmission line time is very important for Detecting, Identifying and Locating of fault, I concluded from this work that conventional Impedance method is requires more time for detecting and location of fault on transmission line.

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