SIMULATION OF MHO CHARACTERISTICS FOR TRANSMISSION LINE PROTECTION USING PSCAD

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ABSTRACT

Modeling of protective relays offer an economical and feasible alternative to investigate the performance of relays and protection systems. In this paper MHO characteristics and Bergeron model type transmission line are modelled and simulated using PSCAD/EMTDC software. To study the performance of the relay characteristics, single line to ground fault at different locations with various fault resistances are considered. A Fast Fourier Transform block in PSCAD/EMTDC has been used to extract the fundamental component. The test network used in this paper is 220kv transmission line system.

Keywords*: Modeling, MHO relay, PSCAD/EMTDC.*

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I. INTRODUCTION

When a short-circuit fault occurs on a transmission line, distance relays gives protection and trips the circuit breaker by disconnecting the faulty portion from the healthy section. To study the behavior of a distance relay during short-circuits, for designing new prototypes, to check and optimize the performance of relays that already installed in power system, to design new relaying algorithms and to check the performance of the new relay equipment it is necessary to model the distance relay. Relay models helps engineers and consultants to select the relay types suited for a particular application and to analyze the performance. Researchers use relay model to investigate and improve protection design and algorithms. Instead of using actual prototypes, manufacturers use relay models to expedite and economize the process of developing new relays. Electric power utilities use 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. The software models could be used for training young and inexperienced engineers and technicians. Thus, Computer models of relays permit investigators to observe in a very detailed way the performance in each internal module of the relay [1-2].

The first transient model of a distance relay was presented in [3], where the ninth-order state space mathematical model of a mho element was developed. Wilson and Nordstrom [4] modeled one measuring unit of a distance digital relay using MODELS of EMTP.

The input filter, analog-to-digital converter, fundamental frequency phasor calculator and relay measuring principle were modeled separately in MODELS. The simulations were compared with laboratory test results. A.A Abdlrahem and H.H Sherwali, [5] described distance relay model using MATLAB environment and the behavior of the distance relay model verified by the Electromagnetic Transient Program. The Electromagnetic Transient Program (EMTP) was the first software that simulates the transient nature of power system [6] which is based on the algorithm proposed in [7]. PSCAD/EMTDC software is an electromagnetic transient analysis program developed by the Manitoba HVDC Research Center having variety of steady state and transient power system studies [8]. The primary solution engine is EMTDC, which solves equations for the entire power system in time domain employing the electromagnetic transient algorithm proposed in [7]. PSCAD is graphical user interface, provides powerful means of visualizing the transient behavior of the systems. PSCAD/EMTDC provides a fast and accurate solution for the simulation of electrical power systems [9].

In this paper, simulation of mho characteristics using PSCAD/EMTDC software has been proposed. The modeling is done by taking voltage and current signals at relay location and apparent impedance is calculated after extracting the fundamental component using Fast Fourier Transform block in PSCAD/EMTDC. To study the performance of the developed characteristics single line to ground fault over the transmission line at different locations and different fault resistances are considered. The transmission line has been represented using the Bergeron line model in PSCAD/EMTDC.

II. DISTANCE RELAYS

A. Impedance seen by the distance relays

Distance relays are designed to protect power systems against four basic types of faults LG, LL-G, LL, and three phase fault. In order to detect any of the above faults, each one of the zones of distance relays require six units. Three units for detecting faults between the phases and the remaining three units for detecting phase to earth faults. The setting of distance relays is always calculated on the basis of the positive sequence impedance. Table. I indicate fault impedance calculation formula for all of the fault types.

Table I: Fault impedance calculation on different faults

Distance Element	Formula
Phase A	$Z_A = V_A/(I_A + 3kI_o)$
Phase B	$Z_B = V_B/(I_B + 3kI_o)$
Phase C	$Z_C = V_C/(I_C + 3kI_o)$
Phase A – Phase B	$Z_{AB} = V_{AB}/(I_A - I_B)$
Phase B – Phase C	$Z_{BC} = V_{BC}/(I_B - I_C)$
Phase C – Phase A	$Z_{CA} = V_{CA}/(I_C - I_A)$

Where, $k = (Z_0-Z_1) / Z_1$, Z_0 and Z_1 are zero sequence and positive sequence impedances.

B. Zones of Protection

Distance relays will have instantaneous directional zone 1 protection and one or more time delayed zones. The tripping signal produced by zone 1 is instantaneous; it should not reach as far as the busbar at the end of the first line so it is set to cover only 80-85 per cent of the protected line. The remaining 20-15 percent provides a factor of safety in order to mitigate against errors introduced by the current and voltage transformers, and line impedance calculations. The 20-15 percent at the end of the line is protected by zone 2, which operates in t_2 seconds. Zone 3 provides the back-up and operates with a delay of t_3 seconds. Three protection zones in the direction of the fault are used in order to cover a section of line and to provide back-up protection to remote sections. Some relays have one or two additional zones in the direction of the fault plus another in the opposite sense, the latter acting as a back-up to protect the busbars. In the majority of cases the setting of the reach of the three main protection zones is made in accordance with the following criteria: Mho relay characteristics for three zones of protection as shown in the Fig. 1

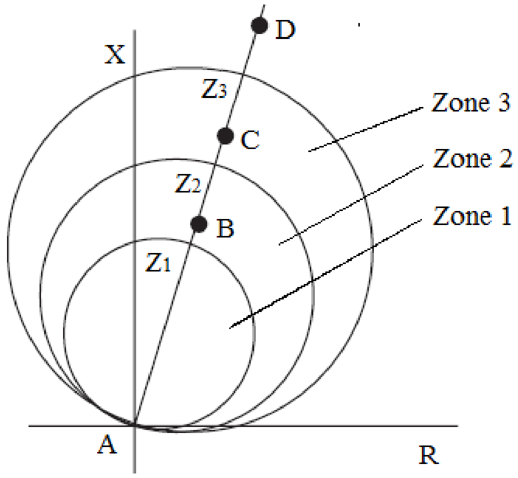


Fig. 1. Mho relay characteristics for three zones of protection.

Relay is located at A. Z1, Z2 and Z3 are the setting impedance of the mho relay for zone1, zone2 and zone3. AD is the total transmission line impedance divided into three zones AB, BC and CD.

Zone 1: This is set to cover between 80 and 85 per cent of the length of the protected line;

Zone 2: This is set to cover all the protected line plus 50 per cent of the shortest next line

Zone 3: This is set to cover all the protected line plus 100 per cent of the second longest line, plus 25 per cent of the shortest next line.

It is clear that the operating time of the relay is not the only factor to be considered while selecting a distance protection for transmission line applications.

C. Effect of fault Resistance on relay coverage

The reach of the mho relay effected in spite of the presence of fault resistance as shown in the Fig. 2. AB is the line to be protected, due to fault resistance BC impedance seen by the relay going out of the zone. Therefore mho relay under reaches because of fault resistance.

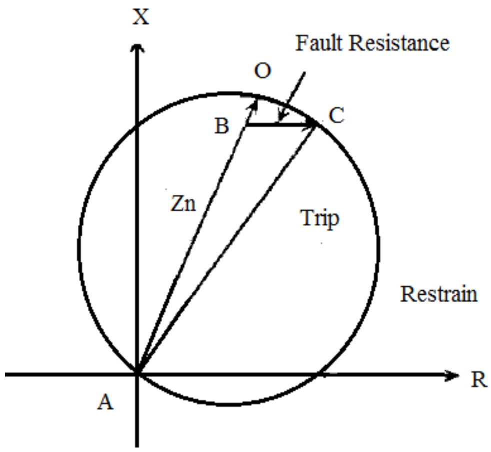


Fig. 2. Effect of fault resistance on reach of the relay.

III. MHO RELAY MODEL ALGORITHM

When a transmission line subjected to a fault, the voltage signals and current signals contain decaying dc components, higher order frequency components and lower order frequency components. The higher order frequency components can be eliminated using low pass anti-aliasing filters with appropriate cut-off frequency, but the anti-aliasing filters cannot remove decaying dc components and rejects lower order frequency components. This affects the performance of digital relay. Therefore, the Discrete Fourier transform is usually used to remove the dc-offset components [10]. The Fast Fourier Transform is a fast algorithm for efficient computation of DFT. FFT reduces the number of arithmetic operations and memory required to compute the DFT. Fig. 3 shows mho relay modeling algorithm, which uses FFT block in PSCAD/EMTDC for extracting the fundamental frequency component.

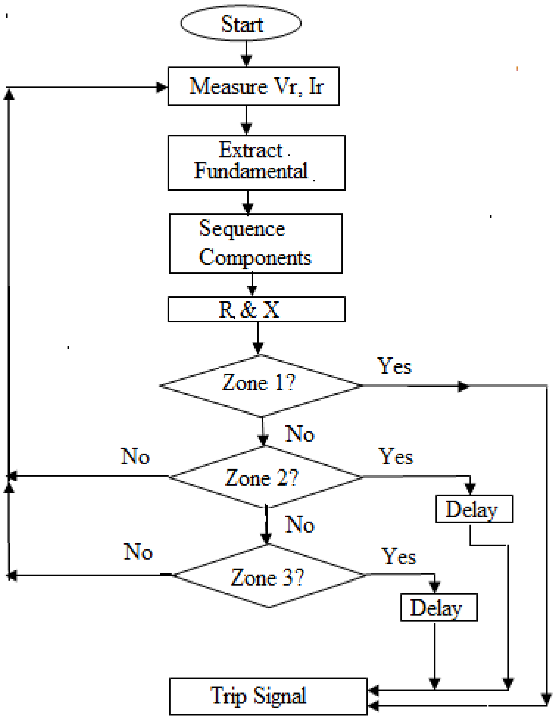


Fig. 3. Mho relay modeling Algorithm

IV. TRANSMISSION LINE MODEL

A Single line diagram of the transmission line operating at 220kV 50 Hz is shown in Fig. 4. The transmission line has been represented using the Bergeron line model in PSCAD/EMTDC software. Relay is located at bus-A. The data for the transmission line system is given in Appendix [1].

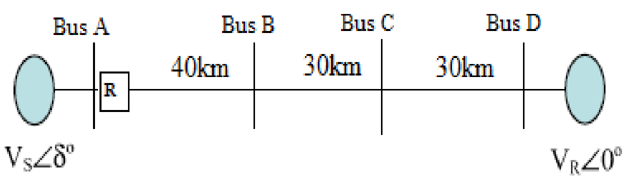


Fig. 4. Single line diagram of Transmission line.

Setting of the mho relay is

Zone-1 = 29.07 Ω (80 % of protected line AB).

Zone-2 = 49.97Ω (100 % of protected line AB + 50 % of the protected line BC).

Zone-3 = 70.41 Ω (100 % of protected line AB + 100 % of the protected line BC+25% of the protected line CD).

Impedance settings for the three zones are given in Table II.

Table II: Settings of Zones of Protection

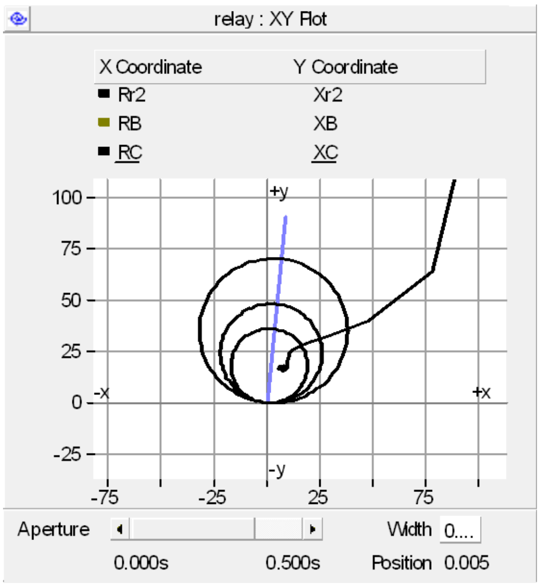
Zone	R	X
1	3.098 Ω	28.908 Ω
2	5.325 Ω	49.687 Ω
3	7.504 Ω	70.013 Ω

V. SIMULATION RESULTS

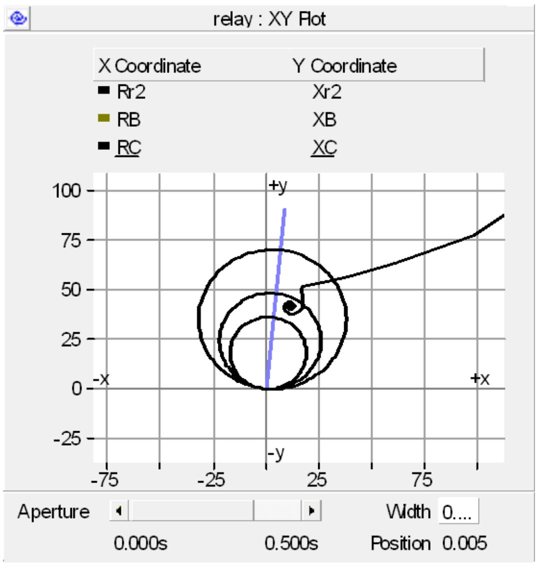
To study the behaviour of the developed mho relay characteristics, fault at different locations on the 220kv, 100km transmission line and fault resistances of different values were simulated using PSCAD/EMTDC software. The behaviour of of the mho relay is as explained hereinafter.

Case 1: - L-G faults at different distances from the relay location.

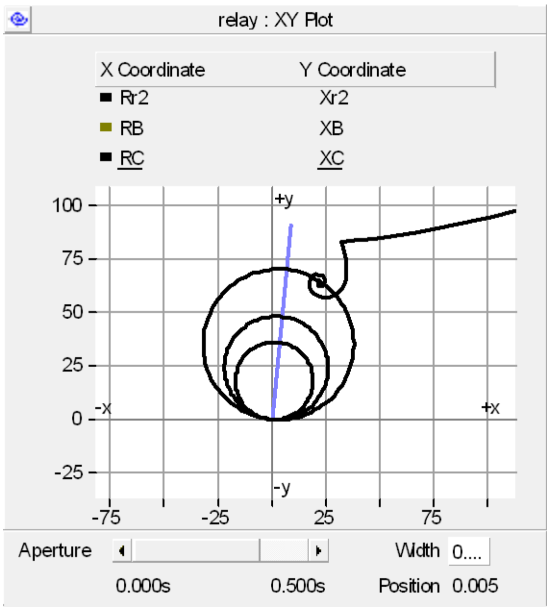
Single line to ground fault were set on the 220kv, 100 km transmission line model at a distance of 30km, 10km and 6 km from the location of bus-A, bus-B and bus-C. Simulation results are shown in Fig. 5a, 5b and 5c.



a) Fault At 30 Km from Bus-A, Zone 1



b) Fault at 10 km from Bus-B, Zone 2

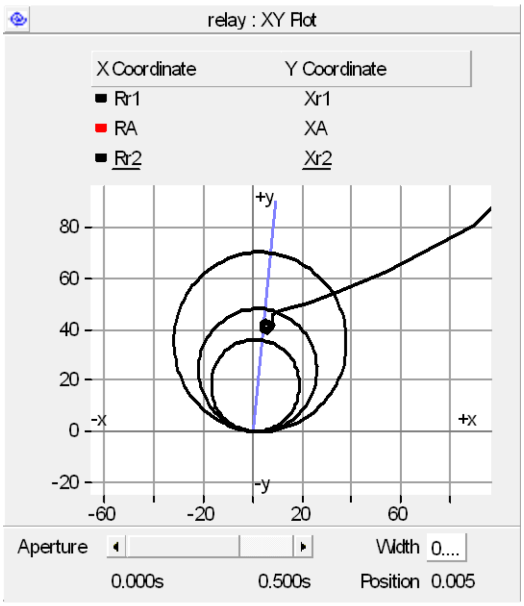


c) Fault at 6 km from Bus-C, Zone 3

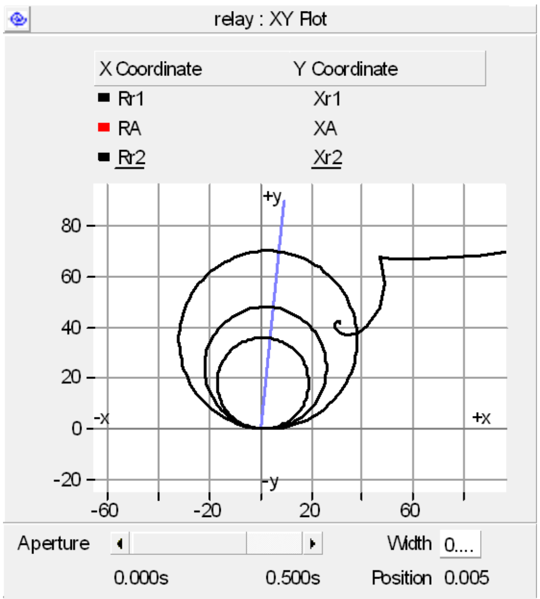
Fig. 5. Impedance trajectory of the relay for LG fault at different locations, case 1.

Case 2: Single line to ground fault with fault resistance

Single line to ground fault with different fault resistance were applied on the transmission line at a location 10 Km from bus-B, zone 2 with different fault resistances. Fig. 6.a and 6.b shows the behavior of the mho relay when fault resistance is 1 Ω and 18 Ω. When the fault resistance is 1 Ω the relay detects the fault in zone 1. Due to increase in fault resistance from 1 Ω to 18 Ω, impedance seen by the relay lies in the zone3 as shown in the Fig 6.b. Thus, mho relay under reaches due to fault resistance.



(a) Fault resistance of 1Ω



(b) Fault resistance of 18Ω

Fig. 6. Impedance trajectory of the relay for LG fault with different fault resistances, case 2.

VI. CONCLUSIONS

In this paper mho relay characteristics are developed using PSCAD. The performance characteristics of mho relay was evaluated at different locations with single line to ground fault. Main conclusion of this work is as follows.

- The developed mho characteristics may be used for training young and inexperienced engineers and technicians.
- Different case studies have been presented in order to illustrate the response of the developed mho characteristics at different locations and different fault resistances. Resistive fault causes the relay to under-reach.

APPENDIX

Source Data at both Sending and Receiving Ends

positive –sequence impedance = 0.819+j7.757 Ω

zero sequence impedance = 3.681+j24.515 Ω

frequency = 50Hz

Transmission line data

voltage = 220kV

positive sequence impedance=0.09683+j0.903 Ω/km

zero sequence impedance = 0.01777+j0.4082 Ω/km

frequency = 50Hz

REFERENCES

1. Hamid Sherwali and Abdlrahem, Matlab - Modelling, Programming and Simulations, InTech publishers, October 2010.
2. Abdlmnam A. Abdlrahem, “Modeling of distance relays for Power Systems Protection”, M.Sc. dissertation, EE&E Dept., Faculty of Engineering, Al-Fatah University, Fall 2007.
3. Z. Peng, M. S. Li, C. Y. Wu, T. C. Cheng, and T. S. Ning, “A dynamic State Space Model of a Mho Distance Relay,” *IEEE Transactions on Power Apparatus and Systems*, Vol. PAS-104, No. 12, December 1985.
4. R. E. Wilson, J. M. Nordstrom, “EMTP Transient Modeling of a Distance Relay and a Comparison with EMTP Laboratory Testing,” *IEEE Transactions on Power Delivery*, Vol. 8, No. 3, July 1993.
5. A.A Abdlrahem and H.H Sherwali, “‘Modeling Of Numerical Distance Relays Using Matlab”, IEEE Symposium on Industrial Electronics and Applications ISIEA, October 2009.
6. H. Dommel, “EMTP Reference Manual,” Bonneville Power Administration 1986.

7. H. W. Dommel, "Digital Computer Solution of Electromagnetic Transient in Single- and Multiphase Networks," IEEE Transactions on Power Apparatus and Systems, Vol. PAS-88, No. 4, April 1969.
8. Introduction to PSCAD/EMTDC V3, Manitoba HVDC Research Centre Inc.,Canada, 2000.
9. Craig Muller, P. Eng. "Power system computer aided design user's guide", Manitoba HVDC Research Centre, September 2005
10. Abdlmnam A. Abdlrahem, Hamid H Sherwali, "Modelling of Numerical Distance Relays Using Matlab", IEEE Symposium on Industrial Electronics and Applications, Kuala Lumpur, Malaysia, October 4-6, 2009.