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Modeling and Simulation of Mho Type Distance Relay for High Voltage Transmission Line Protection

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***Abstract*-This paper describes the opportunity of implementing a model of a Mho type distance relay with three zones by using MATLAB/SIMULINK package. SimPowerSystem toolbox was used for detailed modeling of distance relay, transmission line and fault simulation. The proposed model was verified under different tests, such as fault detection which includes single line to ground (SLG) fault, double line fault (LL), double line to ground fault (LLG) and three phase fault, all types of faults were applied at different locations to test this model. The results show that the relay operates correctly under different locations for each fault type.**

***Keywords*- Distance relay, Single line to ground fault (L-G), Double line to ground (L-L-G), Line to Line fault (L-L), Three phase fault (L-L-L), MATLAB/SIMULINK**.

I. INTRODUCTION

Distance protection is the most widely used method to protect transmission lines. The fundamental principle of distance relaying is based on the local measurement of voltages and currents, where the Relay responds to the impedance between the relay terminal and the fault location [1].

There are many types of distance relays such as Mho, reactance, admittance, quadrilateral polarized- Mho, offset Mho etc. Every type of characteristics has different intended function and theories behind [2].

The basic principle of distance relay is based on the values of voltage and current and the relay operates for the impedance between the relay terminal and the fault location. Every type of relay has same function but, different theories behind [3]. Protection relays have a great impact on power system's reliability and stability and on the main components in power system. Distance relay or impedance relay can be used for main protection or backup protection in transmission lines. Nowadays, numerical distance relays have replaced static distance relays and electromechanical distance relays. The understanding of the operation of distance relay is quite difficult compared to other protection relays such as overcurrent relay, over or under voltage relay and over or under frequency relay etc., due to its complex theories and philosophies [4].

One of the world-wide recognized, powerful analysis software packages, is MATLAB/SIMULINK, which has the capability for modeling, simulating, and analyzing dynamic systems using SimPowerSystems toolbox, inside Simulink package, different components of a system such as three phase transformer, three phase load, distributed parameters of line, circuit breaker, etc. can be used for AC and DC applications [5]. MATLAB/SIMULINK provides a well-known tool for modeling digital protective relays. SIMULINK offers a wide selection of libraries that allow detailed simulation of digital relays. Aspects of digital relaying, such as signal conditioning, analog-to-digital conversion, digital filtering, phasor estimation, protection algorithms, and relay trip logic, can be modeled using general purpose blocks, special blocks from the signal processing block set and user-defined blocks written in S-functions. [6].

This paper emphasizes on building process of Simulink model for distance relay, inside the modeling, fault detection, apparent impedance calculation for all types of faults, zone coordination, designed, implementation and validation of Mho type distance relay.

II. PROTECTION THEORY OF DISTANCE RELAY

Since transmission lines are exposed to atmosphere, faults such as single line to ground (L-G) fault, double line to ground (L-L-G) fault, line to line (L-L) fault and three phase (L-L-L) fault occur on transmission lines and these faults may damage electrical equipment's. Thus, transmission line protection is an important role of power transmission lines.

Distance relays are generally used for medium and long transmission lines. These relays operate by using voltage and current phasors for impedance calculation and to detect whether the fault impedance is within zone of protection or not.

Table I shows fault impedance algorithm for different type of faults used to calculate the impedance at the relay location for different types of fault.

In Table I, A, B and C indicate the phase faults and G indicates the ground fault.

V_A, V_B and V_C are the phase voltages I_A, I_B and I_C are the phase currents

Z_0 is zero sequence impedance

Z_1 is positive sequence impedance

K_0 is residual compensation factor, where

$K_0 = (Z_0 – Z_1)/KZ_1$. K can be 1 or 3 depend on the relay design. [7].

$I_0 = (I_a + I_b + I_c)/3$

TABLE I. FAULT IMPEDANCE ALGORITHM FOR DIFFERENT TYPES OF FAULT

Fault Calculation	**Algorithm**
Phase A – Ground	$Z_A = V_A / (I_A + 3 K_0 I_0)$
Phase B – Ground	$Z_B = V_B / (I_B + 3 K_0 I_0)$
Phase C – Ground	$Z_C = V_C / (I_C + 3 K_0 I_0)$
Phase A - B or A - B – Ground	$Z_{AB} = V_{AB} / (I_A - I_B)$
Phase A - C or A - C – Ground	$Z_{AC} = V_{AC} / (I_A - I_C)$
Phase B - C or B - C – Ground	$Z_{BC} = V_{BC} / (I_B - I_C)$
Phase A - B – C	$Z_{ABC} = (V_A/I_A)$ or (V_B/I_B) or (V_C/I_C)

Setting of relay for three zones is made as follows.

a. Zone 1 setting is 80 to 85 % of protected line and the remaining 15 or 20 % is for some errors such as instrumental and transients.

b. Zone 2 setting is 120 % to 150% of protected line or 100% of protected line in addition 50 % of the shortest next line.

c. Zone 3 setting is 120 % of the sum of protected line and the longest line or 200 % to 250% of protected line.

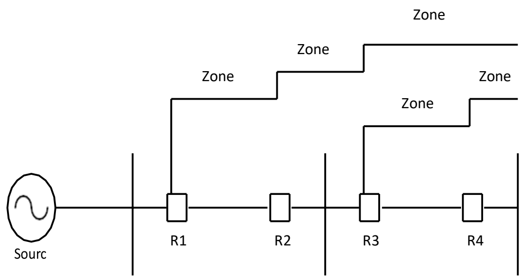

Figure 1- Transmission Line Protection Zone

The distance relay operates on the positive sequence impedance between relay and fault point for phase distance protection. The zero-sequence impedance is for ground distance protection. The Fig. 1 shows the transmission line protection zone.

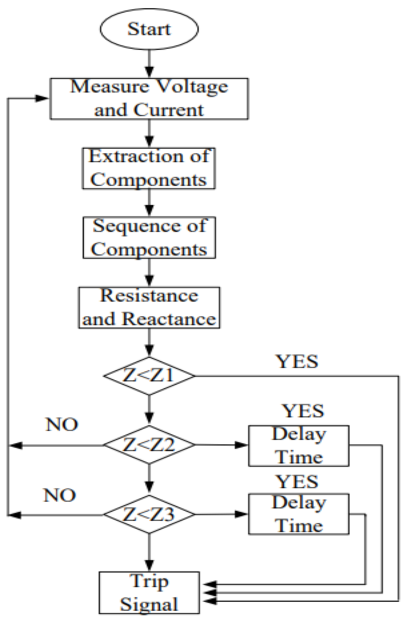

Figure 2-Mho Type Distance Relay Algorithm

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III. DEVELOPMENT OF MHO TYPE DISTANCE RELAY SIMULINK MODEL

The system model consists of

a) Fault detection Block

b) Impedance Computation Block

c) Zone Detection Block

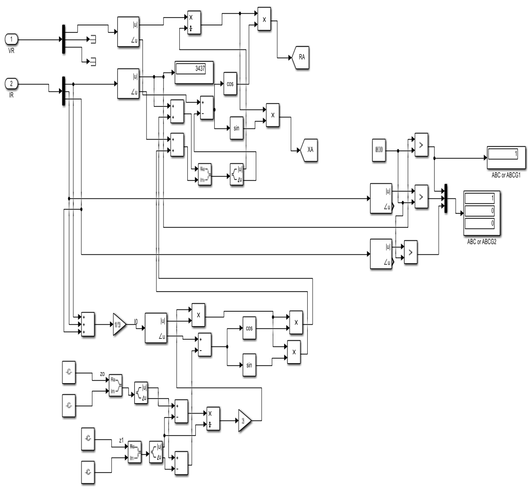
a) Fault Detection Block

This block has impedance computation block and zone detection block. The impedance computing block computes impedances corresponding to different faults using currents and voltages fed to it. Whenever the computed impedance becomes less than the set value , it gives a signal to zone detection block. The zone detection block, identifies the zone in which the fault has occurred and issues the trip signal to circuit breaker of that particular zone to disconnect faulty line. The impedance computation block and zone, and zone detection blocks are shown in figures 3 through figure 6.

b) Impedance Computation Block

The fault detection block determines the fault type, and then sends a signal to the impedance measurement block to determine which impedance measurement algorithm must be used. The impedance measurement block consists of different subsystems used to compute the fault impedance for different types of fault.

Figure 3- Impedance calculation model for single line to ground fault.



c) Zone Detection Block

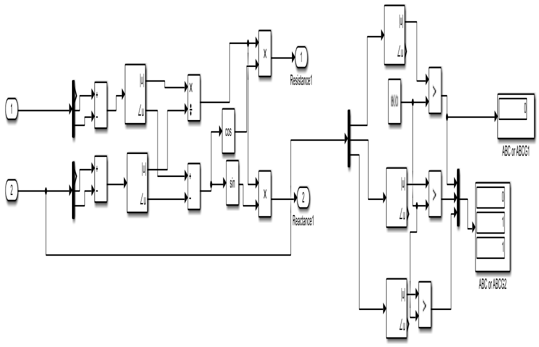


Figure 4-Impedance calculation model for Double line to ground fault/ Line to Line fault.

The careful selection of the reach settings and tripping times for the various zones of measurement enables correct coordination between distance relays on a power system. A Subsystem zone coordination model was created which comprises time settings for a 3- zone distance protection as shown in Figure.6

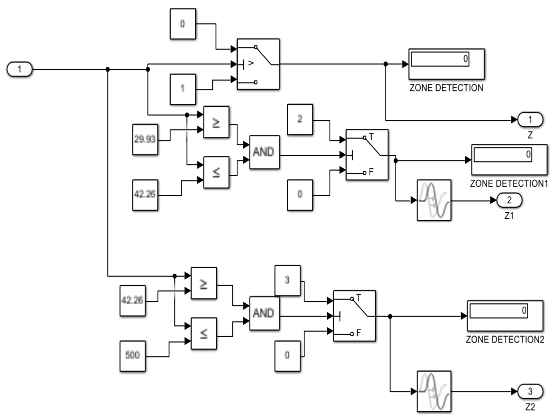


Figure 5-Impedance Calculation Model for Three phase fault.

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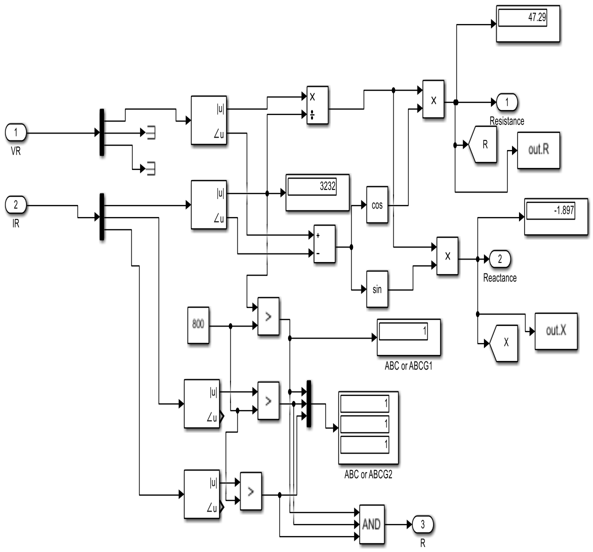
Figure 6- Zone Detection Block



Relay Setting Calculation for Zones of Protection for Mho Type Distance Relay

Line length = 100 km

Resistance = 0.01165 Ω/km

Reactance = 0.32719 H/km

Impedance = R+ j XL

= 0.01165 +j 0.32719 Ω/km

Zone 1 = 80% X (0.01165 +j 0.32719) × 100

Zone 2 = 120% X (0.01165 +j 0.32719) × 100

Zone 3 = 220% X (0.01165 +j 0.32719) × 100.

IV. SIMULATION MODEL AND RESULTS

The network under study consists of one generating bus, supplying a 400 kV transmission line having three sections of 100-km each delivering a power of 260 MVA, to the load at the end of transmission line, the bus bars are equipped with CT, PT, Mho relay and circuit breaker at the sending end as shown in Fig 7.

The relay model developed in SIMULINK is integrated with the power system model in the MATLAB/SIMULINK, several operating and fault conditions have been simulated in order to validate the relay model. The parameters of the power system model and the settings of the relay model used are in Table 2.

Table 2- Power system data and Relay setting

No	Parameters	Value
1	Line Length (L), T.L1 = T.L 2 =T.L 3	100 km
2	Voltage(U)	400kV
3	Nominal frequency	50 Hz
4	Line Resistance (R_1=R_2)	0.01165 Ω/km
5	Line Resistance (R_0)	0.2676 Ω/km
6	Line Inductance (L_1=L_2)	0.8679e-3 H/km
7	Line Capacitance (C_1=C_2)	12.74e-9 F/km
8	Line Inductance (L_0)	3.008e-3 H/km
9	Line Capacitance (C_0)	7.751e-9 F/km
10	Total zero sequence impedance	116.51 $\angle 76.72^0$ Ω
11	Total positive sequence impedance	32.739 $\angle 87.96^0$ Ω

Relay Setting

Zone	Setting	Values (Ω)	Time setting (S)
Zone 1	80% T.L-1	27.82	Instantaneous
Zone 2	T.L-1+20% T.L-2	39.28	0.3
Zone 3	T.L-1+T.L-2+20% T.L3	72.07	0.6

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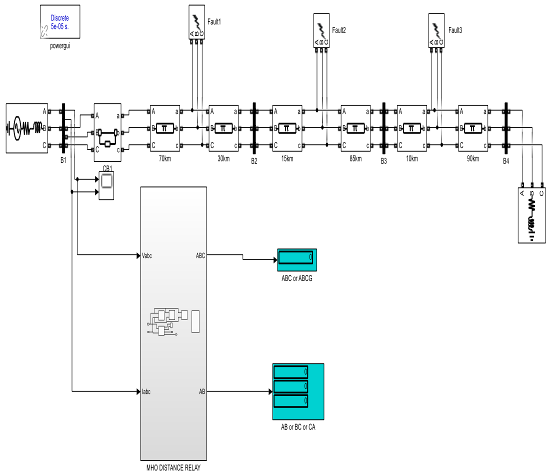


Figure 7-Simulation Model

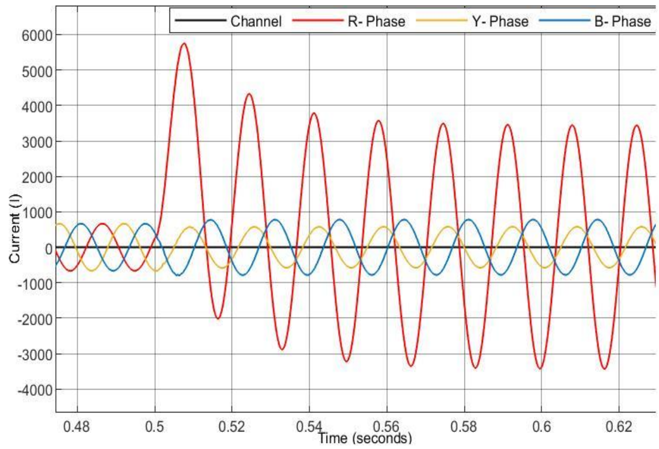


Figure 9- Single Line to Ground Fault Current Waveform

SIMULATION RESULTS

a) Single Line to Ground Fault

Phase to Ground Fault is created on phase- R, in zone 1. The three-phase voltage and current waveforms during the phase to ground fault are shown in Fig. 8 and Fig. 9 respectively. It is evident from the figure that voltage on faulty phase decreases while the voltage in healthy phases rises slightly at the time of occurrence of the fault. It can be observed that the current in faulty phase have more transients or maximum value of current than other phases. Fig. 10 indicates the zone 1 operation and the measured impedance. When fault location change relay identifies correct zone and the measured impedance changes depends on fault locations and the value of fault currents.

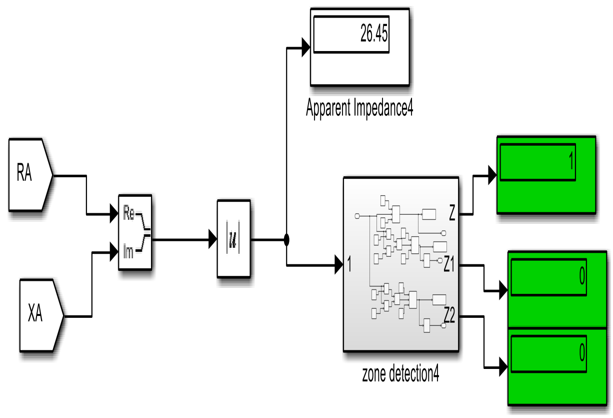
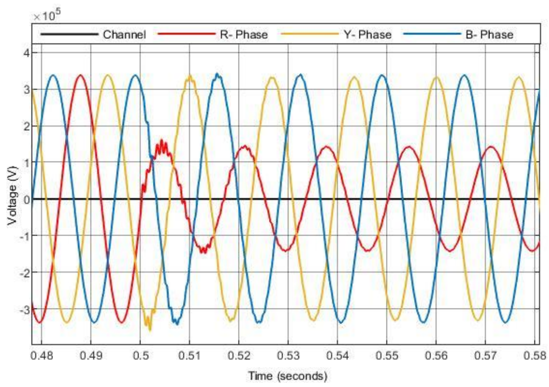


Figure 10- Impedance and Zone detection block

Figure 8- Single Line to Ground Fault Voltage Waveform



b) Double Line to Ground Fault/ Line to Line Fault

The 2LG Fault is created in zone 2. The three-phase voltage and current waveforms during the 2LG fault are provided in Fig. 11 and Fig. 12 respectively. It is evident from the figure that voltage on faulty phase decreases while the voltage in healthy phases rises slightly at the time of occurrence of the fault. It can be observed that the current in faulty phase have more transients or maximum value of current than other phases. The Fig. 13 indicates the zone 2 operation and the measured impedance. When fault location change, the relay identifies correct zone and the measured impedance changes depends on fault location and the value of fault currents.

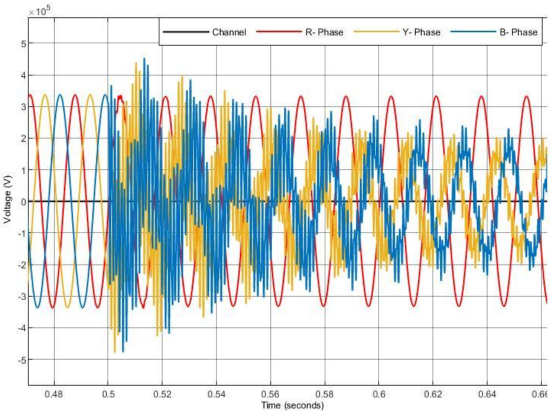


Figure 11- Double Line to Ground Fault/Line to Line Fault Voltage Waveform

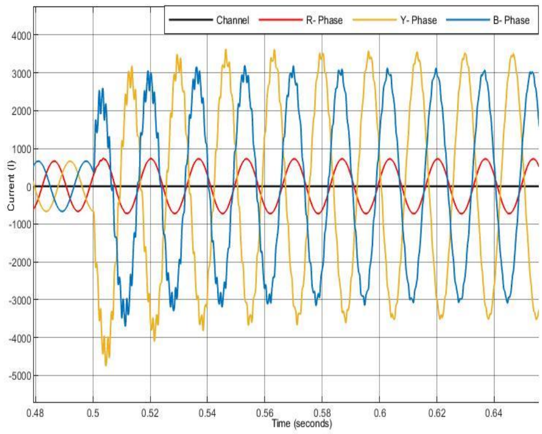


Figure 12- Double Line to Ground Fault/Line to Line Fault Current Waveform

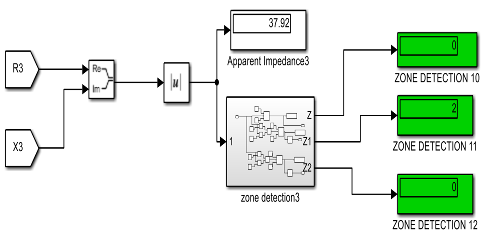


Figure 13-Impedance and Zone detection block

c) Three Phase Fault

The 3L fault is created in zone 3. The three-phase voltage and current waveforms during the phase to ground fault are shown in Fig. 14 and Fig. 15 respectively. It is evident from the figure that, the voltage on faulty phase decreases while the voltage in healthy phases rises slightly at the time of occurrence of the fault. It can be observed that the current in faulty phase have more transients or maximum value of current than other phases. The Fig. 16 indicates the zone 3 operation and the measured Impedance. When fault location change, the relay identifies correct zone and the measured Impedance changes depends on fault locations and the value of fault currents.

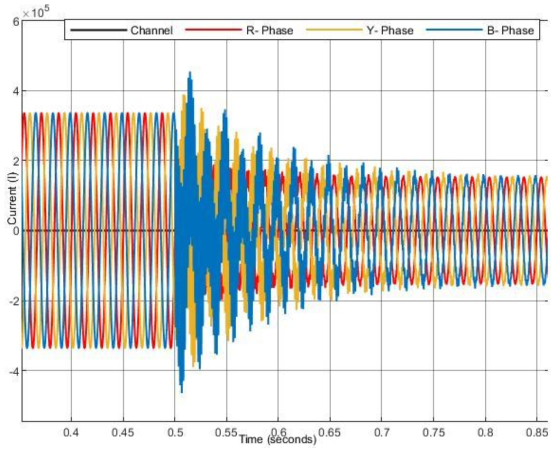


Figure 14 - Three Phase Fault Voltage Waveform

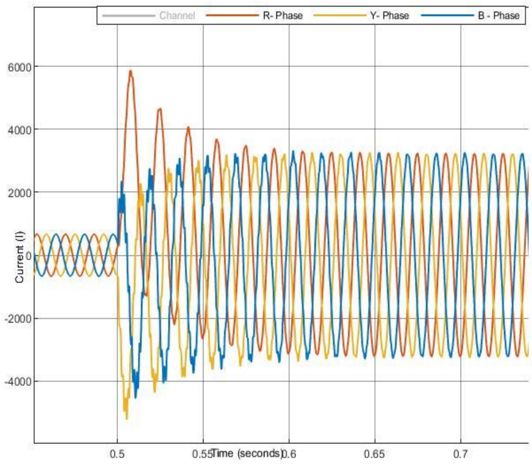


Figure 15- Three Phase Fault Current Waveform

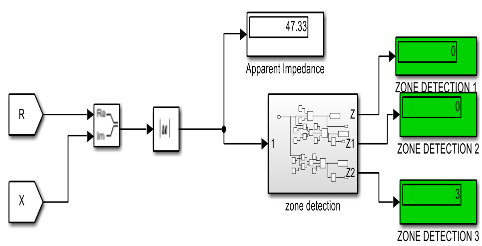


Figure 16- Impedance and Zone detection block

V. CONCLUSIONS

The Mho type distance relay was successfully modeled and simulated by using MATLAB/ SIMULINK software. The functions for Mho type distance relay was created by using special blocks of MATLAB/ SIMULINK. The behavior of the developed Mho type distance relay model at different location of transmission line is studied by means of simulation. The relay model was able to operate all the fault types correctly. Moreover, this relay indicates correct zone of operation in all cases. When fault locations change, the relay identifies correct zones.

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