PSCAD Simulation High Resistance Fault in Transmission Line Protection Using Distance Relay

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Abstract— **This paper deals with simulation of high resistance fault in distance relay using PSCAD software. Impedance, Mho characteristics and Bergeron model type transmission line are modelled and simulated. A Fast Fourier Transform block in PSCAD/EMTDC has been used to extract the fundamental component. To study under reach effect for the developed relay models, various fault resistance are considered at same length over the transmission line. The test network used in this paper is 220kv transmission line system.**

Keywords— **Impedance Relay and Mho relay, Under reach and PSCAD**

I. INTRODUCTION

A protection of power system protects from the deleterious effects of a sustained fault. A fault (meaning in most cases a short circuit, but more generally an abnormal system condition) occurs as a random event. If some faulted power system component (line, bus, transformer, etc.) is not isolated from the system quickly, it may lead to power system instability or break-up of the system through the action of other automatic protective devices. A protection system must therefore remove the faulted element from the rest of the power system as quickly as possible [1].

The distance protection is universal short circuit protection. Its mode of operation on base of evaluation and measurement of short circuit impedance. Distance relays are widely used for protection of high and EHV transmission lines. The first transient model of a distance relay was presented in [2], where the ninth-order state space mathematical model of a mho element was developed. Wilson and Nordstrom [3] 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, [4] 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 [5] which is based on the algorithm proposed in [6]. 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 [7]. The primary solution engine is EMTDC, which solves equations for the entire power system in time domain employing the electromagnetic transient algorithm proposed in [6]. 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 [7-8]. Akanksha and Karishma in [9] explained modeling of impedance relay characteristics using PSCAD. Yashasvi and Vidushi in [10] explained modeling of mho relay characteristic using PSCAD

In this paper, simulation of under reach effect in distance relay using PSCAD/EMTDC software has been proposed. The modelling of impedance and mho characteristics are 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 under reach effect for the developed relay characteristics, various fault resistances are considered at same length over the transmission line. 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	$Z_A = V_A/(I_A + 3kI_0)$
Phase B	$Z_B = V_B/(I_B + 3kI_0)$
Phase C	$Z_C = V_C/(I_C + 3kI_0)$
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

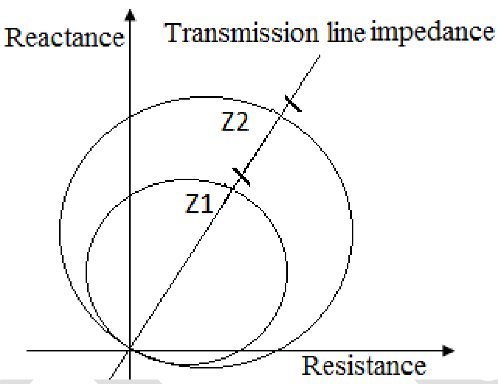


Fig. 1: Mho relay characteristics for two zones of protection.

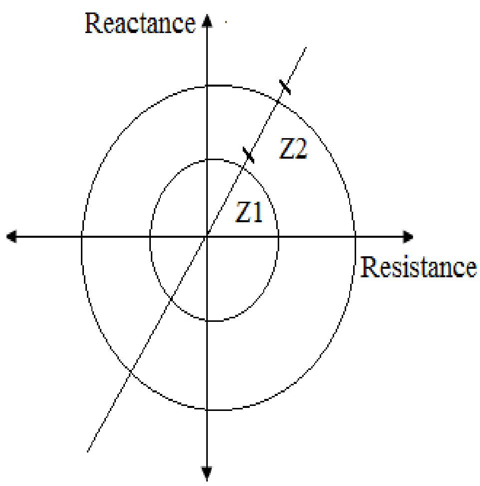


Fig .2: Impedance relay characteristics for two zones of protection.

Relay is located at A. Z_1, Z_2 and Z_3 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.

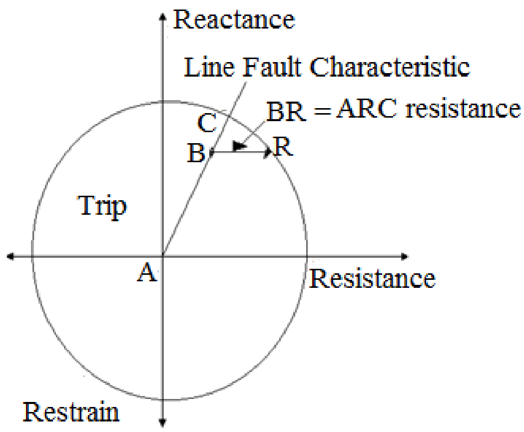


Fig. 3: Effect of fault resistance on reach of the impedance relay.

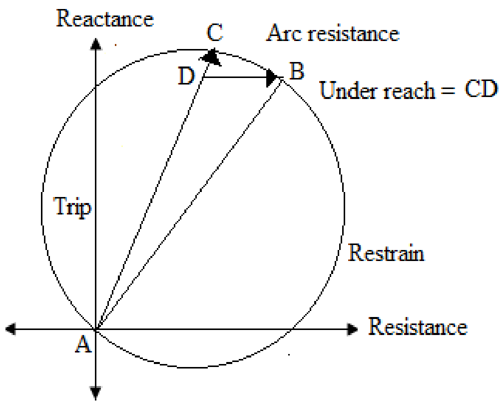


Fig. 4: Effect of fault resistance on reach of the mho relay.

III. DISTANCE 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. 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.

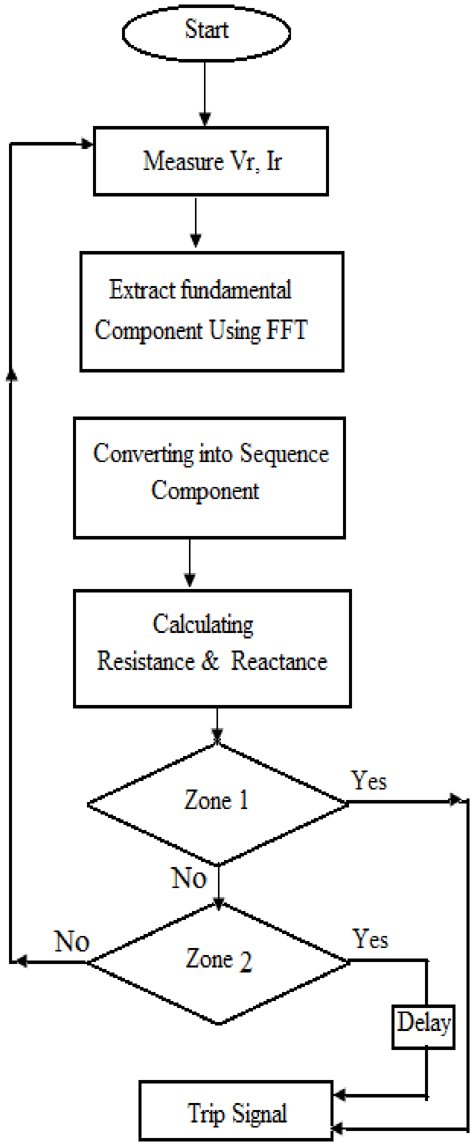


Fig. 5. Distance relay modeling Algorithm

III. TRANSMISSION LINE MODEL

A Single line diagram of the transmission line operating at 220kV 50 Hz is shown in Fig. 6. 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.

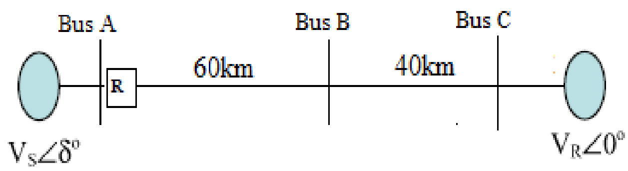


Fig. 6. Single line diagram of Transmission line.

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).

Impedance settings for the two 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

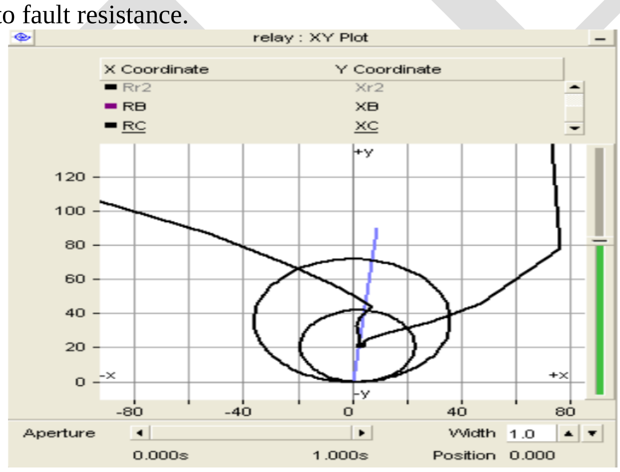
IV. Simulation Results

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

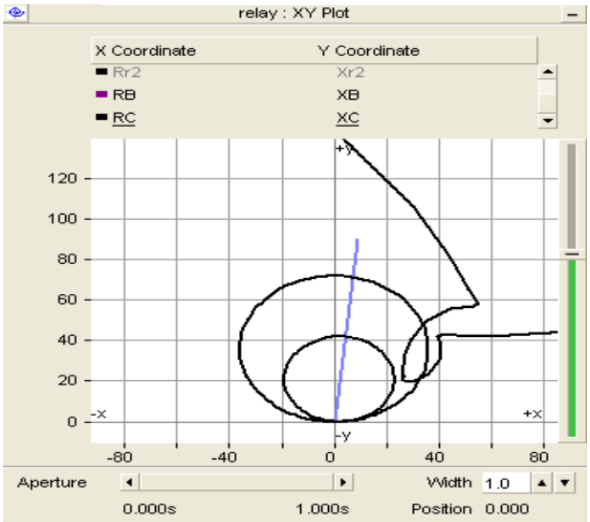
Case 1: L-G fault at same distances and different fault resistance from the relay location.

Single line to ground fault were set on the 220kv, 100 km transmission line model and fault at a distance of 40km with Different fault resistance 0.1ohm and 18Ohm from the location of bus-A, and Simulation results are shown in Fig. 7a and 7b.

Single line to ground fault with different fault resistance were applied on the transmission line at a location 40 Km from bus-A, zone 1 with different fault resistances. Fig. 7.a and 7.b shows the behavior of the mho relay when fault resistance is 0.1Ω 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 mho relay lies in the zone2 as shown in the Fig 7.b. Thus, mho relay under reaches due to fault resistance.



(a) Fault At 40 km with fault resistance 0.1Ohm from Bus-A, Zone 1 of Mho Relay

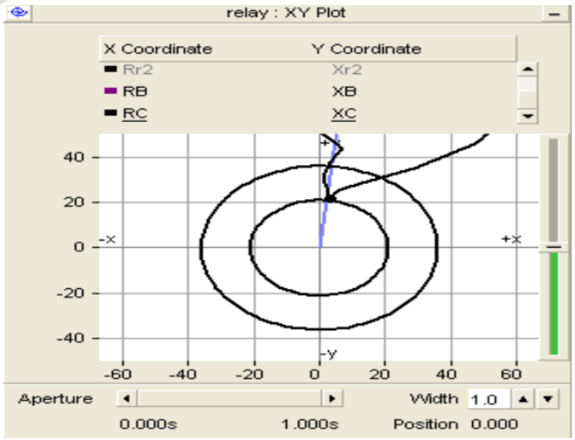


(b) Fault at 40 km with fault resistance 18Ω from Bus-A, Zone 1 of Mho Relay

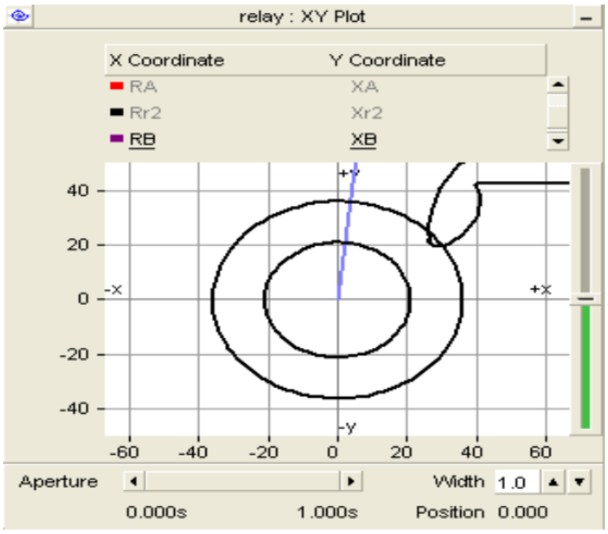
Fig. 7. Mho trajectory of the relay for LG fault with different fault resistances

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 40 Km from bus-A, zone 1 with different fault resistances. Fig. 8.a and 8.b shows the behavior of the impedance relay when fault resistance is 0.1Ω 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 impedance relay lies in the zone2 as shown in the Fig 8.b. Thus, impedance relay under reaches due to fault resistance.



(a)Fault at 40km with Fault resistance of 0.1Ω from Bus-A, Zone I of Impedance Relay



(b)Fault at 40km with Fault resistance of 18Ω from Bus-A, Zone 1 of Impedance Relay

Fig. 8. Impedance trajectory of the relay for LG fault with different fault resistances

V. CONCLUSIONS

In this paper under reach effect of mho and impedance relay are simulated using PSCAD. The performance characteristics of mho and impedance relay are evaluated at same locations but with different fault resistance. Main conclusion of this work is as follows.

- The developed simulation model may be used for training young and inexperienced engineers and technicians.
- Case studies have been presented in order to illustrate the response of the developed mho and impedance characteristics at same locations but with 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

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