

## Modeling and Performance Analysis of Mho-Relay in Matlab

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### ABSTRACT:

This paper describes the opportunity of implementing a model of a Mho type distance relay with a 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.

Also the Mho R-  $jX$  plain was created inside this model to show the trajectory of measured apparent impedance by the relay. The results show that the relay operates correctly under different locations for each fault type. The difficulties in understanding distance relay can be cleared by using MATLAB/SIMULINK software.

### KEYWORDS:

Power system protection, distance relay, line protection, MATLAB/SIMULINK, apparent Impedance.

### 1 INTRODUCTION:

Distance protection is the most widely used method to protect transmission lines. The fundamental principle of distance Relying 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 relay characteristic such as mho, reactance, admittance, quadrilateral polarized-mho, offset mho etc. Every type of characteristics has different intended function and theories behind [2].

In order to understanding the function of Relays, software relay models must be realized, modeling 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. Electric power utilities use computer-based relay models to confirm how the relay would perform during systems disturbances and normal operating conditions and to make the necessary corrective adjustment on the relay settings. [3][4]. One of the world-wide recognized, powerful analysis software package, is a MATLAB/SIMULINK, which has the capability for modeling, simulating, and analyzing dynamic systems using SimPowerSystems toolbox, in side Simulink package, different parts of a system such as three phase transformer, three phase load, distributed parameters 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 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]. The goal of this paper is to explain the building process of Simulink model for distance relay, inside the modeling, fault detection, apparent impedance calculation for all types of faults, zone coordination were designed and implemented, a Mho type distance characteristic was chosen to be as the protection scheme for this relay is the developed model can be included in one block set only by creating the subsystem for the developed model. The created subsystem block set also can be copied and pasted at any space or file thus eliminates the multiple building of the model.

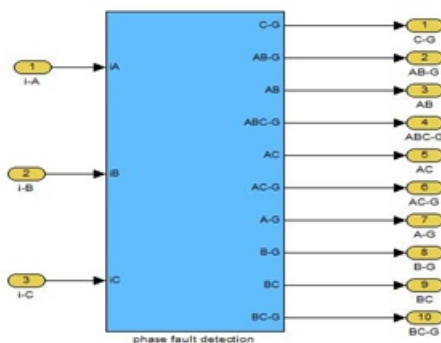
## 2 BUILDING DISTANCE RELAY MODEL:

In the following, the main functions included in the digital relay model are presented.

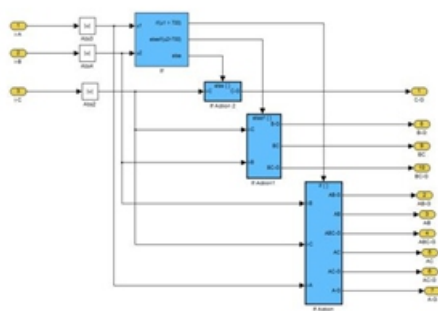
- 1- Fault detection;
- 2- Impedance measurement;
- 3- Zone protection coordination

### 2.1 Fault Detection Block:

The relay permit direct detection of the phases involved in a fault or called faulted phase selection, which then permits the appropriate distance-measuring zone to trip. Without phase selection, the relay risks having over or underreach problems, or tripping three phases when single-pole fault clearance is required. The 'Delta' algorithm techniques [7], was selected for a phase selection, which comparing the step change of level between pre-fault load, and fault current, this is achieved by a logic circuit. Figure.1 shows the fault detection block built in MATLAB, it is clear the relay can discriminate all types of fault. While figure 2 represents the scheme logic designed in MATLAB/SIMULINK, where a function block parameter if [5], the If blocks, along with If Action subsystems containing Action Port blocks were used to achieve this logic circuit.



**Figure 1. Fault detection block**



**Figure 2. Logical fault detection scheme**

### 2.2 Impedance Measurement 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. Table 1 shows the different algorithm used to compute the apparent impedance at the relay location for a various types of fault [3][7]. An illustration of computed impedance for a single phase to ground fault, and double phase to ground fault, being developed in SIMULINK environment, are shown in Figure 3, and figure 4, respectively.

**Table 1. Fault impedance Algorithm for various fault types**

Fault type	Algorithm
ABC or ABCG	$(V_A / I_A) \text{ or } (V_B / I_B) \text{ or } (V_C / I_C)$
AB or ABG	$(V_A - V_B) / (I_A - I_B)$
AC or ACG	$(V_A - V_C) / (I_A - I_C)$
BC or BCG	$(V_B - V_C) / (I_B - I_C)$
AG	$V_A / (I_A + 3 k_0 I_0)$
BG	$V_B / (I_B + 3 k_0 I_0)$
CG	$V_C / (I_C + 3 k_0 I_0)$

Where:

A, B and C indicates faulty phases, G indicates ground fault.

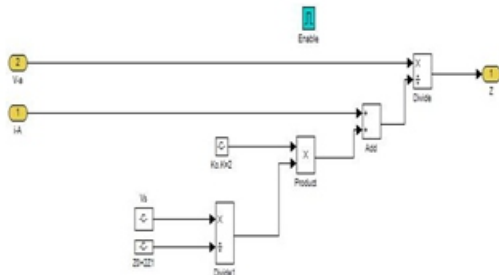
$V_A, V_B$  and  $V_C$  indicate voltage phases  $I_A, I_B$  and  $I_C$  indicate current phases  $Z_0$  = line zero-sequence impedance

$Z_1$  = line positive-sequence impedance

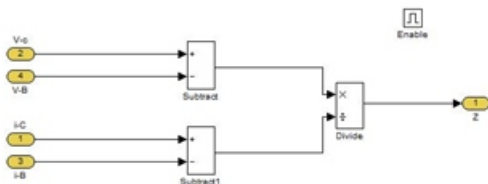
$K_1$  = residual compensation factor where  $k_0 = (Z_0 - Z_1) / KZ_1$ .  $K$  can be 1 or 3 depend on the relay design.

$I_0 = (V_s / Z_0 + 2Z_1)$

Where  $V_s$  is phase voltage during the phase to ground fault



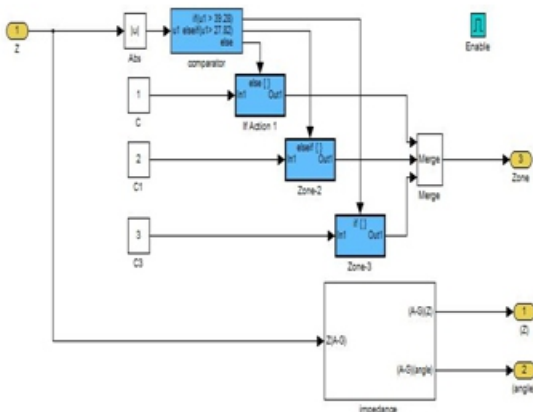
**Figure 3. Apparent impedance model for SLG Fault**



**Figure 4. Apparent impedance model for DLG Fault**

### 2.3 Zone Protection Coordination:

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. Subsystem zone coordination model was created which comprise time settings for a 3- zone distance protection as shown in Figure.5

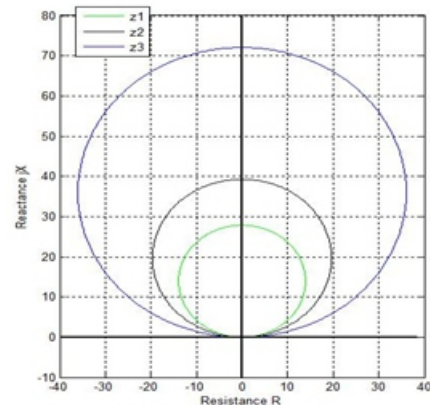


**Figure 5. Zone coordination Subsystem**

### 2.4 Building Shape Mho Characteristics:

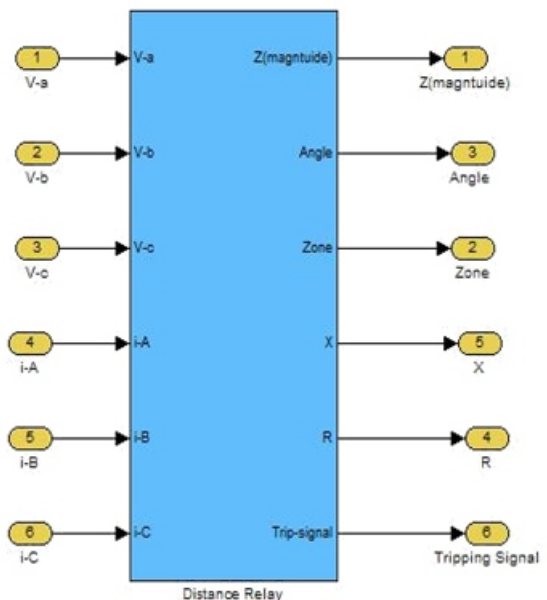
The final stage of the model is to develop the Mho characteristics of the distance relay. This stage enhances the understanding of the distance relay behavior.

To obtain the shape of mho characteristic by using M-file MTALAB, the calculations of the setting impedance for each zone has to be performed first, and then attaching the corresponding results in a specific code in M-file MTALAB , which draws the shape of each zone of Mho relay characteristic, as presented in figure 6.



**Figure 6. Mho shape characteristics**

The whole model of a Distance relay developed in SIMULINK is shown in Figure 7. With mention of its inputs and outputs.



**Figure 7. Distance Relay Model**

## 3 SIMULATION AND RESULTS:

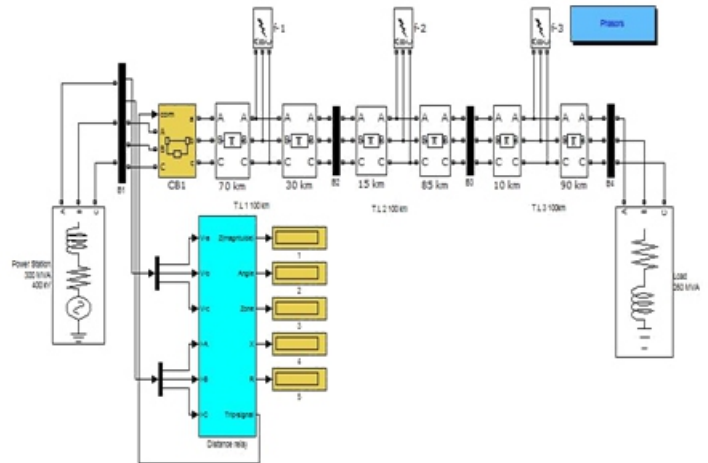
The network under study consists of one three phase power supply as a power station supplying 400kv transmission line, the three separate transmission

line each 100-km, is designed to deliver power of 260 MVA, to the load at the end of transmission line, the bus bars are equipped by current measurement and voltage measurement, Each line is equipped separately by two main circuit breaker at the sending and receiving ends as is shown in figure 8.

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**

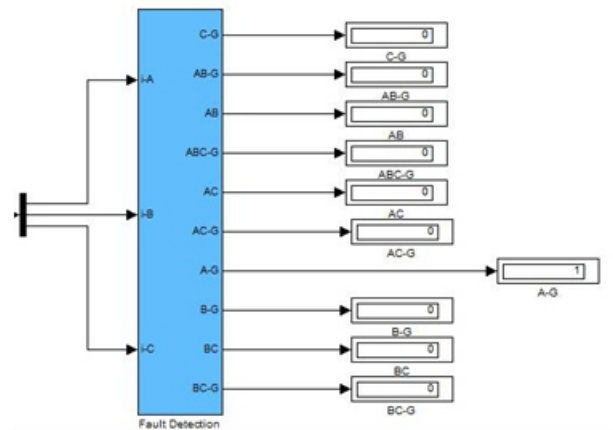
No	Parameters	Value
1	Line Length (L), T.L 1 = T.L 2 = T.L 3	100 Km
2	Voltage(U)	400Kv
3	Nominal frequency	60 Hz
4	Line Resistance (R1=R2)	0.01165 $\Omega$ /km
5	Line Resistance (R0)	0.2676 $\Omega$ /km
6	Line Inductance (L1=L2)	0.8679e-3 H/km
7	Line Capacitance (C1=C2)	12.74e-9 F/km
8	Line Inductance (L0)	3.008e-3 H/km
9	Line Capacitance (C0)	7.751e-9 F/km
10	Total zero sequence impedance	116.51 $\angle$ 76.72 $^{\circ}$ $\Omega$
11	Total positive sequence impedance	32.739 $\angle$ 87.96 $^{\circ}$ $\Omega$
Relay setting		
Zone	Setting	Values ( $\Omega$ )
Zone1	80% T.L-1	27.82
Zone2	T.L-1+20% T.L-2	39.28
Zone3	T.L-1+T.L-2+20% T.L-3	72.07
		Time setting (S)
Zone1		Instantaneous
Zone2		0.3
Zone3		0.6



**Figure 8. Overall simulation model**

### 3.1 Case.1. Fault Detection

In this case a phase A to ground fault was performed on the line, it is clear from the figure 9, that the relay can discriminate the type of fault which give output 1 that mean phase A to ground fault occur.



**Figure 9. Phase A to ground fault output**

### 3.2 Case 2 Zones of Protection:

In this case the relay will determine the correct zone of the measured impedance for different locations of each fault type. 3.2.1. Single Line to Ground Fault Figure 10(a). Shows trace of apparent impedance as seen by the Mho distance relay due to SLG fault at 70 km .The impedance trajectory fall in the first zone of R-jX plain which is correct function of the relay.



while figure 10(b) and figure 10(c) demonstrate the impedance measured by the Mho distance relay under SLG fault at the distance of 115 km and 210 km from the relay location respectively, the results shows that the relay has indicate impedance in the second and third zone respectively ( correct function).

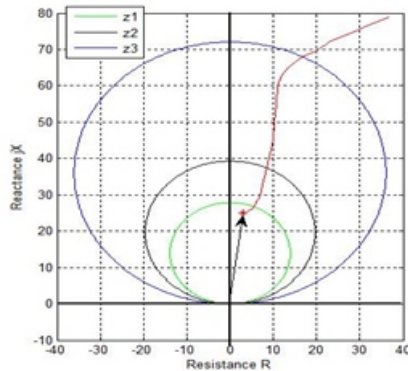


Figure 10(a). R-jX plot Impedance for a fault at 70 km distance

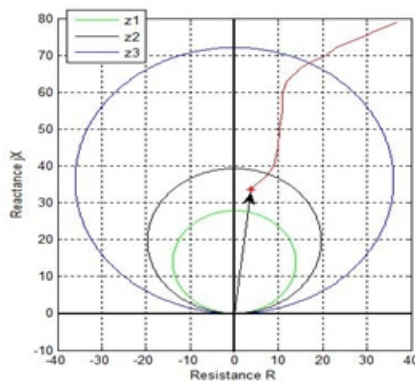


Figure 10(b). R-jX plot Impedance for a fault at 115 km distance

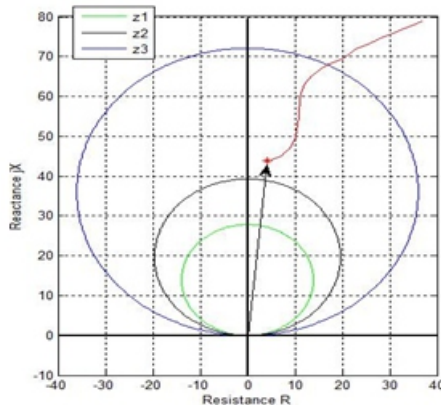


Figure 10(c). R-jX plot Impedance for a fault at 210 km distance

### 3.2.2 Three Phase Fault:

Three phase fault where set at distance 30 km, 90 km and 130 km to check the behavior of Mho distance relay of this type of fault. The impedance trajectory seen by the Mho distance relay due to this type of fault is shown in figure 11(a, b, c).

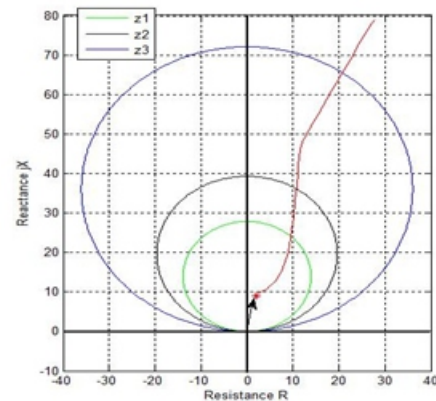


Figure 11(a). R-jX plot Impedance for a fault at 30 km

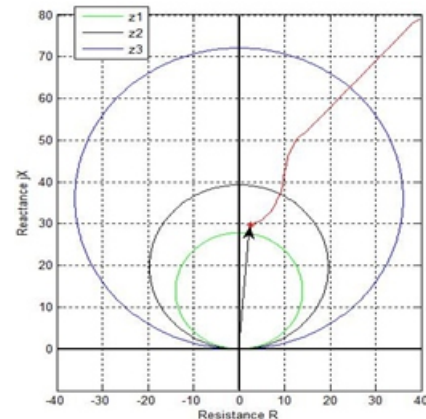


Figure 11(b). R-jX plot Impedance for a fault at 90 km

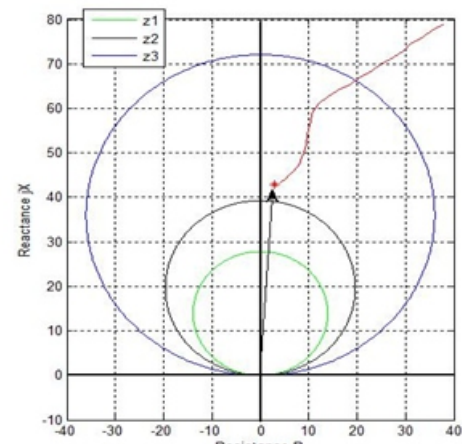


Figure 11(c). R-jX plot Impedance for a fault at 130 km

## 4 CONCLUSIONS:

A Mho type distance relay was successfully developed based on MATLAB/SIMULINK package, (each part of the relay is implemented as a separate function). Each function has been created using special blocks of SIMULINK. By testing the behavior of the developed relay model under different fault conditions, the relay model was able to recognize the appropriate fault type. From perspective impedance calculations, the relay model has the ability of indicating the correct zone of operation in all cases. The relay identifies the fault locations as expected, as the fault location is changed, the measured impedance change consequently. The impedance path which reflects the behavior of the model under different fault conditions was presented and discussed.

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