MODELING OF IMPEDANCE RELAY USING PSCAD/EMTDC

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ABSTRACT

Modeling of relays permits to check and optimize the performance of relays that are already installed in power systems. Designing new relaying algorithms or new relaying equipment is also improved with relay modeling. This paper deals with modeling of Impedance relay using PSCAD/EMTDC software. 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 model different types of shunt fault at different length over the transmission line with various fault resistances are considered. The impedance relay is tested on 220KV power network.

***Keywords**: Modeling, Impedance Relay, PSCAD.*

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I. INTRODUCTION

An electrical power system consists of generators, transformers, and transmission and distribution lines. If short circuit persists for longer period, it causes damage to the important sections of the power system. 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 [1].

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 [8].

In this paper, Impedance relay modeling 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 model different types of shunt fault at different length over the transmission line with various fault resistances are considered. The transmission line has been represented using the Bergeron line model in PSCAD/EMTDC. The developed impedance relay model is tested on 220KV power network.

II. DISTANCE RELAYS

Distance relays compare measured impedance with the setting impedance to determine if the fault is inside or outside the protected zone. If the measured impedance is inside the protected zone, trip signal will be generated. Different formulas should be adopted when calculating the fault impedance due to different fault types. Table 1 indicates fault impedance calculation formula for all of the fault types.

Table I: Fault impedance calculation on different faults

Fault type	*Formula*
AG	$Z_A = V_A/(I_A + 3kI_o)$
BG	$Z_B = V_B/(I_B + 3kI_o)$
CG	$Z_C = V_C/(I_C + 3kI_o)$
AB or ABG	$Z_{AB} = V_{AB}/(I_A - I_B)$
BC or BCG	$Z_{BC} = V_{BC}/(I_B - I_C)$
CA or CAG	$Z_{CA} = V_{CA}/(I_C - I_A)$

A. Zones of Protection

Distance relays are set on the basis of the positive-sequence impedance from the relay location up to the point on the line to be protected. Normally, 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:

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.

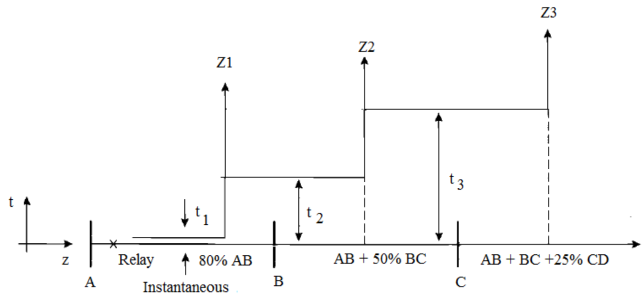


Fig. 2. Distance relay protection zones

In addition to the unit for setting the reach, each zone unit has a timer unit. The operating time for zone 1, t_1, is normally set by the manufacturer to trip instantaneously since any fault on the protected line detected by the zone 1 unit should be cleared immediately without the need to wait for any other device to operate. The operating time for zone 2 is usually of the order of 0.25 to 0.4 s, and that of zone 3 is in the range of 0.6 to 1.0 s. In the case of zone 3, when the settings of relays at different locations overlap, then the timer for the zone 3 of the furthest relay should be increased by at least 0.2 s to avoid incorrect co-ordination. However, the operating time for the zone 3 unit should also be set at a value that will ensure that system stability is maintained and therefore, if necessary, consideration may have to be given for reducing zone 3 operating time in such circumstances.

Since 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 measurement transformers and line impedance calculations. The 20-15 per cent to 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. Since the reach and therefore the operating time of the distance relays are fixed, their co-ordination is much easier than that for overcurrent relays.

It is clear that the operating time of the relay is not the only factor to be considered while selecting a distance protection for real-world transmission line applications .The setting of distance relays should ensure that they are not going to operate when not required and will operate to trip when necessary.

B. Impedance Relay model Algorithm

When a fault occurs on transmission line, the voltage and current signals are severely distorted. These signals may contain decaying dc components, high frequency oscillation quantities, and etc. The higher 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 reject low frequency components. This affects the performance of digital relay. Therefore, the Discrete Fourier transform is usually used to remove the dc-offset components [9]. 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 impedance relay modeling algorithm, which uses FFT block in PSCAD/EMTDC for extracting the fundamental component.

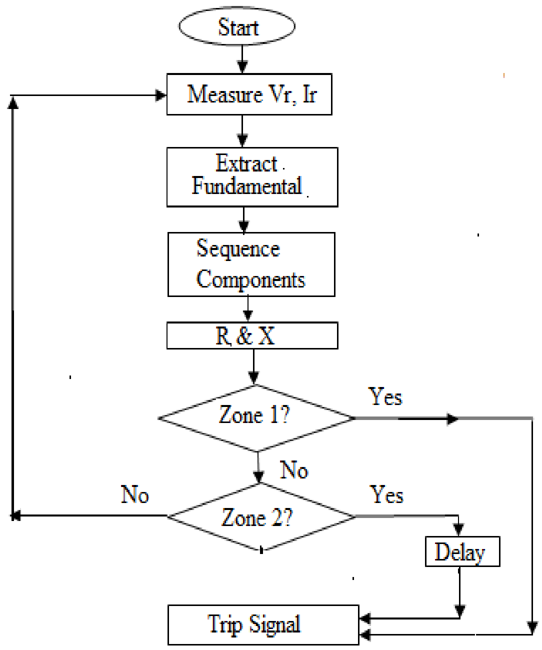


Fig. 3. Impedance relay modeling Algorithm

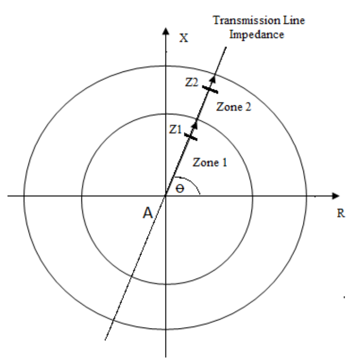


Fig. 4. Impedance relay characteristics for two zones of protection

III. TRANSMISSION LINE MODEL

A Single line diagram of the transmission line network operating at 220kV 50 Hz is shown in Fig. 5. The transmission line has been represented using the Bergeron line model in PSCAD/EMTDC. To study the performance of the impedance relay model for forward faults and reverse faults, relay is located at Bus B. The data for the transmission line system are given in Appendix.

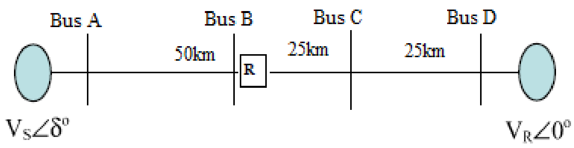


Fig. 5. Single line diagram of Transmission line

Setting of the relay is

Zone-1 = 18.17 Ω (80 % of protected line BC).

Zone-2 = 34.07Ω (100 % of protected line BC + 50 % of the protected line CD).

Impedance relay characteristics for two zones of protection is shown in the Fig. 4.Impedance settings for the two zones are given in Table 2.

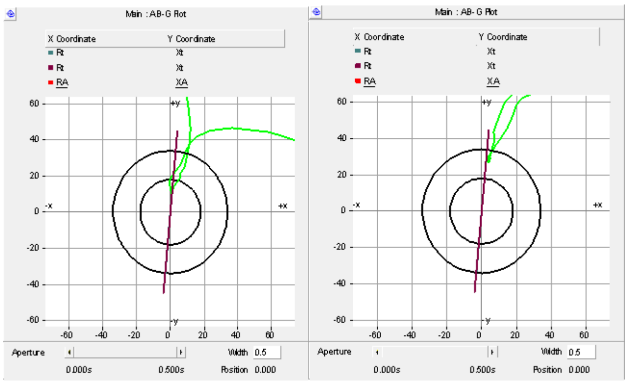
Table II: Settings of Zones of Protection

Zone	R	X
1	1.936 Ω	18.068 Ω
2	3.631 Ω	33.877 Ω

IV. SIMULATION RESULTS

To study the behaviour of the developed impedance relay model different fault locations on the 220kv, 100km transmission line with different fault resistances were simulated in PSCAD. The behavior of the impedance relay is as explained hereinafter.

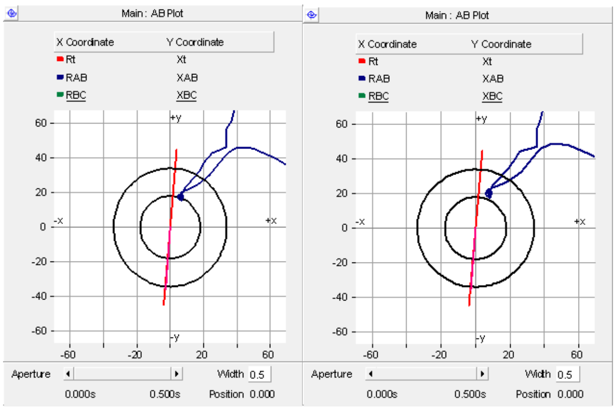
Case 1: - L-G faults at different distances from the relay location.



a) At 5 Km from Bus-B b) At 10 km from Bus-C

Fig. 6. Impedance trajectory of the relay for LG fault at different locations

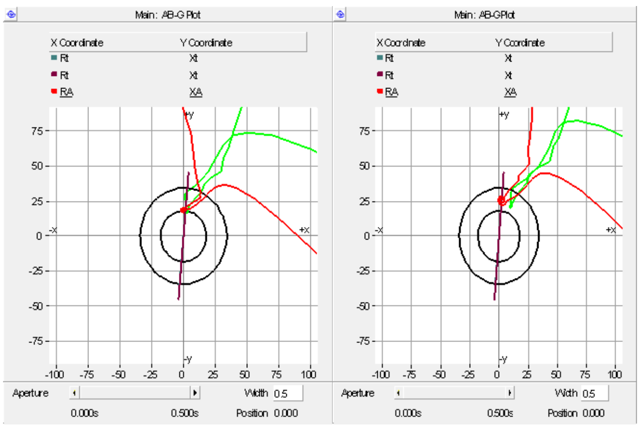
Case 2: L-L fault at different distances from relay location



a) At 15 Km from Bus-B b) At 5 km from Bus-C

Fig. 7. Line Impedance trajectory of the relay for LL fault at different locations

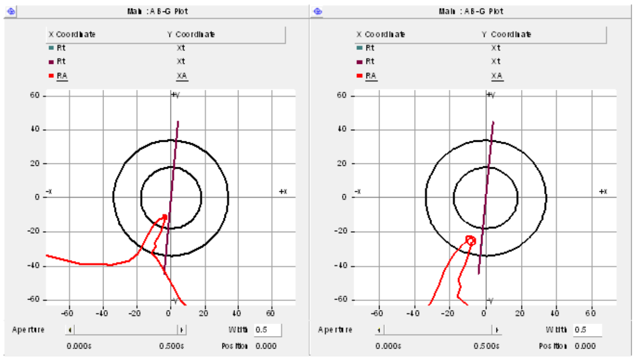
Case 3: LL-G fault at different distances from relay location



a) At 15 Km from Bus-B b) At 10 km from Bus-C

Fig. 8. Impedance trajectory of the relay for LL-G fault at different locations

Case 4: Reverse L-G fault

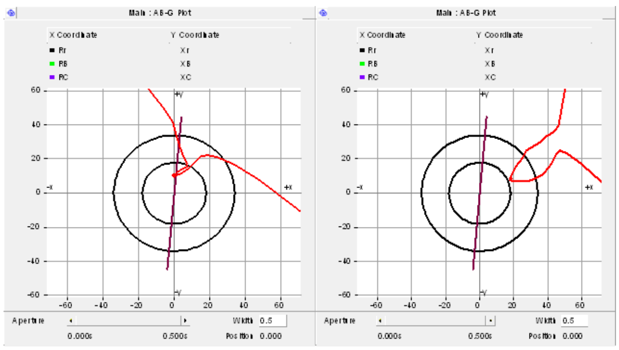


a) At 40 Km from Bus-A b) At 20 km from Bus-A

Fig. 9. Impedance trajectory of the relay for reverse LG fault at different locations

Case 5: 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 distance 15km from bus B. Fig. 5 shows the behavior of the relay when fault resistance is 0.1 Ω and 15 Ω. In first case the relay detects the fault in zone 1. In the case the even though fault is in zone 1 due to increase in fault resistance impedance seen by the relay lies in the zone2.



(a) Fault resistance of 0.1Ω (b) Fault resistance of 15Ω

Fig. 10. Impedance trajectory of the relay for AG fault with different fault resistances

V. CONCLUSIONS

In this paper Impedance relay model is developed using PSCAD/EMTDC software. The performance of Impedance relay model characteristics evaluated at different locations at various types of faults with different fault resistance. Main conclusion of this work is as follows

- Different case studies have been presented in order to illustrate the response of the developed distance relay model at different operating conditions, i.e. non-resistive faults and resistive faults. Resistive fault causes the relay to under-reach.
- The developed distance relay model may be used as a training tool to help users understand how the relay works.

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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