# Differential Protection for $\Delta - Y$ Connected Power Transformer

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***Abstract:*** **This paper brings an idea for dual slope differential relay parameters for the various faulty conditions on the system. Differential protection of transformer is a unit type protection scheme. The protection scheme should only operate for the internal fault, and must remain stable for the external fault and during magnetizing inrush current due to energization of the transformer under no load condition and also due to external fault removal. Fast Fourier Transform technique is used to provide the operating quantity for the dual slope differential relay. A standard power system model is simulated using PSCAD/EMTDC software and is run for various internal fault and no fault conditions. The differential current obtained from the various cases is used for further analysis to distinguish internal fault from no fault conditions.**

***Keywords:*** **Differential protection, Inrush current, Power transformer**

**Introduction**

The basic operating principle of differential protection is to calculate the difference between the current entering and leaving the protected zone. There is a phenomenon that occurred during removal of external through fault or due to energization of the transformer under no load condition named magnetizing inrush current. The differential protection scheme should remain insensitive for such magnetizing inrush current. The protection operates when the differential current exceed the set bias threshold value. For external faults, the differential current should be zero, but error caused by the CT saturation and CT ration error leads to non-zero value. To prevent maloperation the operating threshold is raised by increasing the relay setting. Mal-operation of the differential protection of power transformer may occur due to Magnetizing inrush current, CT saturation and Through Fault Inrush. Among all these three; magnetizing inrush results during excitation of Transformer under no load condition. It can also come in to picture during the energization of parallel connected power transformer. To set the relay four different relay parameters are needed.

IS1: The basic differential current setting
K1: The lower percentage bias setting
IS2: The bias current threshold setting
K2: The higher percentage bias setting

Fast Fourier Transform technique is used for preventing the maloperation. The secondary current signals from the CTs are sampled at a regular interval. This is an online Fast Fourier Transform (FFT), which can determine the harmonic magnitude and phase of the input signal as a function of time. The input signals first sampled before they are decomposed into harmonic constituents. PSCAD software includes the online FFT block which is shown below. The tripping criteria can be formulated as:

CASE 1: $I_{bias} < I_{s2}$ if, $I_{diff} > K_1 \times I_{bias} + I_{s1}\ THEN\ TRIP$
CASE 2: $I_{bias} < I_{s2}$ if, $I_{diff} > K_2 \times I_{bias} - (K_2 - K_1) \times I_{s2} + I_{s1}\ THEN\ TRIP$

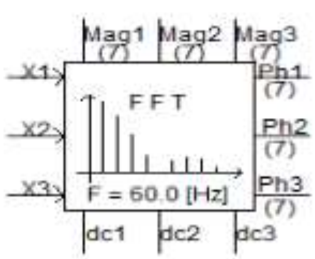


Fig 1.1 Fast fourier transform block

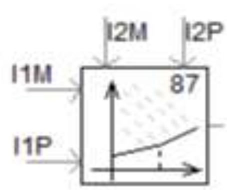


Fig 1.2 Dual slope differential relay element

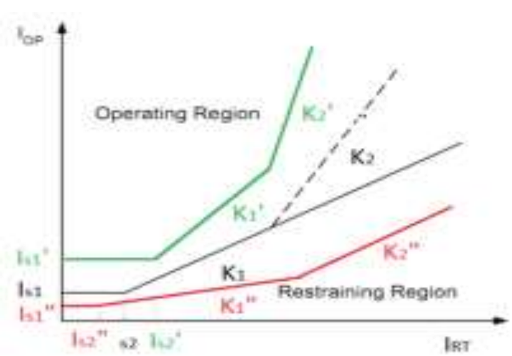


Fig 1.3 Dual slope differential relay characteristics

## I. SYSTEM MODEL

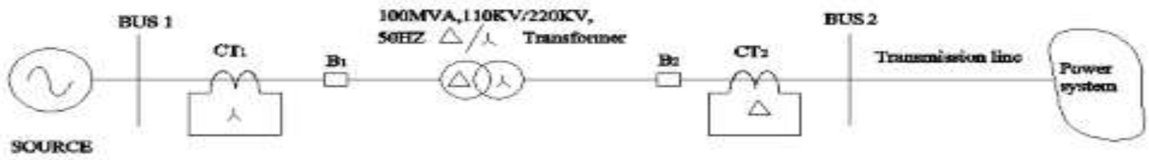


Fig 2. System model

PSCAD/EMTDC software is used for modeling and simulating a power system. A part of power system consisting of an 110KV source, three phase 100MVA, 110KV/220KV, 50 Hz, Δ/Y transformer connected to an infinite bus bar is modeled and simulated as shown in Figure2. Two circuit breakers B1 and B2 are installed on LV and HV side of the transformer and are controlled by variable slider with time varying from 0 to 5secs. The two breakers are kept open as default and can be closed at any desired time between 0sec and 5secs. The type of fault is varied with the help of fault type control dial. The following is the list of the input control dial values that correspond to specific fault types.

0 = No Fault
1 = Phase A to Ground
2 = Phase B to Ground
3 = Phase C to Ground
4 = Phase AB to Ground
5 = Phase AC to Ground
6 = Phase BC to Ground
7 = Phase ABC to Ground
8 = Phase AB
9 = Phase AC
10 = Phase BC
11 = Phase ABC

Timed fault logic is used specifically for controlling the time of the fault start and duration of fault from 0 to 5secs. The fault resistance can also be varied from 0 to 150 s. The fault locations can also be varied. For internal faults, the fault is located within the two CTs, whereas for external faults, the fault is located outside the two CTs. The rated current on the LV side with 110KV is 525A and the rated current on the HV side with 220KV is 262A. Therefore, CT 1 of turn's ratio of 600:1 is installed on the LV side and CT of turn's ratio of 300:1 is installed on the HV side. Voltage and current waveforms on both LV and HV side are plotted for analysis. Vector correction is done to the difference of the secondary currents of the two CT's and the differential current is calculated and plotted. The restraining current is also calculated and plotted. The fundamental, second harmonic and the third harmonic components are plotted for all the three phases of the differential current. The channel plot step is 500 s i.e., 2000 samples/sec. The current waveform generated using PSCAD/EMTDC is of 50Hz i.e., 50cycles/sec. Therefore, there are 40 samples/cycle i.e., 400 samples for 0.2sec. Harmonic restraint differential relay operates only when the differential current is greater than the restraining current and also when the second harmonic component is less than 15% of the fundamental component of the differential current.

## II. : SIMULATION AND RESULT

1. Simulation for normal operating condition

PSCAD/EMTDC simulation is run for a normal operating condition with both the breakers B1 and B2 closed at 0sec. No fault is applied. The simulation is run for 0.2sec and the results are shown in the Figure3.1.V1B and V2B are the bus voltages on the LV side and HV side of the transformer respectively and V1B is plotted on the Y-axis. I1s represents the current in the secondary side of the CT1 in Amperes (A) and I2s represents the current in the secondary side of the CT2 in amperes. X-axis represents the time in seconds. The differential current and restraining current are calculated and plotted. It is observed from the results in Figure3.1 that the restraining current is higher when compared to the differential current during normal operating conditions. The results in Figure3.1, show that the second harmonic component is only 1% of the fundamental and is below the harmonic setting (15%). The harmonic restraint differential relay does not operate as the restraining current is greater than the differential current.

2. Simulation for A-G internal fault with fault resistance of 4Ω

Faults which occur in between the two CTs of the transformer are called internal faults. Single phase A to Ground (A-G) internal fault with a fault resistance of 4Ωis applied in between the breaker B1 and the transformer at 0.1sec for duration of 0.05sec. Both the breakers B1 and B2 are closed at 0sec. PSCAD/EMTDC simulation is run for 0.2secs and the results are shown in Figure3.2. The voltage and current waveforms clearly show that fault has occurred in phase A, as the voltage has dropped heavily and the current has increased heavily in phase A. The differential current and restraining current is calculated and plotted. The differential current waveform shows that fault has occurred in phase A. It is also observed from the results in Figure3.2 that the differential current is higher when compared to the restraining current during A-G internal fault. It is noted that the fundamental component of the differential current of the faulty phase i.e., phase A increases very high after 0.1sec, as the fault current increases very high during fault. It is also noted from the results that the second harmonic component takes one cycle to settle down to approximately 1% of the fundamental component and is below the harmonic setting i.e., 15%. From the results, it is concluded that though the differential current is greater than the restraining current, but the condition for harmonic restraint gets satisfied only after one cycle. Therefore, harmonic restraint differential relay operates for the A-G internal fault only after one cycle.

3. Simulation of A-G external fault with fault resistance 15Ω

External faults are the faults which occur outside the protective zone. A-G external fault of resistance 15Ω occurs beyond the breaker B2 at 0.1sec for duration of 0.4sec. Both the breakers B1 and B2 are closed at 0sec. PSCAD/EMTDC simulation is run for 0.5secs and the results are shown in the Figure3.3. From the results, it is seen that the percentage of second harmonic component is below the harmonic setting in all the three phases but the restraining current is more than the differential current. Thus, the relay restrains for external faults.

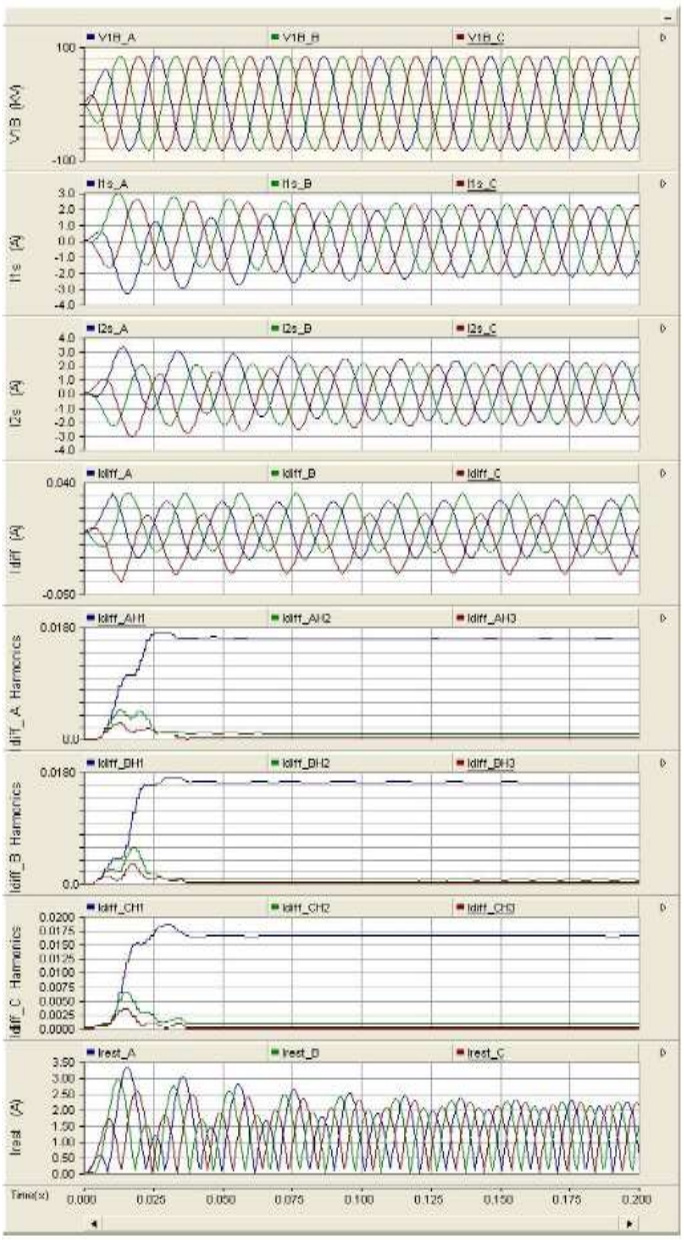


Fig 3.1 Simulation for Normal Operating Condition

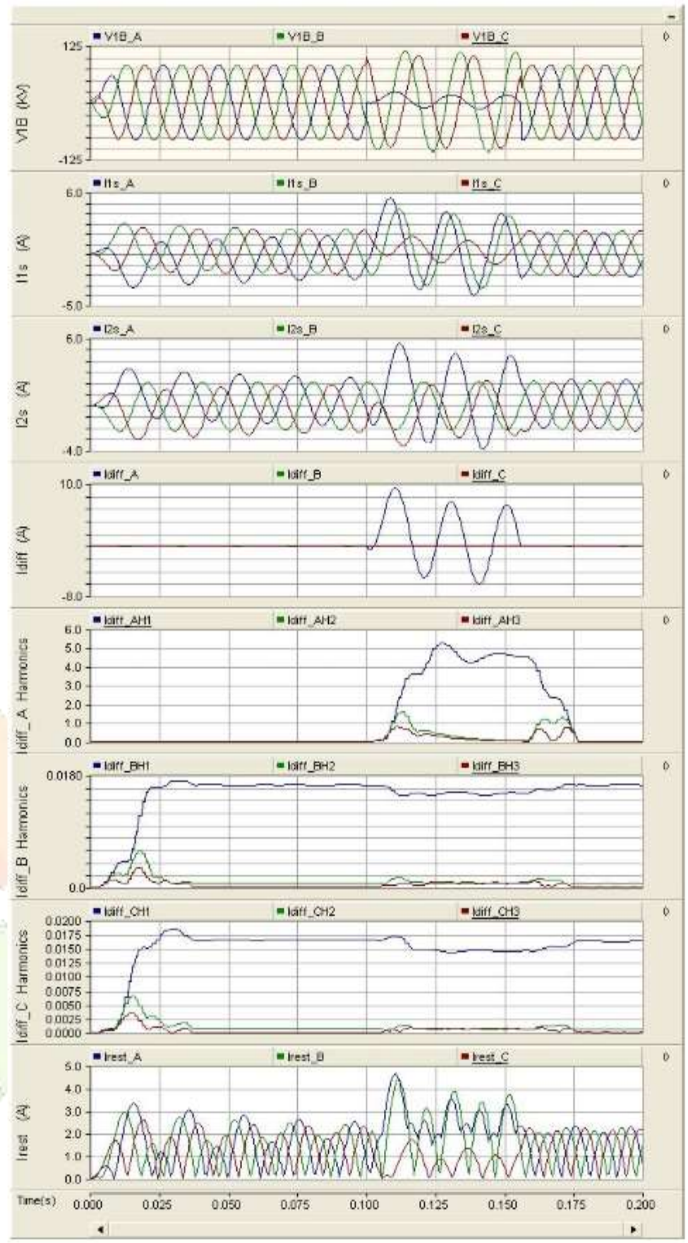


Fig 3.2. Simulation of A-G internal fault with fault resistance of 4Ω

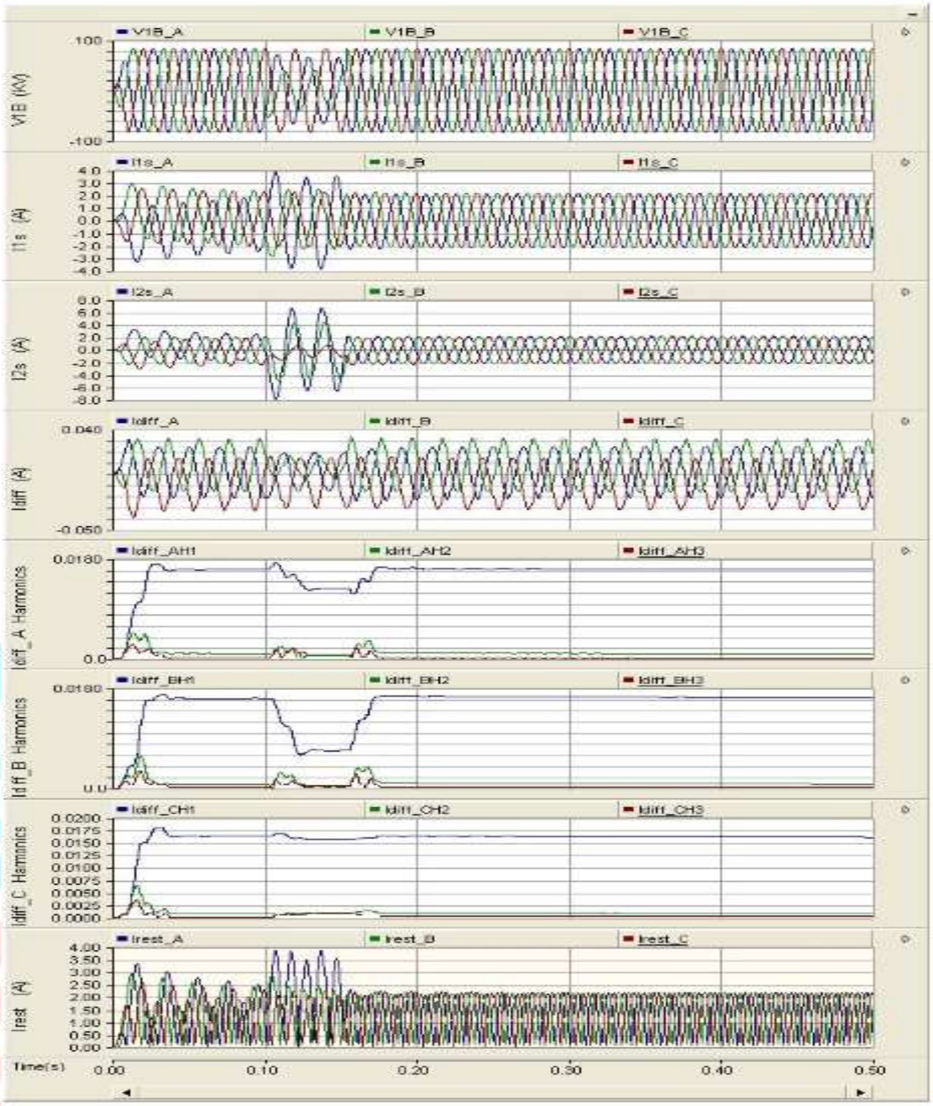


Fig 3.3 simulation of A-G external fault with fault resistance of 15Ω

## III. CONCLUSIONS

In this paper a standard power system model is simulated using PSCAD/EMTDC and the results are obtained for various types of internal and external fault. Effective setting of the four basic parameters of the dual slope differential relay will prevent any maloperation of the differential protection scheme. FFT is used to provide the different harmonic content in the supply signal. To provide safe operation of differential relay the differential current threshold is to be raised under no-load condition, but care must be taken for the relay sensitivity for internal fault. The second slope K2 is selected based on the CT saturation possibility.

| Sr. No | Differential Relay Parameter Setting | | |
|---|---|---|---|
| | Parameter | Symbole (P.U) | Value |
| 1 | Differential current threshold | IS1 | 1.9 |
| 2 | Lower percentage bias setting | K1 | 0.6 |
| 3 | Bias current threshold setting | IS2 | 1.2 |
| 4 | Higher percentage bias setting | K2 | 0.8 |

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