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IMPEDANCE BASED FAULT DETECTION IN TRANSMISSION LINES

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Abstract - *For calculating the fault distance in a transmission line various impedance based algorithms have been formulated. Every algorithm has its own input requirements. It is important to understand each fault locating method for the purpose of choosing the most appropriate algorithm. This project gives us a detailed study of impedance based one ended fault location algorithms and how error sources DC offset, CT saturation, untransposed lines, system load, uncertainity in earth resistivity and mutual coupling effect each algorithm. The location of a fault is estimated with the help of PLC and SCADA. The program to find the fault distance is written in PLC and then the PLC is interlinked with SCADA for controlling and monitoring the process. From field data testing and theoretical analysis fault location application scenario and data availability are the criteria for selecting suitable algorithms.*

***Keywords* –** *Fault location, impedance-measurement, Programmable Logic Controller(PLC), Supervisory Control And Data Acquisition (SCADA), power system faults, power system reliability, transmission line measurements.*

I. INTRODUCTION

There is a frequent occurrence of electrical faults in transmission lines due to lighting strikes during rough weather conditions, animal contact, tree contact or due to insulation failure. To improve system reliability and accelerate service restoration, impedance based algorithms are usually used for finding the location of a fault in a line. When the line impedance in ohms is given the accurate distance to a fault can be obtained. When a fault occurs, the PLC captures the voltage and current waveforms to find the impedance between the location of the fault and the PLC. One ended algorithms are the algorithms that make use of data captured by PLC at one end. It is important to know the fault position in permanent faults where the power supply is restored once the technician has repaired the damage. Otherwise it becomes necessary to inspect the entire line to find the damage. Thus it is required to locate the fault with the greatest accuracy possible. In this method the power supply is restored quickly. This also reduces the expenditure and the time spent on inspection and repair. Blackouts can also be prevented this way. Temporary faults, where the continuity of supply is not permanently affected are self-cleared and the location of such faults is also necessary. Here the fault location helps to recognize the weak places on the line.

II. METHODOLOGY

This paper helps us to calculate the distance to a fault in a transmission line. During a fault, PLC captures the voltage and current wave forms to find the impedance between the PLC and the fault location. The accurate fault distance can then be obtained when the line impedance is given in ohms.

PLC that is comparable to a collection of relays is the brain of this model and makes use of 24 volt supply. By making use of an advanced software called SCADA that is supervisory control and data acquisition, one of the communication port can be connected to a computer. This works parallel with the PLC. The processes and the condition that are supposed to take place inside the PLC do not require the changing of wires. Instead the programming is done on the computer system by using a software in which all the processes that have to take place inside the PLC is specified in a user friendly visual manner. The programming language used to write the program in PLC to calculate the fault distance is the functional block diagram. The PLC software that we use to implement this project is Unity Pro XL of Schneider Electric Company.

All the processes are controlled by a computer using the SCADA software. The SCADA software used here is the VijeoCitect 7.4 from Schneider Electric, France Company. It acts as a Human Machine Interface (HMI) for visualization and control of any process.

Potential transformers are used in controlling and protecting circuits, to operate relays, circuit breakers etc. Potential transformers are used to measure high current with low range ammeter and high voltage with low range voltmeter. It is also used to insulate the high voltage circuit to protect the measuring instruments from burning. The function of PT is to step down the voltage to the level of voltmeter. Current transformer is used to measure the high current. The function of CT is to step down the current. Figure 1 shows the block diagram of the system.

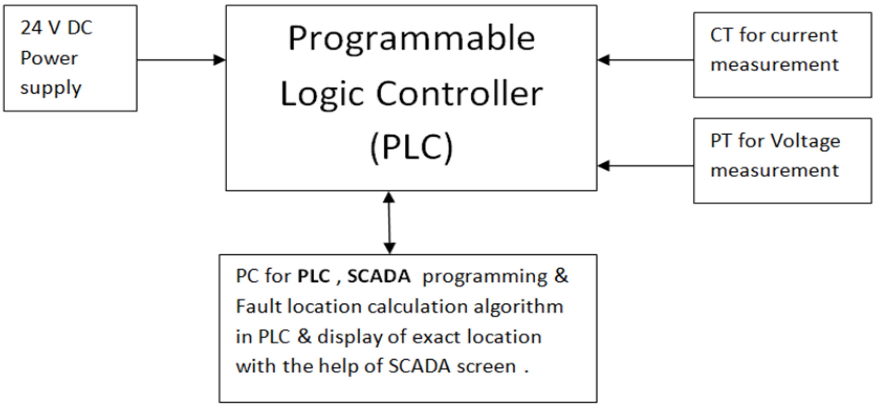


Figure 1.Block Diagram of the System

III. ONE ENDED IMPEDANCE-BASED FAULT LOCATION ALGORITHMS

This part gives the details about one-ended algorithms that are generally used to find the place of damage in a transmission line.By examining a transmission line from one end these algorithms estimate the fault distance as shown in figure 2. One-ended algorithms are advantageous since a communication channel or remote data is not required. They also implement and yield proper location estimates. Figure 2 shows a two-terminal transmission network.

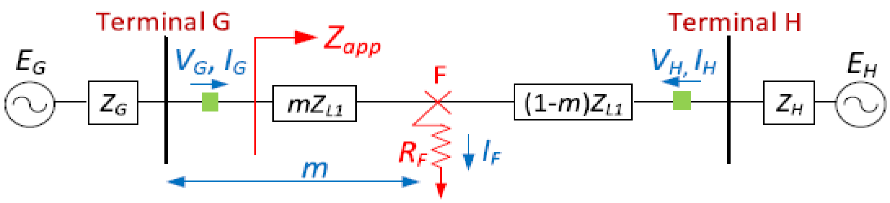


Figure 2.Two-Terminal Transmission Network

The voltage drop from terminal G by making use of Kirchhoff's laws can be given as

$$V_G = mZ_{L1}I_G + R_F I_F$$

Where *VG* and *IG* depends on the fault type. The impedance to the fault *Zapp* that is measured from the terminal G can be obtained by dividing throughout by *IG* and this can be expressed as

$$Z_{app} = \frac{V_G}{I_G} = mZ_{L1} + R_F\left(\frac{I_F}{I_G}\right)$$

This fundamental equation has three unknowns namely *m*, *RF* and *IF* since measurements are used from only one end of the line. Several algorithms have been formulated to remove *RF* and *IF* from the fault location calculation.

3.1 Simple Reactance Method

The term *RF* (*IF* /*IG*) reduces to a real number if currents *IF* and *IG* are assumed to be in phase. The distance to a fault can be obtained by considering only the imaginary components of the fundamental equation of one-ended algorithms and this is given by

$$m = \frac{\text{imag}\left(\frac{V_G}{I_G}\right)}{\text{imag}\left(Z_{L1}\right)}$$

3.2 Takagi Method

When a fault occurs the network is disintegrated into a pure fault and prefault network by using the superposition principle.This method increases the efficiency of simple reactance method and the fault distance is given as

$$m = \frac{\text{imag}\left(V_G \times \Delta I_G^*\right)}{\text{imag}\left(Z_{L1} \times I_G \times \Delta I_G^*\right)}$$

where*VG*, *IG* and Δ*IG* depends on the fault type. This method is majorly successful if the transmission network is homogeneous.

3.3 Modified Takagi Method

Instead of Δ*IG*, zero sequence current *IG*0 is used by this method to avoid using prefault current as it may not be ready for use. This substitution is attainable because *IG*0 is similar to Δ*IG* and the distance to a fault is given as

$$m = \frac{\text{imag}\left(V_G \times 3I_{G0}^*\right)}{\text{imag}\left(Z_{L1} \times I_G \times \ 3I_{G0}^*\right)}$$

3.4 Eriksson Method

This method helps in knowing the root-cause of a fault. To eliminate reactance error, this method makes use of source impedance parameters to calculate the location estimate of a fault. The following quadratic equation gives the fault distance.

$$m = \frac{\left(a - \frac{eb}{f}\right) \pm \sqrt{\left(a - \frac{eb}{f}\right)^2 - 4\left(c - \frac{ed}{f}\right)}}{2}$$

Fault resistance can be computed using the following expression

$$R_F = \frac{d - mb}{f}$$

3.5 Novosel et al Method

This method has been specially formulated for finding defects in a short radial transmission line. This modified version of Eriksson method is as shown in Figure 3.

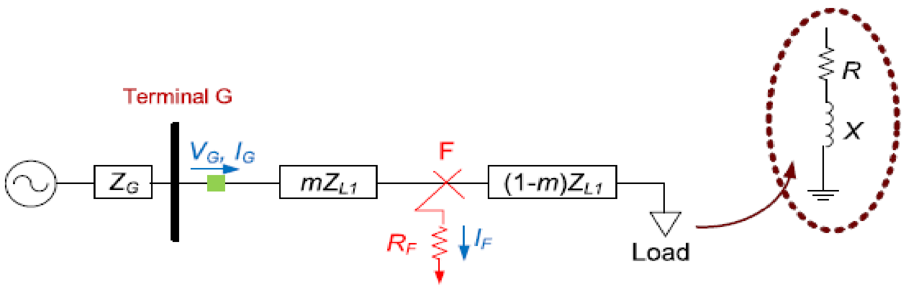


Figure 3.Illustration of Novosel et al Method

IV ERROR SOURCES IN IMPEDANCE-BASEDFAULT LOCATION ALGORITHMS

Errors are found in the fault location due to mutual coupling, load, remote infeed or fault resistance as they violate assumptions made by the algorithms. Another reason for an error to occur in the location estimate is the inaccuracy in the input parameters.

4.1 DC Offset and CT Saturation

Fault locating algorithms require current and voltage phasor quantities to calculate the fault distance.

As shown in figure 4, computation of these phasor quantities is complicated by the existence of decaying DC offset. CT saturation also introduces error in the fault location.

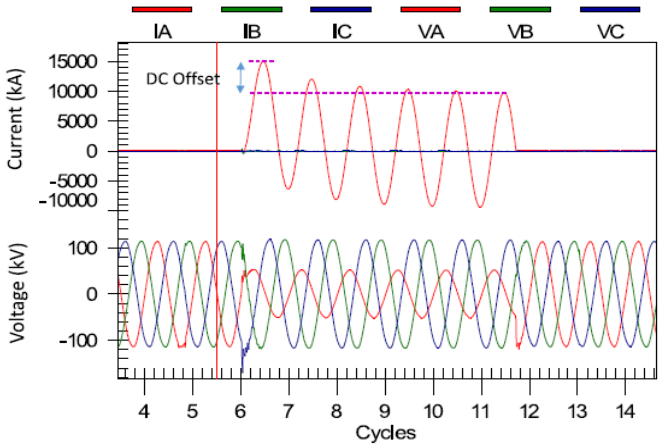


Figure 4.Fault Current Showing Significant DC Offset

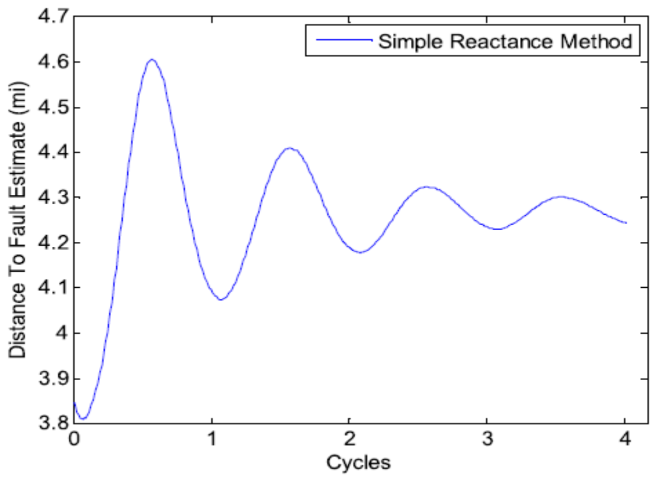


Figure 5.Variation in the Fault Location Estimate due to DC Offset. FFT Filter is used to compute the Current and Voltage Phasors

4.2 Untransposed Lines

Transmission lines are supposed to be transposed when computing sequence line parameters. Effect of the untransposed transmission lines for one-ended methods is as shown in figure 6.

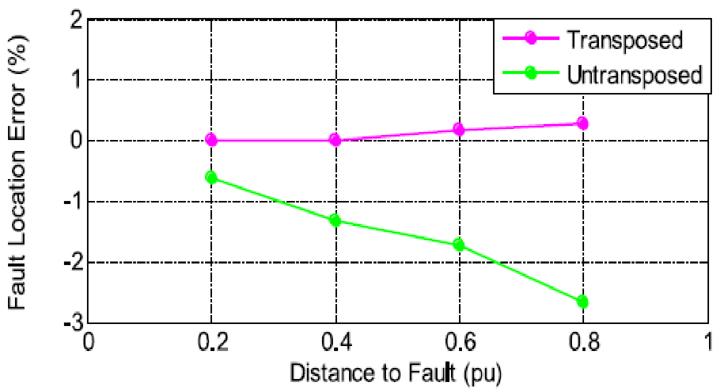


Figure 6.Error due to Untransposed Lines

4.3 Uncertainity in Earth Resistivity

When computing impedance of a line, the earth resistivity plays an important role. Effect of the resistivity of the earth for one-ended methods is as shown in figure 7.

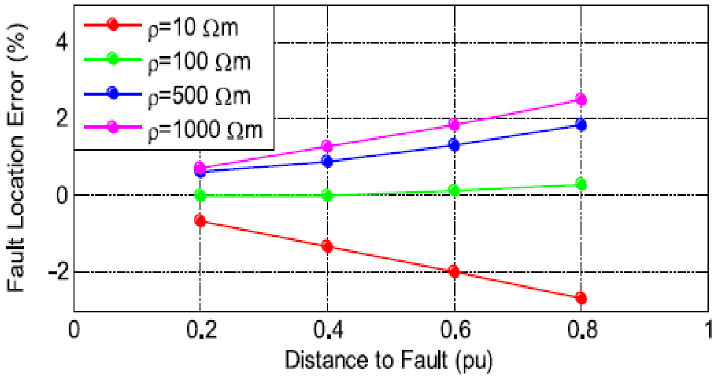


Figure 7.Error due to Uncertainty in Earth Resistivity

4.4 Effect of System Load

Error occurs in the simple reactance method due to the effect of load in the system and this is illustrated in figure 8.

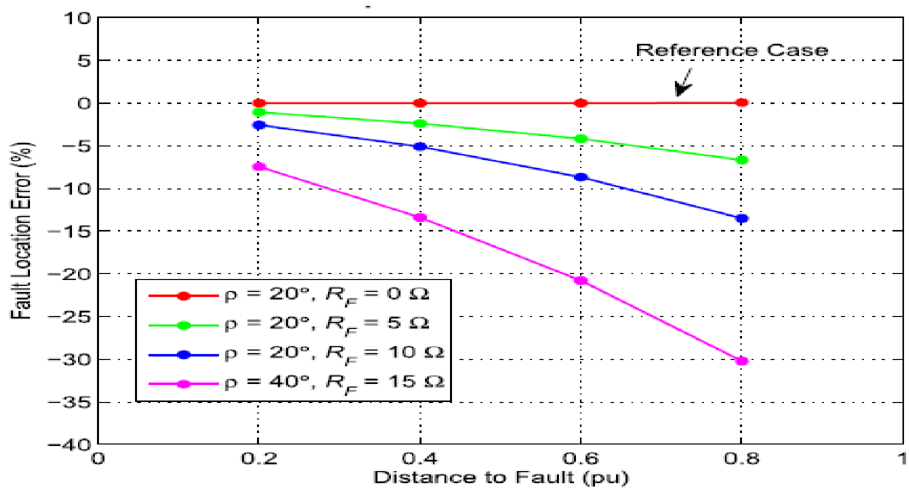
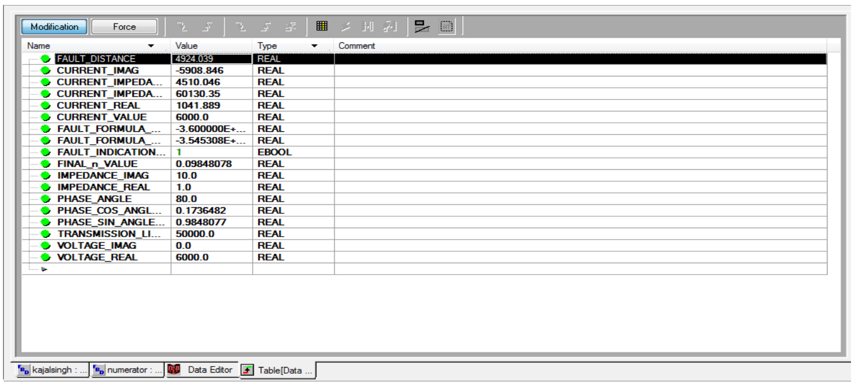


Figure 8.Reactance Error due to Load in Simple Reactance Method

V RESULTS AND DISCUSSIONS

After the PLC program using the functional block diagram is written, the distance to a fault in metres can be obtained on the PLC screen itself as shown in the screenshot below.



PLC can be interlinked with the SCADA software VijeoCitect 7.4 which acts as a human machine interface. The process screen is as shown in figure 9.

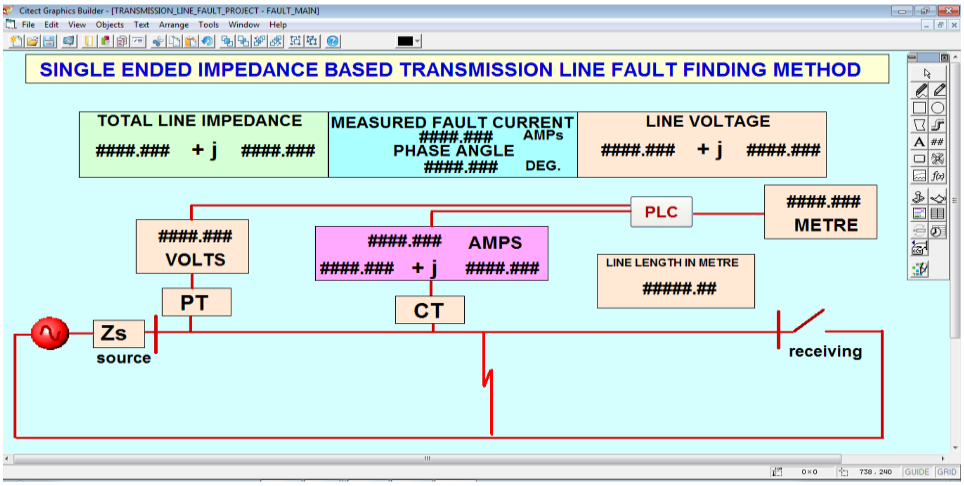


Figure 9.Process Screen

After the process screen is developed on the Citect Graphics Builder, the result that is the fault distance in metres can be obtained by entering the values of the measured fault current, the line voltage, the phase angle, the total line impedance and the transmission line length in metres. This is illustrated in figure 10.

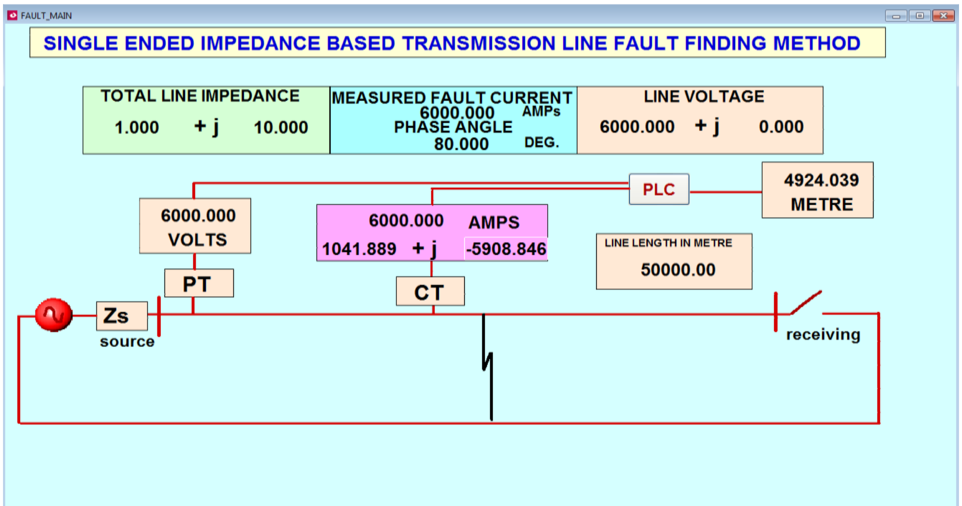


Figure 10.Process ScreenShowing Result

VI CONCLUSION

This paper shows the successful implementation of PLC and SCADA for the purpose of computing the fault distance in a transmission line. Here we study in detail about the one ended impedance based fault locating algorithms and how the error sources effect each one of these. When there is a damage on the line, the PLC captures the voltage and current waveforms to calculate the impedance and fault location. Data availability and application scenario are the two criteria for choosing the most appropriate method for locating a fault. One ended fault locating algorithms are simple and cost effective, hence they are employed to achieve the objective of faster service restoration. SCADA is used as a man machine interface for visualisation and control of any process. By making use of SCADA, the process of finding the fault location is better understood.

VII FUTURE SCOPE

Electrical faults occur frequently in transmission lines due to animal or tree contact, insulation failure in power system equipment or due to lightning strikes. The one ended fault location algorithms we study in this project, when calculating the distance to a fault assumes that at a given point in time only a single fault exists in the entire line. But during lightning strikes, there are more than one fault locations and this challenges the application of these algorithms. Hence work has to be carried out to develop alternative methods to deal with multiple fault locations at a given point in time.

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