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# Review on Digital Differential Protection of Power Transformer

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**ABSTRACT:**This paper gives a brief general review of the principles of transformer digital differential protection. The word "Protection" is employed to explain the full concept of protecting an electrical power system. Transformer protection is that the vital significance to produce reliable operation of grid. The most challenge in transformer protection is to seek out a quick and efficient differential relay algorithm that isolates the transformer from the system causing the least damage. Digital differential protection is a developed idea of the old system of conventional differential protection, which had made perfect solution to the issues that the old system suffers. During this paper, differential protection using relay is presented. MATLAB/SIMULINK platform were accustomed analyze differential protection relay for an outsized power transformer.

**KEYWORDS**: Differential relay, Differential protection.

## I. INTRODUCTION

Power transformers are the most important equipment in substation and power stations. Thus, protection of the power transformers is vital important for proper operation of power system. Among various power transformer operations, the differential operation is the most common method.A power transformer is a static piece of device with two or further windings. It works on the principle of electromagnetic induction in which it transforms a system of interspersing voltage and current into another system of voltage and current generally of different values and at the same frequency for the purpose of transmitting electrical power. Power transformer is one of the most important Apparatus in electrical power system, for which numerous types of self-protective andmonitoring schemes have been developed for numerous times. A power transformer is a veritably precious electrical device, and itsoperation directly affects the performance of another outfit to which it's connected.

## II. CONVENTIONALDIFFERENTIAL PROTECTION SCHEME

A differential protection scheme is applied on busses, generators, transformers, and huge motors. Specialized relays exist for every of those applications, and their settings are described in the manufacturer's literature.

Differential relays need careful choice of current transformers. The total winding ought to be used once multi quantitative relation CTs are utilized in differential schemes, and different relays and meters ought to be fed from totally different current transformer circuits. Transformers differential protection needs current transformers with restricted couple. Generally, differential protection is applied to electrical device banks of 10 MVA on top of. The secret's the importance of the electrical device within the system, differential is also fascinating for smaller units to limit harm in essential interconnections. The elemental operative principle of electrical device differential protection relies on comparison of the electrical device primary and secondary coil currents. For a perfect electrical transformer, having a 1:1 quantitative relation and neglecting magnetizing current, the currents getting into and going away the electrical device should be equal.

This scheme is based on the concept that under normal conditions the input power to the power transformer id equal to the output power and no current will flow into the differential relay current coil. Whenever a fault occurs, within the protected zone, the current balance will not exist for long, and the relay contact will close the primary and secondary winding currents of the power transformer. Current transformers are used to reduce the currents in such a way that the secondary side currents are equal. Fig1 shows the differential relay in simplest form. The polarity of currenttransformer is such as to make the current flow normally without going through the

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relay,during normal load conditions and external faults.

The differential relay really compares between primary current and secondary current of power transformer device, if any unbalance encountered in between primary and secondary currents the relay actuates and entomb trip each the first and secondary electrical fuse of the electrical device. In fig1 shows the differential relay in its simplest form.

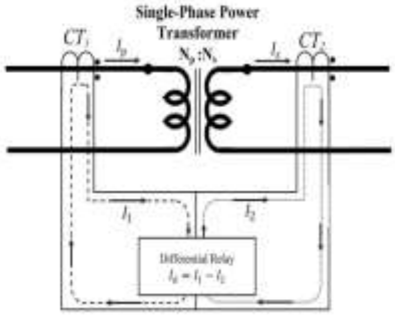


**Figure 1: Differential protection scheme**

According to the conventional percentage differential relay is the differential current Id is more than a predetermined percentage of the restrain current Ir shown in figure below.

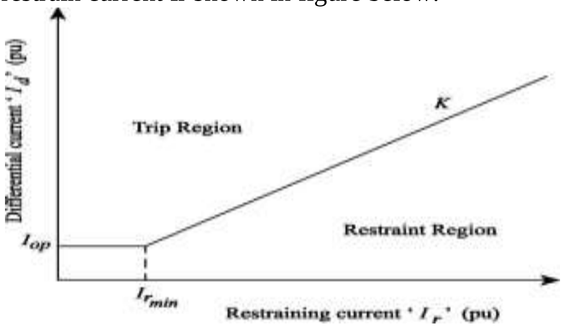


**Fig2: percentage relay differential characteristics.**

A number of factors have to be compelled to be taken into consideration in planning a scheme to fulfil these objectives. These embrace Current imbalance made by tap changing, Handling zero sequence currents, phase shift through the transformer, Magnetizing inrush current.

CTs ratings chooses carefully to be exactly matched with the power transformer current ratings to which they are connected so as the secondary winding side currents are equal. However, the problem is that the Current transformer ratios available in the market have standard ratings. They are not available same as the desired ratings. Therefore, the primary ratings of the CTs are usually limited to those of the available standard ratio Current transformers. Commonly the primary side of the current transformer has only one turn and the secondary side has many turns depending on the transformation ratio (N) of the Current transformer, that is chosen to match the ratings of the power transformer. The transformation ratio of transformers is the ratio between the number of turns in the primary side to the number of the turns in the secondary winding side. Therefore, the turn ratio of the primary side current transformer and the secondary side CTs are 1N1 and 1N2 respectively. The turn ratio of primary side of current transformer and the turn ratio of secondary side of the power transformers are 1/N1 and 1/N2 respectively. The secondary CT current located in the primary side of the power transformer is

$$I_1 = \frac{I_P}{N_1} \qquad \dots (1)$$

where

$I_P$: primary side current of power transformer, $N_1$:no. of turns in secondary side of CT1, $I_1$ secondary side current of CT1

Now for the CT located at secondary side of power transformer is

$$I_2 = \frac{I_S}{N_2} \qquad \dots \ (2)$$

Where

$I_S$: secondary side current of power transformer, $I_2$: secondary side current of CT2, $N_2$: no. of terns in secondary side of CT2

As the differential current is $I_d = I_1 - I_2$ ,

Then from equation (1) & equation (2) the differential current from the relay operating coil is

$$I_d = \frac{I_P}{N_1} - \frac{I_S}{N_2} \qquad \dots (3)$$

if there is no internal fault occurring inthe power transformer protected zone, the currents $I_1$&$I_2$ are assumed to be equal in magnitude and opposite in direction. it means that the differential current $I_d$=0 as shown in figure 1. The primary and secondary sides of current of the power transformer are related to each other by equation (4);

$$\frac{I_P}{I_S} = \frac{N_s}{N_p} \dots (4)$$

Where, $N_p$&$N_s$are the turns of primary and secondary side of powertransformer respectively.

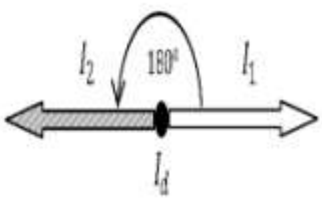


**Fig3: output currents of CTs, Equal in magnitude and opposite in direction**

If any fault occurs in the power transformer protected zone, the currents $I_1$ and $I_2$ are no longer equal in magnitude and opposite in direction. That means the differential current $I_d = I_d \angle \Theta$ shownin fig4.

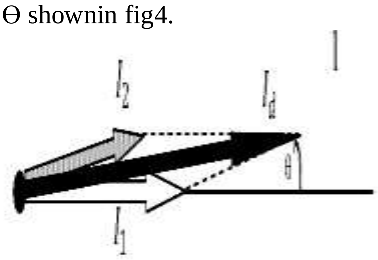


**Fig4. CTs output current not unequal in magnitude & direction**

The current $I_d = I_d \angle \Theta$ introduces relay operating to trip signal to the circuit breaker for isolation.
From equation 4, the secondary current w. r. t primary of the power transformer is

$$I_S = \frac{I_p * N_p}{N_s} \quad \ldots (5)$$

By multiplying equation (3) & (5),

$$I_d = \frac{N_p}{N_2}\left(1 - \frac{\frac{N_p}{N_s}}{\frac{N_2}{N_1}}\right) \quad \ldots (6)$$

$$\rho = 1 - \frac{\frac{N_p}{N_s}}{\frac{N_2}{N_1}} \quad \ldots (7)$$

from equation 6, it is clear that the termρ is equal to zero as to make $I_d = 0$.

$$\frac{N_2}{N_1} = \frac{N_p}{N_s} \ldots (8)$$

In power transformers, the input power is up to the output power. However, thevoltage and therefore the current in each the primaryand secondarysides are completely different looking on whether or not the transformer is accelerated (step up) or step down.

## III. DIFFICULTIES IN CONVENTIONAL SCHEME

Generally, there are three main difficulties in the conventional protection scheme They induce the differential relay to release a false trip signal without the existing of any fault. These complications should be overcome so as to create the differential relay operating properly.

- Magnetizing inrush current during initial energization,
- CTs Mismatch and saturation,
- Transformation ratio changes due to Tap changer.

3.1 Magnetizing inrush current

This phenomenon, the transient magnetizing inrush or the exciting current, occurs in the primary side of the transformer whenever the transformer is switched on (energized) and the instantaneous value of the voltage is not at900. At this time, the first peak of the flux wave is higher than the peak of the flux at the steady state condition. This current appears as an internal fault, and it is sensed as a differential current by the differential relay. The value of the first peak of the magnetizing current may be as high as several times the peak of the full load current. The magnitude and duration of the magnetizing inrush current is influenced by many factors, some of these factors are

- The instantaneous value of the voltage waveform at the time of closing CB,
- The value of the residual magnetizing flux,
- The sign of the residual (remnant) magnetizing flux,
- Type of iron laminations used in the transformer core,
- The transformer core saturation flux density,
- The full impedance of supply circuit physical size of the transformer,
- The maximum flux-carrying capability of the iron core laminations
- The voltage level of input supply.

The impact of the inrush current on the differential relay is fake tripping the transformer while not of any existing sort of faults. From the principle of operation of the differential relay, the relay compares the currents returning from each side of the power transformer as explained. However, the inrush current is flowing solely within the primary side of the power transformer. So that, the differential current can have a big worth because of the existence of current in precisely one aspect. Therefore, the relay needs to be designed to acknowledge that this current may be a normal phenomenon and not to trip because of this current.

3.2 False trip due to C.T characteristics

The performance of the differential relays depends on the accuracy of the CTs in reproducing their primary currents in their secondary side. In several cases, the primary ratings of the CTs, set within the high voltage and low voltage sides of the power transformer, doesn't precisely match the power transformer rated currents. because of this discrepancy, a current transformersmismatch takes

place, that successively creates a small false differential current, depends on the amount of this mismatch. Sometimes, this quantity of the differential current is enough to work the differential relay. Therefore, CTs quantitative relation ratio correction has to be done to beat thisCTs mismatch by using interposing CTs of multi taps.

Another drawback which will face the perfect operation of the CTs is the saturation problem. once saturation happens to one or all CTs at totally different levels, false differential current seems within thedifferential relay. This differential current may cause mal-operation of the differential relay. The dc element of the primary side current could produce the worst case of CT saturation. In which, the secondary current contains dc offset and additional harmonics.

3.3 False trip due to tap changer

On-Load Tap-Changer (OLTC) is installed on the power transformer to control the transformer output voltage automatically. This device is needed wherever there are heavy fluctuations in the power system voltage. The transformation ratio of the CTs can be matched with only one purpose of the tap-changing range. Therefore, if the OLTC is changed, unbalance current flows within the differential relay operating coil. Thisaction causes CTs mismatches. This current is going to considered as a fault current which makesthe relay to release a trip signal.

## IV. DIGITAL DIFFERENTIAL PROTECTION

Many digital algorithms are proposed so far when the invention of the computer. These algorithms do an equivalent job with totally different accuracy and speed. The suitable speed consistent with IEEE standard for transformer protection is one hundred milliseconds. All fashionable algorithms are quicker than this IEEE normal. Nowadays, there are some algorithms performs their function in in the ten milliseconds. During this chapter, a quick formula is introduced. Its speed is within the vary of one to fifteen milliseconds. This formula is predicated on the Fast Fourier Transform formula (FFT). This algorithm isn't new; however, significant changes has been introduced to make it much quicker.

The planned digital differential relay is meant employing a simulation technique in MATLAB Simulink environment. The design is enforced to protect the power transformer against internal faults and stop interruption because of inrush currents.

This algorithm is made on the principle of harmonic-current restraint, where the magnetizing-inrush current is characterized by large harmonic components content that doesn't seems to be present in fault currents. Because of the saturated condition of the transformer iron, the waveform of the inrush current is highly distorted. The amplitude of the harmonics, compared with the fundamental is somewhere between 30% to 60% and the 3rd harmonic 10% to 30%. The other harmonics are progressively less. Fast Fourier Transform (FFT) is employed to implement this approach. Any periodic signal f(t)can be decomposed to its sine and cosine components as follows:

$$f(t) = \frac{a_0}{2} + \coprod_k = C_k\cos(kwt) + S_k\sin(kwt)$$

where: $a_0$ is the direct current component of f (t), and $C_k$, $S_k$ are the cosine and sine coefficients of the frequencies in f(t), respectively. The discrete forms of the coefficients $C_k$, $S_k$are as follows:

$$C_k = \frac{2}{N} \coprod_n = x(n)\cos(\frac{2kwt}{N})$$

$$S_k = \frac{2}{N} \coprod_n = x(n)\sin(\frac{2kwt}{N})$$

The Fourier harmonic coefficient is, $F_k = \sqrt{S_k^2 + C_k^2}$

Where: $F_k$is Kth harmonic coefficient for K = 1, 2, 3, …., N and x(n) is the discrete signal form. The FFT produces precisely the same results as DFT; but, the FFT is way quicker than DFT, wherever the speed of calculation is that the main consider this method.

Fig5; illustrates the flow chart of the designed digital Fourier Transform primarily based logic technique algorithm. In this algorithm the output currents of the current transformers undergo over two analysis processes, amplitude comparison process and harmonic content calculation process. The amplitude comparison between the Root Mean Square values of the current transformers output currents (|Id1—Id2|) is in the LHS of the flowchart, and the harmonic calculation is in the RHS of the flowchart.

The algorithm is implemented according to the following step for the amplitude calculation, if the absolute difference (|Id1—Id2|) between the current transformers output currents is greater than zero i.e., logic (1) takes place, which proves the case of an inrush current or any internal fault. Otherwise, if the logic (0) takes place, which proves a detection of an external fault.

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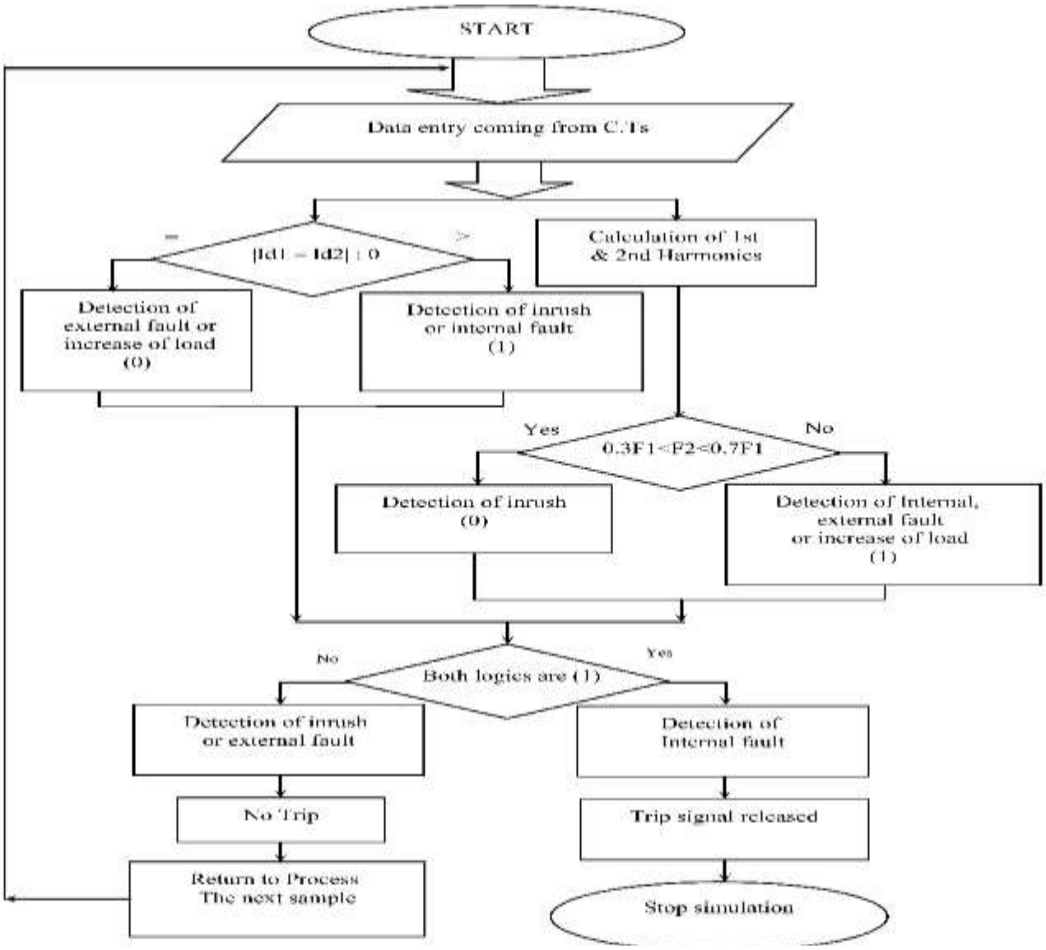


**Fig6. Flowchart for the Digital Differential Protection Scheme**

In a meanwhile, the harmonic calculation is performed. If the percentage value of the 2nd harmonic amplitude is in the range of 0.3 to 0.6 of the fundamental components of amplitude, then the logic (0) occurs, that means the detection of inrush current. Otherwise, the logic (1) takes place, which proves a detection of an internal or external fault.
Taking the final decision as:

If the logic received from both the cases (a & b) in step 2 are both (logic 1), that indicates a recognition of an internal fault. Then a trip signal will release to stop the simulation. For the other logic options of (0,1) means an external fault happens, (1,0) means an inrush current (surges), or (0,0) indicate an occurrence of an inrush current (surges) or an external fault, and the simulation goes back to step 2 to start the calculation again for the next sample.

**Advantages:**

- It is used to protect a specific piece of equipment such as transformer, Generator, Bus section etc.
- Its operation time is very fast and easily coordinated with other types of relaying, fusing protection schemes,
- Required less power for control operation.
- No fire hazards.

## V. CONCLUSION:

This paper represents the basics, advanced level information as well as an overview of the conventional differential technique and digital differential techniquefor power transformer protection. The equipment's liketransformer and generators are very costly so protection of them is mostimportant. The planned digital differential relay is meant to employing a simulation technique in MATLAB Simulink environment. The design is enforced to protect the power transformer against internal faults and stop interruption because of inrush currents.

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