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Numerical Distance Protection of Transmission Line

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Abstract-
This paper presents a study of the performance of numerical distance relay for a 400 kV electrical transmission line using MATLAB/ SIMULINK. The basic principle is the calculation of fault current and voltage applying phase to ground fault at different distances. The proposed model was verified with no fault condition and under fault condition particularly Single Line to ground fault and fault impedance is observed along with fault current and voltages. The trajectory of measured fault impedance is shown on R-X diagram. The results, obtained with different locations of fault on transmission line, show that the relay operates correctly in all fault conditions.

I. INTRODUCTION

To match the demand and supply, rapid development of power systems and the large amount of interconnection is involved to ensure continuity of supply and good voltage regulation. Therefore isolation of faulty section and fast fault clearance with system co-ordination has become very important [1]. To meet this requirement high speed protective systems, suitable for use with the automatic reclosure system of circuit breaker are under continuous development and widely used for protection of EHV transmission Line. Distance Protection is the most widely used method to protect transmission line for inter phase fault and phase to ground fault. The fundamental principles of distance relay to measure voltages and currents where the relay responds to the impedance between the relay terminal and fault location. Numerical signal processing and evaluation of algorithms facilitate measuring techniques with increased accuracy and protection functions with improved selectivity [2].

1.1 Numerical distance protection (relay)

Numerical distance protection is fully digital distance protection with analogue to digital conversion of the measured values (current and voltage), computed (numerical) distance determination and digital processing logic. Distance relay measures the impedance between the relay point and the fault location [3]. This impedance is proportional to the length of the conductor and hence to the distance between the relaying point and the fault location. Distance protection determines the fault impedance from short circuit voltage and current at the location where the relay is installed. Distance protection relays are so-called secondary relays fed with current and voltage measured signals from the primary system i.e. overhead line via measurement Transformers [4]. Therefore, the relay measures the secondary impedance resulting from the ratio of current transformation and voltage transformers.

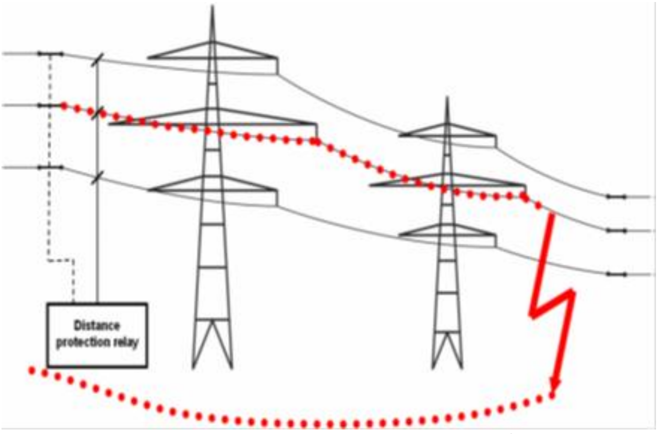
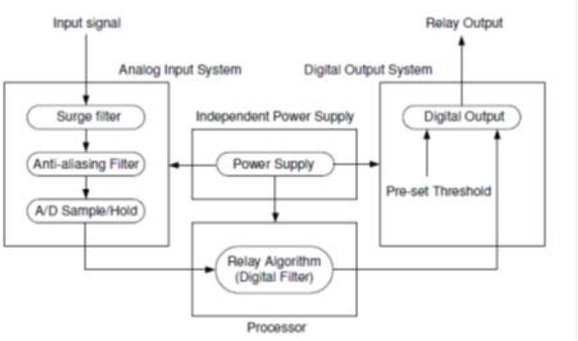


Figure 1. Impedance loop on a single phase ground fault

II. NUMERICAL DISTANCE RELAY MODEL AND SIMULATION

In order to understand the function of Relays, software relay models must be realized, modelling of protective relays offer an economic and feasible alternative to studying the performance of protective relays. Relay models have been long used in a variety of tasks, such as designing new relaying algorithms, optimizing relay settings [5].

MATLAB/SIMULINK provides a well-known tool for modeling numerical distance relays. SIMULINK offers a wide selection of libraries that allow detailed simulation of distance relays [6]. Numerical Distance Relay consist of signal conditioning, analog-to-digital conversion, digital filtering, protection algorithms, and relay trip logic [7].



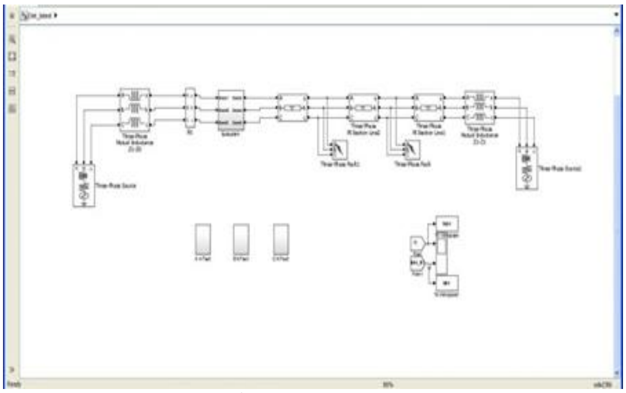


Figure 2. Main Model of Numerical Distance Protection System

2.1 Details of Model

Block 1:-3θ Source Considering two machines System. Block 2:- Mutual Inductance: - It is as substitute for source impedance + Generator Transformer + Transmission network. Block 3:- simply a 3θ voltage & Current Measurement. Block 4:- Use for calculating per phase current & per phase voltage in terms of Magnitude & Current. Block 5:- A "π" model of Transmission Line. Block 6:- A fault Simulator.

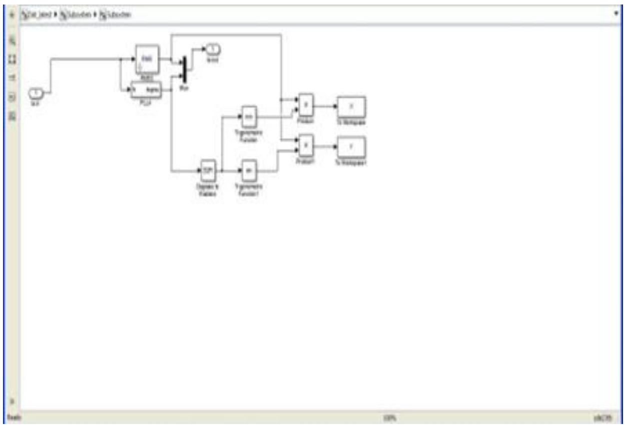


Figure 3. Current/Voltage Angle & Magnitude

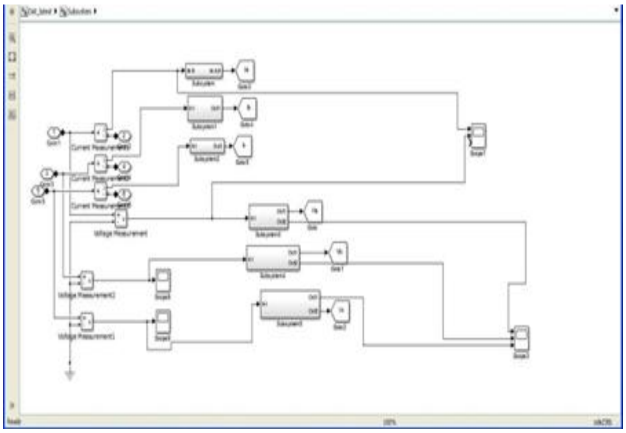


Figure 4. Measurement Block

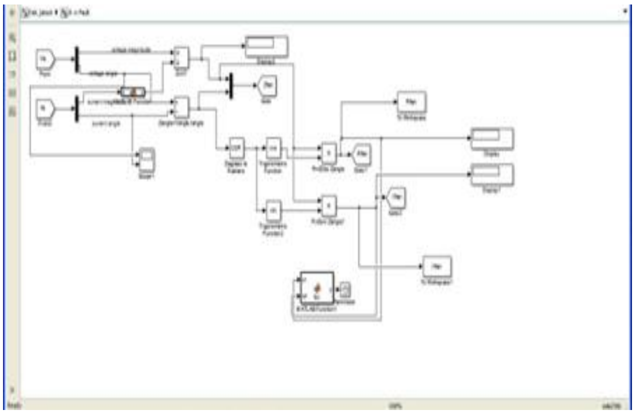


Figure 5. A Phase to Ground Logic.

III. NUMERICAL RELAY OPERATING PRINCIPLES

The distance relays receive discrete voltage and current signal and converts it in to a phasor. However faults on transmission lines cause the voltage and current signals to be severely distorted. It measures the fault impedance from the relay to fault location and give signal to the Circuit Breaker which in turn the tripping of circuit breaker and separate out the faulty section [8].

3.1 Impedance Calculation Algorithm

A relay algorithm is a set of equations whose evaluation and comparison with certain predetermined levels determines the operation of relay. The algorithm based on the differential equations to be used in estimating the R and L of the model [9]. The algorithms are classified according to the approach used to calculate the impedance based on the voltage and current measurements. The three phase Transmission Line can be represented by differential equations in terms of Resistance, inductance and capacitance to which the relay is connected is composed of a series resistance and inductance, the fundamental equation is

$$V(t) = Ri(t) + L\frac{di_{(t)}}{dt} \quad .....(1)$$

The measured values of the current s and voltages are taken in the form of samples and the measurements are usually done simultaneously on all three phases [10]. To solve the equation (1) and calculate *R* and *L*, two equations are required. This can be achieved by measuring *v(t)*, *i(t)* and *di/dt* at two different instants of time [11].

$$V(t_n) = Ri(t_n) + L\frac{di_{(t_n)}}{dt} \quad .....(2)$$

$$V(t_{n-1}) = Ri(t_{n-1}) + L\frac{di_{(t_{n-1})}}{dt} \quad ....(3)$$

Solving equation (2) & (3), R&L may obtained from following equation

$$\begin{bmatrix} V(t_n) \\ V(t_{n-1}) \end{bmatrix} = \begin{bmatrix} i(t_n) & \frac{di(t_n)}{dt} \\ i(t_{n-1}) & \frac{di(t_{n-1})}{dt} \end{bmatrix} \begin{bmatrix} R \\ L \end{bmatrix} \quad .....(4)$$

$$\begin{bmatrix} R \\ L \end{bmatrix} = \frac{1}{D} \begin{bmatrix} \frac{di(t_{n-1})}{dt} & -\frac{di(t_n)}{dt} \\ -i(t_{n-1}) & i(t_n) \end{bmatrix} \begin{bmatrix} V(t_n) \\ V(t_{n-1}) \end{bmatrix} .(5)$$

The 'D' indicated above in equation (4) is matrix determinant. The derivative of the current can be calculated from

$$\frac{di(t_n)}{dt} = \frac{i(t_n) - i(t_{n-1})}{T} \quad (6)$$

In this algorithm, it measures the apparent impedance of the fault loop [12].

TABLE I. PARAMETERS FOR CALCULATION OF IMPEDANCE

Sr. No	Parameters	Particulars
1	Conductor	0.5 Moose ACSR
2	Voltage	400 Kv
3	Length of line	100Km
4	R1 Ohms/Km	0.027
5	X1 Ohms/Km	0.334
6	Ro Ohms/Km	0.262
7	Xo Ohms/Km	1.04
8	Re/Rl=1/3((Ro/R1-1)	1/3(0.262/0.027-1)=2.9012
9	Xe/Xl	1/3((1.04/0.334-1)=0.704
10	Arc Resistance	40 Ohm
11	Tower footing resistance	20 Ohm
12	Fault Level	40/50 KA for 1sec
13	MVA Capacity	1500
14	Source Imp.	400/√3x20=11.54
15	C.T.Ratio	2500/1=2500
16	C.V.T. Ratio	400Kv/110 v = 3636.36
17	CTR/CVTR	0.6875
18	Impedance	0.027+j0.334= 0.335 Ω/Km
19	A.C.resistance of conductor	0.07111 Ω/Km at 75 deg.C.
20	Current Carrying	836 amps at 75 deg.C.

*[15]

IV. RESULTS

TABLE II. PARAMETERS FOR CALCULATION OF IMPEDANCE

Sr. No	Fault Distance	Simulated Value Zf	Vf (kV)	If (kA)
1	25 Km	24.31 Ω	231.5	9.521
2	50 Km	39.67 Ω	261	6.579
3	75 Km	55.57Ω	278	5.002
4	100 Km	68.98 Ω	286.5	4.153

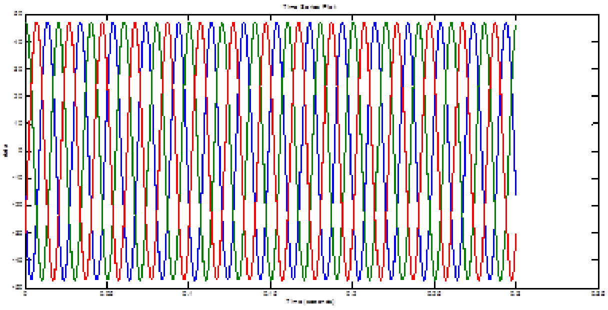


Figure 6.Current Waveform without fault

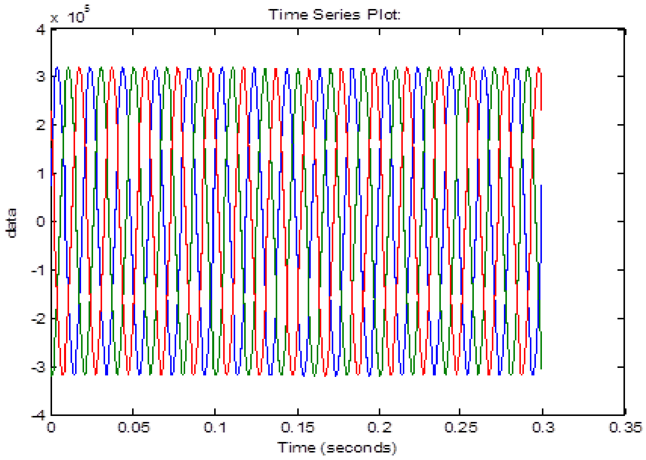


Figure 7 Voltage Waveforms without fault

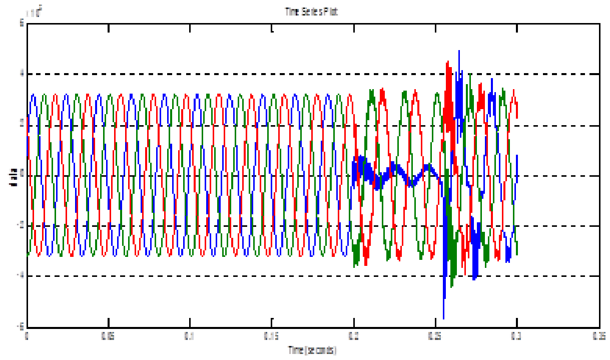


Figure 8.Current Waveforms with fault

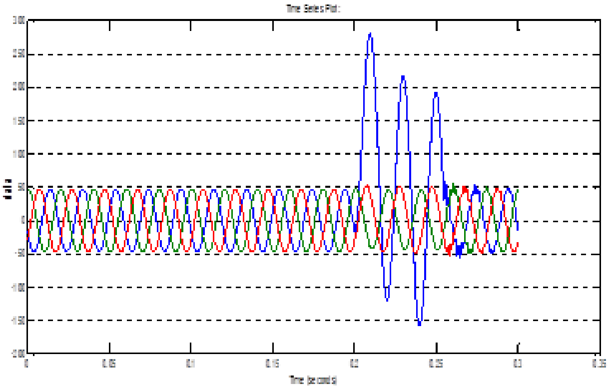


Figure 9.Voltage Waveforms with fault

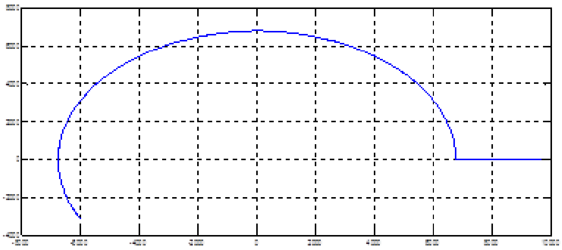


Figure 10.Impedance Locus without fault on R-X diagram

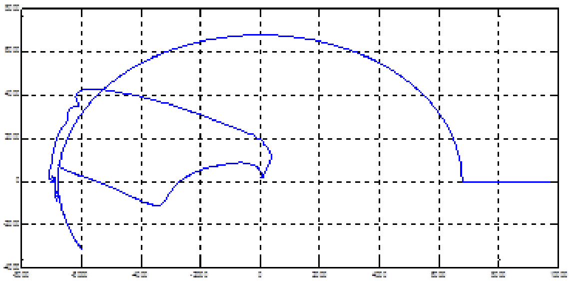


Figure 11 Impedance Locus with fault on R-X diagram

TABLE III. SETTING IMPEDANCE FOR VARIOUS DISTANCES

Sr. No	Distance Km	Z setting Ω/Km	A.R.+ T.F.R. Ω	CTR/ CVTR	Z* Setting
1	25 Km	0.335	60	0.6875	47 Ω
2	50 Km	0.335	60	0.6875	53 Ω
3	75 Km	0.335	60	0.6875	59 Ω
4	100 Km	0.335	60	0.6875	64 Ω

Z*setting =
[(Ω/Km x distance) + (A.R. +T.F.R.)] X CTR/CVTR

IV. CONCLUSION

400 kV e.h.v.transmission line for 100 km length is considered for the protection of line through numerical distance protection. Uniform wave is observed when no fault is applied to the impugned transmission line as indicated in Fig. 6 a & b. However when fault is applied waveform got distorted. Short circuit current is increased and voltage got reduced. The position is depicted in Fig.7 a & b. Impedance locus is away from zero when there is no fault and very nearer to zero when the fault occurred on transmission line as shown in Fig. 8.

The fault is applied at various distance of fault at 25Km, 50Km, 75 Km and 100 Km and the readings of fault current, fault voltage and fault impedance is recorded in Table 2. The setting impedance is calculated and shown in Table-3 by using data shown in table1.It would be seen that the value of fault impedance is less than the value of setting impedance which is essence of numerical distance protection wherein the value of fault impedance is less than the value of set impedance at different distances of fault as can be gathered from the value indicated in table II and III.

Differential equation algorithm for calculation of impedance is operated as distance relay is sense the fault and trips the circuit breaker at stipulated distances. Therefore object of numerical distance protection is achieved within the available constraint and data indicated in table I.

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