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RESEARCH ARTICLE

PROTECTION OF POWER TRANSFORMER BY ADVANCED DIFFERENTIAL PROTECTION SCHEME

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ABSTRACT

Power transformers are the boon of the power supply system as it transform the voltage to a very high level for the transmission of power over long distances. Transformers, just like generators, transmission lines and other elements of the power system, requires protection from possible damage by various faults. The differential protection is the most widely used scheme for the protection of power transformer from the internal faults. However this conventional scheme suffers serious difficulties due to reasons such as saturation of current transformers, magnetizing inrush current etc which causes maloperation of relays. It can not eliminated by using conventional scheme. This paper proposes design of the digital differential relay based upon the Clarke's transformation approach. This relay effectively discriminates between inrush current and fault current and hence improves the sensitivity and reliability of the operation of protection scheme. The proposed scheme is implemented with MATLAB/SIMULINK software.

INTRODUCTION

The advancement in the field of power system is reflected in the improvement of all the power system devices generators, transformers with different sizes, transmission lines and the protection equipment. Modern power transformer is one of the most vital devices of the electrical power system, as it is of huge size, rating and one of the most expensive devices used in the power system. If the power transformer goes out of service due to abnormal conditions or any other reason, it may cause interruption in the power supply leading the whole grid to collapse. Hence its protection is a very critical issue. For this reason, the protection of power transformers has taken an important consideration by the researchers over many decades. The differential protection scheme can be used to protect both the primary and secondary winding of a three-phase transformer against faults. The method fundamentally based on the discrimination between faults and other operating conditions (Blackburn *et al*, 2009). The major challenge for the protective relay lies in discriminating between inrush current and fault current, as inrush current is as high as fault current. If the relay fails to identify the difference between two, it maloperates. Many research work has been reported in this field. The second harmonic restraint method is the most common method employed for this purpose. The factors affecting the second harmonic ratio in inrush current is studied in (Jialong *et al*, 2008), (M. Jamali *et al*, 2011) also investigated the effects of some parameters on the characteristics of inrush current in MATLAB Simulink. (Abdolmutaleb Abou-Safe *et al*, 2005) presented a mathematical model for an unloaded saturated transformer. There are a small number of variations of harmonic restrained differential protection (Jialong Wang, 2008). The Fifth Harmonic blockade technique, (Ouahdi Dris *et al*) has stated in their paper. (Mr. Saeed Jajebi *et al*, 2010) in their paper, presented a combinatorial scheme based on hidden Markov models (HMM) and wavelet transform (WT). It is found that after 1990, researchers have developed differential power transformer protection using fuzzy logic concept. One of the paper in 2009 authored by (Ahmad Abdulkader Aziz *et al*, 2009).

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Mr. Iman Sefari Rad and *et al*, 2011)In one of the paper researchers used fuzzy logic for internal fault detection in differential protection of power transformers. Another most powerful mathe- matical tool of recent times is Artificial Neural Networks (ANN) which attracts the researchers to tackle the transformer protection problem. Dr Horward Silver in his session published in proceedings (Dr Horward Silver, 2006). (SR Paraskar *et al*, 2011) developed a new method of discriminating magnetizing inrush current from inter-turn faults in a transformer. (Venkatesan *et al*, 2012), in their paper work reported and demonstrated the use of an Artificial Neural Network (ANN) as a pattern classifier for differential relay operation in the protection scheme for power transformer protection and Symmetrical components as an ANN's inputs. Under ANN, one strong method to discriminate between inrush and internal fault current is Probabilistic neural network (PNN) authored by (Manoj Tripathy *et al*, 2010). In some papers, the architecture of adaptive fuzzy network has been utilized. (H. Khorashdi-Zadeh *et al*, 2005) in their work presented a new inrush detector algorithm for differential protection of power transformer based on the fuzzy- Neuro method. (Tripathy *et al*, 2010) in their continuous work on the subject matter authored earlier that an approach based on Fuzzy-Neuro techniques ensures relay stability against external faults, magnetizing inrush, sympathetic inrush, over excitation conditions and its operation on internal faults. In this paper a new digital differential protection scheme is proposed which is formulated based upon the Clarke's transformation. The Clarkes transformation is a well-known transformation presented by Edith Clarke (Clarke, 1943).

Differential Protection Scheme

Differential protection is one of the most reliable and popular techniques in power system protection. Differential protection matches the currents that enter with the currents that leave a zone. If the total sum of the currents that enter and the currents that leave a protection zone is essentially zero, it is concluded that there is no fault in the protection zone. But, if the total sum is not zero, then the differential protection determines that a fault occurs in the zone and takes steps to isolate the zone from the rest of the system. Generally, three main difficulties handicap the conventional differential protection. They prompt the differential relay to discharge a false trip signal without the existing of any fault. These are described as below.

Magnetizing Inrush Current

This phenomenon, the transient magnetizing inrush, take place in the primary part of the trans- former on every occasion when the transformer is switched on and the instantaneous value of the voltage is not at 90. At this time, the leading top of the flux wave is higher than the peak of the flux at the steady state condition. This current seems to bean internal fault, and it is known as a differential current by the differential relay. The importance of the leading top of the magnetizing current may be as high as several times the peak of the full load current. The effect of the in rushcurrent on the differential relay is false tripping the transformer without of any existing kind of faults. From the principle of operation of the differential relay, the relay matches the currents arriving from both sides of the power transformer as clarified above. Yet, the inrush current is flowing only in the primary side of the power transformer. Thus, the differential current will have a significant value due to the existence of current in only one side. So, the relay has to be planned to recognize that this current is a normal phenomenon and to not trip due to this current.

False tripping 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 circumstances, the primary ratings of the CTs, situated in the high voltage and low voltage sides of the power transformer, does not precisely match the power transformer rated currents. Because of this discrepancy, a CTs mismatch happens, which in turn creates a small false differential current, subject to the quantity of this mismatch. Sometimes, this quantity of the differential current is sufficient to activate the differential relay. So, CTs ratio modification has to be done to get ride of this CTs mismatch by using interposing CTs of multi taps (Areva, 2001).

Another problem that may encountered in the way of perfect operation of the CTs is the saturation problem. When saturation occurs to one or all CTs at different stages, false differential current looks in the differential relay. This differential current might 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 has dc offset and extra harmonics (Rebizant *et al*, 2004), (Zocholl *et al*, 2000).

False tripping due to tap changer

On-Load Tap-Changer (OLTC) is installed on the power transformer to control automatically the transformer output voltage. This device is mandatory wherever there are heavy fluctuations in the power model. The transformation ratio of the CTs can be matched with only one point of the tap-changing range. Hence, if the OLTC is changed, unbalance current streams in the differential relay operating coil. This act causes CTs mismatches. This current will be measured as a fault current which makes the relay to release a trip signal (Marty *et al*,1988),(ABB relays, 1998).

Digital Differential Protection Scheme

The proposed methodology in this paper is described in three subsections. In the first and second section mathematical representation of electrical signal and Clarke's transformation is described respectively. The third section deals with the proposed idea for the improvement of differential protection.

Mathematical Representation of Electrical Signals

when the electronic computers began to be part of the scientific research, the conception of the real world had to change to fit it with a new world: a digital one. Hence the continuous signals must be converted into digital ones and the old systems are replaced by new discrete ones. In this section it is explained how an analogue signal can be processed by a digital machine through a mathematical representation. Let us begin with the mathematical representation of a three phase signal.

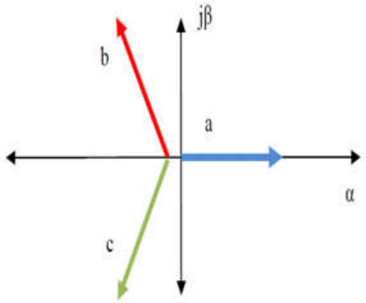

Fig. 1. Three variable scalars at complex plane

Va = √2Vsinwt Vb =√2Vsin(wt-2*π/3) Vc=√2Vsin(wt-4*π/3) (1)

The following mathematical operator is defined
γ = ej(2π/s) = -0.5+j0.866 (2)

If any real vector is multiplied by (2) the result will be a vector with the same amplitude but with a counter clockwise change in the vectors angle. The operator (2) helps to create the following vector.
p=a+bγ+c(γ)2 (3)

Clarke's transformation

Here is again the Space Vector equation expressed in rectangular form.

p =a+b*(-0.5+0.866j)+c*(-0.5+0.866j) (4)

Then taking the real and imaginary part of the space vector
preal = a - 0.5b - 0.5c (5)

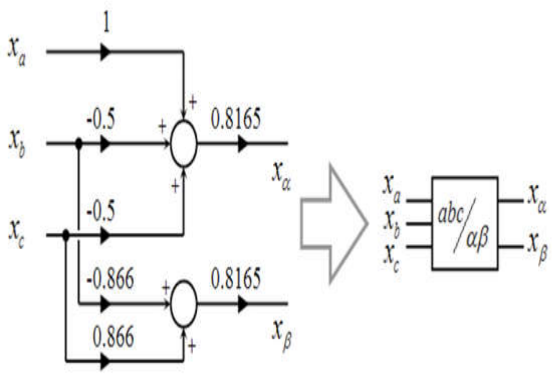

Fig 2 Clarkes transformation implementation

pbeta = 0.899jb - 0.899jc (6)

Finally, rewriting the last two expressions in matrix format.

$$\begin{bmatrix} p_{real} \\ p_{beta} \end{bmatrix} = \begin{bmatrix} 1 & -0.5 & -0.5 \\ 0 & 0.866 & -0.866 \end{bmatrix} \times \begin{bmatrix} a \\ b \\ c \end{bmatrix}$$

Equation (7) shows that a matrix multiplication gives us the two instantaneous components of the Space Vector at every time. The shape of alpha and beta are a cosine and a sine. The last method also can be seen as a transformation which reduces a three phase system to a two phase system, for balanced signals.

$$\begin{bmatrix} \alpha \\ \beta \end{bmatrix} = \begin{bmatrix} 1 & -0.5 & -0.5 \\ 0 & 0.866 & -0.866 \end{bmatrix} \times \begin{bmatrix} a \\ b \\ c \end{bmatrix}$$

In order to the transformation to be invertible, a third variable, known as the zero –sequence component, is added. The resulting transformation is The implementation of equation (8) in a micro controller or a computer can be obtained following the structure shown in figure (2).

Proposed Methodology

1. First, the three phase current on both sides of transformer is measured.
2. Then Clark transformation on these phase currents is performed. The main idea of using Clarkes transformation is to carry out in a pattern-recognition process to discriminate certain conditions of transformers.
3. Then the difference between phase to phase transformed current is obtained, which gives the information about the pattern difference between phase to phase current.
4. By the analysis of this we developed a lookup function which is monitoring as:

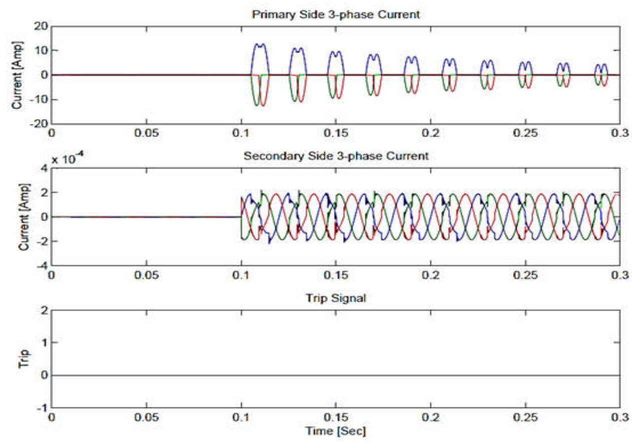

Fig 3 Waveform of magnetizing current

a. If the absolute instantaneous values of difference of transformed current for phase A and B are greater than 20 amp and for phase C is greater than 1 milli ampere then trips has to be released. or
b. If the absolute instantaneous values of difference of

transformed current for phase A and B are greater than 50 amp and for phase C is greater than 0.1 milli amp then trips has to be released.

c. These requires very less hardware than the base paper.

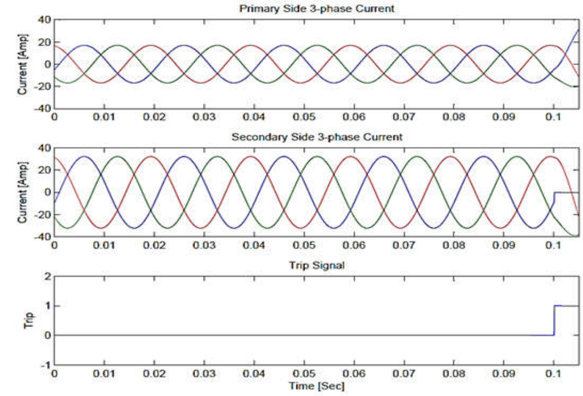

Fig. 4 Plot for A-G fault

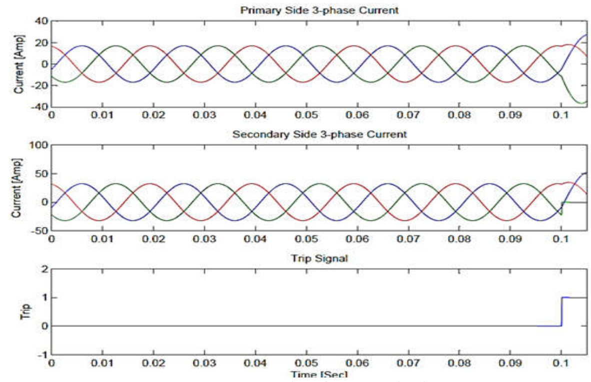

Fig. 5 Plot for B-G fault

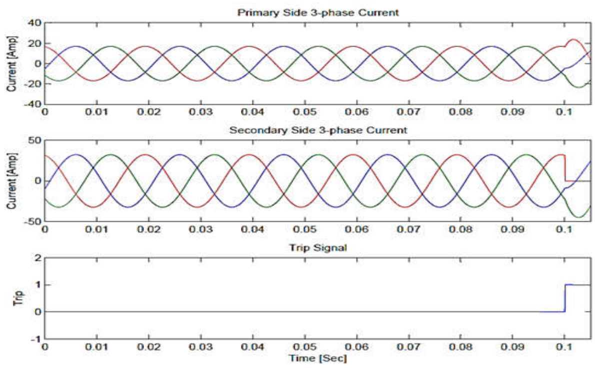

Fig. 6 Plot for C-G fault

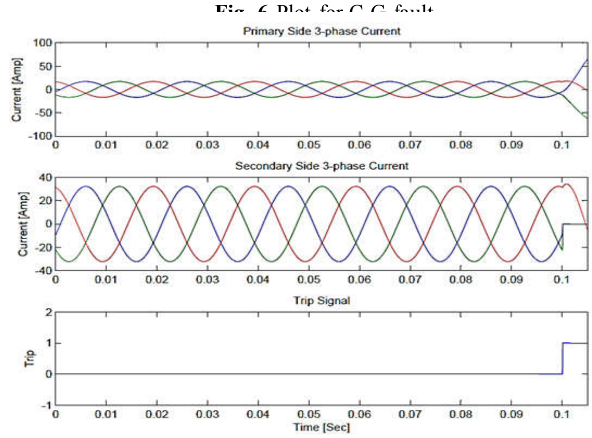

Fig. 7 Plot for A-B fault

RESULTS AND DISCUSSION

The study of the digital differential protection for the power transformer has been carried out using SIMULINK/MATLAB software. All the graphs for inrush current, various fault current and the input is shown in this section from fig-4 to fig-10.

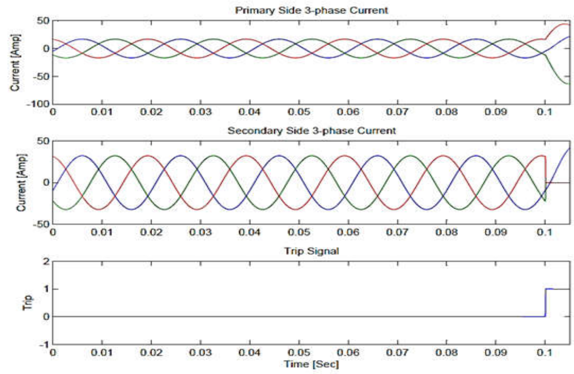

Fig. 8 Plot for B-C fault

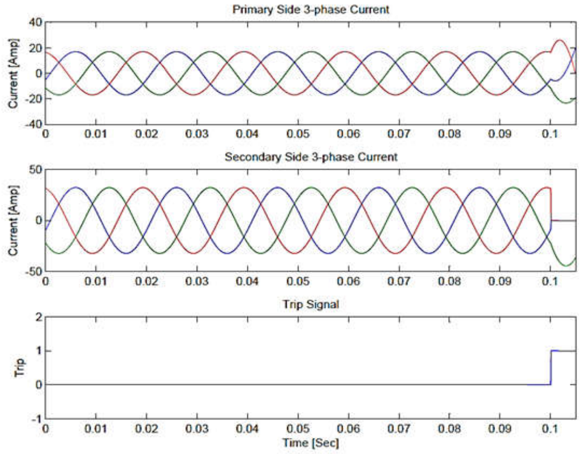

Fig 9 Plot for C-A fault

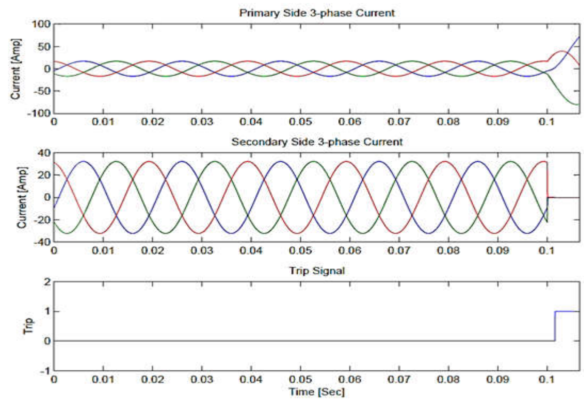

Fig 10 Plot for ABC-G fault

CONCLUSION

A MATLAB simulation of a laboratory level power transformer is presented in this research work. The simulation result thus obtained is shown in this literature, the research has been done in many fault cases such as line to ground, line to line, three phase etc and for all cases result obtained for this modified relay is satisfactory. The trip time taken is (50 micro sec) is also acceptable in order to ensure that the algorithm will give a proper decision to discriminate between a fault current and an inrush current. On the other hand the relay is restrained in all the cases for the inrush current, normal load current or the external fault current. Hence, from this research work, it can be concluded that this relay has capability to discriminate between fault current and inrush current and this relay can be an alternate to differential protection for power transformer protection under all conditions.

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