PREDICTION OF UNSYMMETRICAL FAULTS IN SMART POWER SYSTEM USING MHO RELAY CHARACTERISTICS

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Abstract : This paper deals with model of Mho relay characteristics for the prediction of unsymmetrical faults in a power system using PSCAD software. Mho relay characteristics, frequency dependent phase model type transmission line is modelled and simulated using PSCAD Software. To study the performance of the relay characteristics, line to ground faults at different locations are considered. The test network used in this paper is 220kV transmission line system. 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. Impedances are compared and the location of fault is predicted in the power system. A 100km long transmission line divided into 2 zones of protection is modelled in this paper.

***Index Terms* - Mho relay, PSCAD, Unsymmetrical faults, Zone impedance, Simulation.**

I. INTRODUCTION

The protection of the power system from the deleterious effect occurs as a random event. Hence, the power supply should be such that it delivers the generated energy to utilization load economically [3]. An electrical power system consists of generators, transformers, and transmission and distribution lines. Often, abnormal condition arises in the power system which causes the change in the impedance of the line, which is called as fault [3].

Fault may be short circuit fault or open circuit fault causing damage to the important sections of the power system. In order to protect the healthy line from the fault line, circuit breakers and relays (protective devices) are used under the fault condition to prevent the damage of the equipment of the power system. The function of relay is to detect and locate a fault and to send command to circuit breaker to disconnect the faulty element [4].

In this paper, study of the unsymmetrical fault (specifically, LG fault) in power system using Mho relay is simulated using PSCAD software. PSCAD software is an electromagnetic transient analysis program developed by the Manitoba HVDC research center having variety of steady state and transient power system studies [5].

Mho relay also known as Admittance relay is a high-speed relay which combines the properties of impedance and directional relay. It is inherently directional and only operates for faults in front of the relay location, since it detects the fault only in forward direction. The modelling is done by taking voltage and current parameters from the voltmeter and ammeter respectively at the relay location and an apparent impedance is calculated using the Fast Fourier transform block in PSCAD. The developed relay model is tested on 220kV, 50Hz power network.

II. SYSTEM ANALYSIS

This paper explains the protection of high voltage long transmission line using Mho relay by zone protection method and analysis of the Mho characteristics for the fault in the different locations of transmission line. The most effective and fast method to analysis the short circuit (unsymmetrical fault) is by using the distance relay. This section presents the methodologies used to determine the Line to Ground fault in a power system using Mho characteristics.

2.1. Distance relay

Distance relay is mainly used in high voltage transmission lines as the main protection device. Distance protection is the widely used method for the short circuit study, since it compares impedance of the line with the apparent impedance as seen by the relay form the relay location [4]. The current and voltage input from the current transformer and potential transformer respectively is obtained by relay during the fault occurrence. Distance relay protection can be classified into several zones, normally as zone1, zone2 and zone3. In this paper, protection is set for two zones i.e. zone1 and zone2 as shown in Fig1. Relay acts as the main protection for the fault which occurs within the zone1 where as zone2 and zone3 are zones of the protection for the adjacent lines [2].

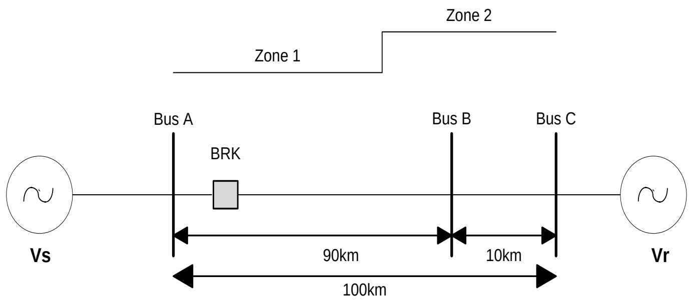

Fig. 1. Block diagram

2.2. Types of distance relay

Distance relays are classified depending on their operating characteristic in the R-X plane.

2.2.1. Impedance relay

An impedance measures the impedance of the line at the relay location. When a fault occurs, the measured impedance is the impedance of the line section between the relay location and the point of fault. Which is proportional to the length of the line and hence to the distance along the line. In distance relaying terminology the term impedance includes both resistance and reactance. And in this type of relay, current actuates operating torque and voltage actuates the restraining torque. The disadvantage of impedance relay is, it is not directional. And it is also affected by the arc resistance and is highly sensitive to oscillations on the power system.

2.2.2. Reactance relay

The reactance relay has an overcurrent element developing positive torque, and a current-voltage directional element that either opposes or aids the overcurrent element, depending on the phase angle between the current and the voltage. In other words, the reactance relay is an over-current relay with directional restraint. The directional element is arranged to develop maximum negative torque when its current lags its voltage by 90°. The reactance relay is designed to measure only reactive component of the line reactance and the fault resistance has no effect on the reactance relay.

2.2.3. Mho relay

The Mho relay also known as Admittance relay is a voltage controlled directional high-speed relay. It combines the properties of impedance and directional relay. It consists of two torque for the operation, operating torque and restraining torque. The operating torque is obtained by volt-ampere element and restraining torque by voltage element [1]. Mho characteristics when plotted on impedance diagram (R-X diagram) is a circle passing through the origin, which makes relay naturally directional. The relay because of its directional characteristic, requires only one pair of contacts which makes it fast tripping for fault clearance and reduces the burden on current transformer [2]. Mho relay is widely used in the long transmission over the other two relay because the long lines are highly exposed to the power swing, load shedding effect and the long lines are not fully loaded, therefore in practical use the Mho relay provides the better accuracy and avoids the unwanted trip due to these transient changes.

2.3. Methodology

Mho relay estimates the distance to a fault by calculating the voltage to current ratio. In this paper, the relay is set on the basis of the positive sequence impedance, from the relay location up to the end point on the line which are protected under the zones. Zone1 covers between 80-90 percent of the entire length of the protected line and the zone2 covers the entire line and in addition to that, it provides the backup protection to the next shortest adjacent line as shown in the Fig 1.

During the fault condition, the voltage and current signal consists of the dc component, higher order frequency components and lower frequency components. The higher frequency can be removed by using anti-aliasing low pass filters with the appropriate cut-off frequency but it cannot remove the dc offset so it manipulates the performance of any digital relay. So Fast Fourier block in PSCAD is used to remove the dc offset. Fast Fourier transform is efficient computation of the DFT which extract the magnitude and the phase of each voltage and current phasors [6]. The signal (voltage and current) from the FFT block is given to sequence filter block to perform the calculation of phase angle and magnitude of the signal. Fig 2 shows the algorithm of the mho relay.

The signal from the FFT and sequence filter block is fed to the impedance block whose output will be voltage-current ratio. To determine if a fault has occurred in the zone, the measured impedance (Z_M) is compared against the known impedance of the reach point (Z_{RP}). This is carried out by Mho circle component in PSCAD.

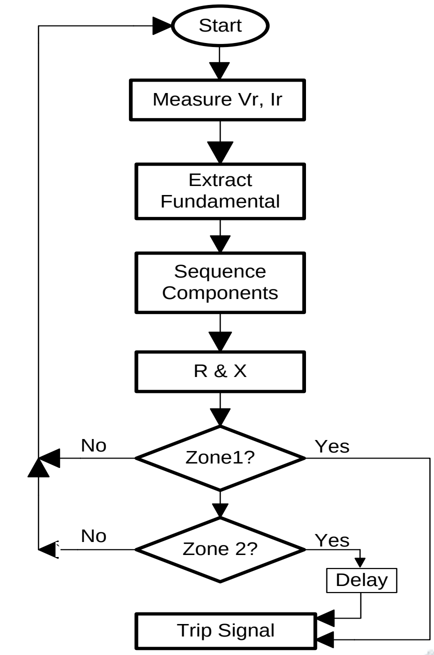

Fig. 2. Algorithm of Mho relay

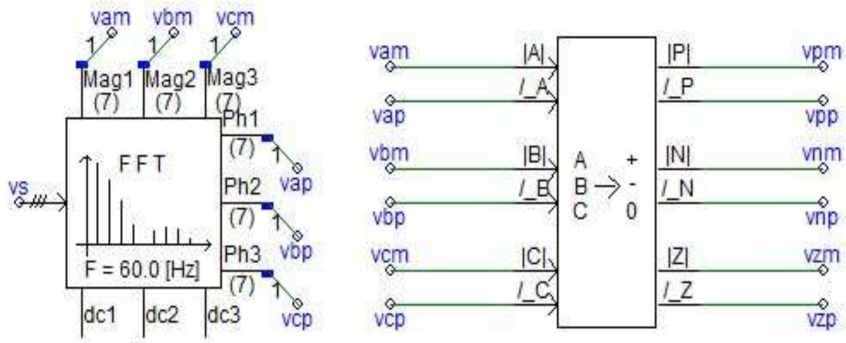

Fig. 3. FFT and sequence filter block of line voltage (V_S)

It compares the Z_M against $Z_{RP,}$ if Z_M falls within the trip zone then the logic circuit concludes that fault has been occurred in a system and simultaneously interrupts the breaker(B1) [7]. But the logic circuit (Fig 4, shows logic circuit for L-G fault) receives signals from all the lines of the system and hence it cannot determine in which line the fault has been occurred and the location of the fault. To determine this, the analysis of impedance path of each line in the Mho circle is done.

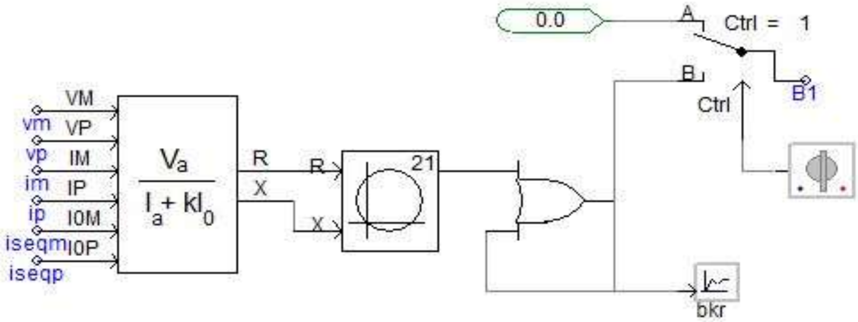

Fig. 4. Logic unit for L-G fault in single line

III. DESIGN CALCULATION

Mho relays protects the power system against all types of unsymmetrical faults like line-ground fault, line to line fault, line to line ground fault and three phase fault. In this paper, the system is modelled and simulated for line-ground fault for all the phases. In order to calculate the impedance of each of the zones, the following formula as shown in table1 are used.

Table 1. Fault impedance calculation on different L-G faults

Distance element	formula
Phase A	$Z_A = V_A/(I_A + 3kI0)$
Phase B	$Z_B = V_B/(I_B + 3kI0)$
Phase B	$Z_C = V_C/(I_C + 3kI0)$

Where:
A, B and C indicates faulty phases, G indicates ground fault
V_A, V_B and V_C indicate voltage phases
Vs is phase voltage during the phase to ground fault
I_A, I_B and I_C indicate current phases
Z_A = impedance of phase A
Z_B = impedance of phase B

z_C = impedance of phase C
k = residual compensation factor
where, $k = (Z_0 - Z_1)/kZ_1$ (1)
(k can vary from 1 to 3 depending upon the relay design)
$I_0 = (Vs / Z_0 + 2Z_1)$ (2)

Transmission lines are usually protected by step distance protection using the Mho or quadrilateral relay characteristic with three or four zones of protection. Each zone of protection is based on a percentage of the line impedance, which varies depending on the philosophy and criteria of each utility. However, in this paper, zone 1 is 90%, zone 2 is 120%.

The total line impedance in per unit $(Z_L)_{PU} = 0.684\Omega$ (3)
Thus, for each zones' coverage area:
Zone1: 90 % of the transmission line
$Z_L = (0.9\times90\times0.684)$
$=31.45 \sim 32\ \Omega$ (4)
Zone2**:** 120% of line = 100 % + 20 % of the adjacent
$Z_L = (1\times90\times0.684) + (0.2\times10\times.684)$
$= 41.77 \sim 42\ \Omega$ (5)

The Z_L is the positive sequence primary phase-to-neutral line impedance. In a 50 Hz system, the impedance is about 0.8 Ω/mile. The angle (α) of this impedance depends on the conductor size and spacing, but generally it is in the range of 70-85 degrees for an overhead line [8]. In the design, value of α is taken as 80°. Once plotted, we can easily observe that the line R+jX components can be derived by the following relationship for the zones:

Zone1-

- Resistance, $R = Z_L \times \cos\alpha$ (6)
  $=32\times\cos(80)$
  $=5.5\ \Omega$ (7)
- Reactance, $X = Z_L \times \sin\alpha$ (8)
  $=32\times\sin(80)$
  $=31.5\ \Omega$ (9)

Zone2-

- Resistance, $R = Z_L \times \cos\alpha$
  $=42\times\cos(80)$
  $=7.25\ \Omega$ (10)
- Reactance, $X = Z_L \times \sin\alpha$
  $=42\times\sin(80)$
  $=41.36\ \Omega$ (11)

IV. SIMULATION

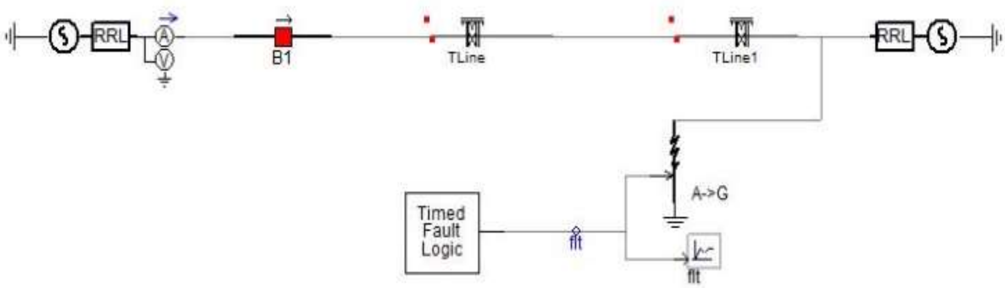

Fig 5. Simulation module

Study of the developed relay model for different unsymmetrical faults on the 220kV, 50Hz, 100km transmission line with different fault resistances and fault location was modelled and simulated in PSCAD software. Simulation model is shown in Fig 5. The model consists of 3 phase generator, 220kV-100km long transmission line, a circuit breaker which is situated near to the source, ammeter and voltmeter to measure the current and voltage signals respectively, fault logic to enable the fault at particular time for a given period.

4.1. Transmission Line design Parameters:

- Voltage = 230kV
- Frequency = 50Hz
- Positive & Negative Sequence Impedance,
  (Z_1) & (Z_2) = 0.1231 + j0.673 Ω/km
- Zero Sequence Impedance(Z_0)
  = 0.0894 + 0.2398 Ω/km

V. SIMULATION RESULTS

Simulation are performed to get an early view of a design. The simulation was done using PSCAD and expected results were obtained for 220kV 100km transmission line using Mho relay and analysis of the impedance path of the Mho characteristics of a relay was performed. The fault was been created for duration of 0.1sec at the instant t=0.2sec.

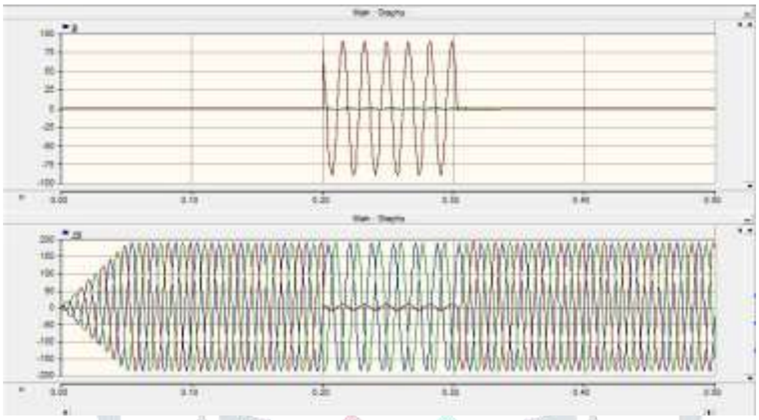

Fig. 6. Vs and Is during C-G fault

From the Fig 6, it is observed that when the fault occurs, current flowing through the line increases and the voltage across the source will decrease (approx. zero). This results in increase of admittance value or decrease in the impedance value.

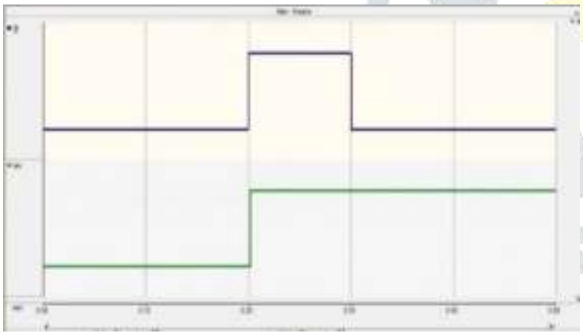

Fig 7. Fault signal and trip signal condition in zone1

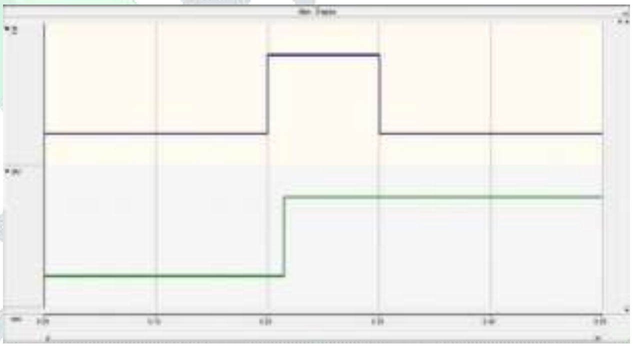

Fig 8. Fault signal and trip signal condition in zone2

If the fault is seen under zone1, then fault point will be near to breaker i.e. less than 90% of transmission line, then the relay trips and operate the breaker instantaneously. If the fault is detected under the zone2 then fault point will be between 90-120% of the transmission line. If the fault is in zone2 then the relay takes a greater number of cycles to determine the fault hence breaker takes higher time to operate after certain delay, as shown in the above graph.

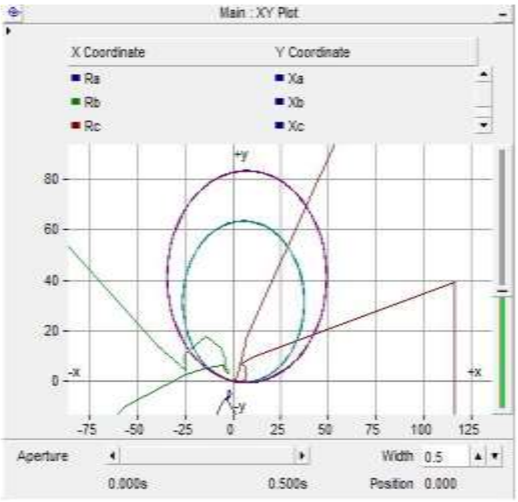

Fig. 9a. C-G fault within 90% line

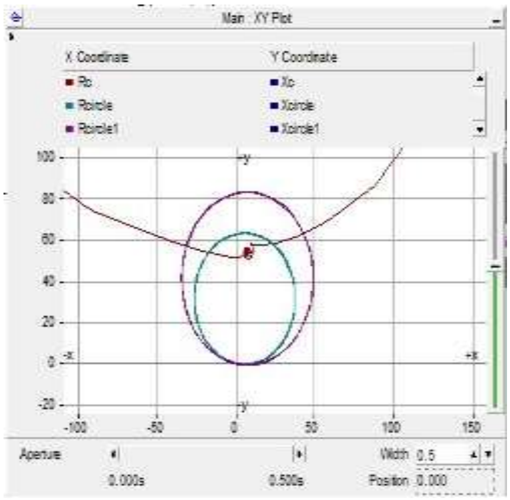

Fig. 9b. C-G fault between 120% line

The fig 8a and 8b shows trajectory of the impedance path of line in zone1 and zone2 respectively. The above graph shows the mho characteristics of the relay. The study of the mho circle is essential for the setting of the relay impedance for the different zone. The diameter of the mho circle is equal to the reach point impedance. During the fault condition the impedance of a line fall inside the circle which makes the relay to command the breaker to operate.

VI. CONCLUSION

In this paper, the prediction of the unsymmetrical fault has been determined and analyzed by the study of mho characteristics. Mho relay is developed using PSCAD software. The performance of the mho relay is evaluated at the different location for the unsymmetrical fault on 220kV transmission line. The result from the previous part shows the adaptability of the proposed scheme at different location of the transmission line. The scheme started with calculation of impedance of the line for the different zone. The voltage and current parameter of the source is considered. Finally, the measured impedance is compared with calculated reach point impedance.

VII. ACKNOWLEDGMENT

The authors are grateful to Dr. Niranjan N Chiplunkar, Principal, NMAM Institute of Technology, Nitte for the opportunity and Dr. Nagesh Prabhu, HOD, Department of Electrical and Electronics Department for the support. The authors are also immensely grateful to Mr. Dinesh Shetty, Assistant Professor Dept. of Electrical and Electronics Engineering for his guidance and comments that greatly improved the paper.

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