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Power transformer protection using Clark's transformation and fuzzy logic.

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ABSTRACT: *This paper proposes a simple and effective technique based on the Clark's transformation and fuzzy system for avoiding the mal-operation of differential protection relays during inrush currents. Exhaustive investigations are carried out by simulating 100 MVA, 220/66 KV three phase transformer in MATLAB for inrush condition and other faulty conditions.*

KEYWORDS : *Power transformer, magnetizing inrush current, differential protection, Clark's transformation, Fuzzy system.*

I. INTRODUCTION

Power Transformers are the most important component in a power system. So it is very important to avoid any mal-operation of required protective system. Thus here Protection system contains the differential relay, which operates for all types of internal fault in power transformer and also it should block due to inrush current. But the major drawback of the differential protection relays is mal-operation which is caused by the transient inrush current, which flow when the transformer is energized. In 2003, Shin et al. reported improved power transformer protection using fuzzy logic with flux-differential current and harmonic restraint [1]. In 2008, Wang and Hamilton analyze factors affecting the second harmonic ratio in inrush current, and describe various harmonic restraint methods and compare their performance [2]. In 2012, Balachandran and et-al gives state of the art technique for the transformer inrush current detection involving the determination of second harmonic content in the current waveform fails in modern transformers as this is inherently less in them [3]. In 2012, Dey and et-al presents a method for protecting and monitoring power transformers based on fuzzy logic with the application of Clarke's transform [4].

In this paper a method for protecting and monitoring power transformers based on fuzzy logic along with the application of Clarke's transform. The fuzzy logic allows to analyze the operating condition of power transformers including the fault condition and inrush condition. Decision making is performed by fuzzy logic after the pre-processing of the input signals through Clarke's transformation. Modeling of electrical power system is done using MATLAB software with Fuzzy Logic Toolbox to obtain the operational conditions for faulty conditions only. The differential relay based on Clark's Transform, sends input to Fuzzy Logic which, analyses the operating condition for the equipment and eliminates the abnormal work situations which generate failures.The proposed logic was thoroughly tested by simulating various types of faults,

energization conditions on a 220 kV system modeled in MATLAB with a 100MVA, 220 KV/66 KV Transformer.

II. MAGNETIZING INRUSH PHENOMENON

The inrush currents are caused by saturation effects in the iron core when a transformer is energized [5]. The saturation of the core is due to the change in the system voltage which may be caused by switching transient. While switching on the power transformers, due to the change in flux demand, the core draws more current from the source, as shown in Fig. 1. This current drawn by the system is called as the inrush current.

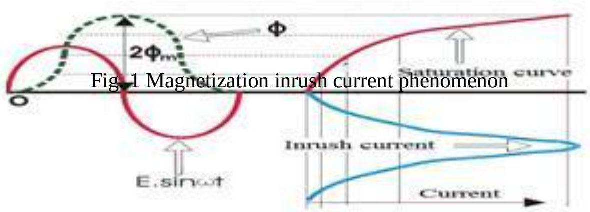


Fig.1 Magnetization inrush current phenomenon

Magnetizing inrush current exist for few seconds in transformer and is three to ten times greater than the rated current. Although the magnitude of inrush current is so high but it generally does not create any permanent fault in transformer as it exists for very small time [6].

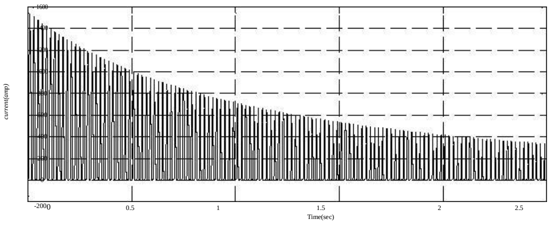


Fig. 2 Primary current I_{a1} simulated for 2.5 sec

Fig. 2 shows the nature of magnetizing inrush current when transformer is energized. The magnitude of

$$\Delta\alpha = I_{\alpha 1} + I_{\alpha 2}$$

$$\Delta\beta = I_{\beta 1} + I_{\beta 2}$$

$$\Delta\gamma = I_{\gamma 1} + I_{\gamma 2}$$

Inrush current is 1540 A at the first instant, which is about 4 times the rated current. And after 2.5 sec, it comes up to around 367A.

III. PROPOSED METHOD

In this paper, an effective method based on Clarke's transform with fuzzy logic is used for differential protection of power transformers. In this paper, the input variables of the fuzzy system are differential currents obtained from Clarke's transformation. The data from both primary and secondary of power transformer are obtained and processed using Clarke's transform and differential currents are calculated. These differential currents are given as inputs to the fuzzy system. The fuzzy system is designed to distinguish internal faults from other operating conditions of power transformer. The proposed Fuzzy system computes each differential α-β-γ component independently. The following sections will describe each block individually. The block diagram of proposed method is shown in Fig. 3

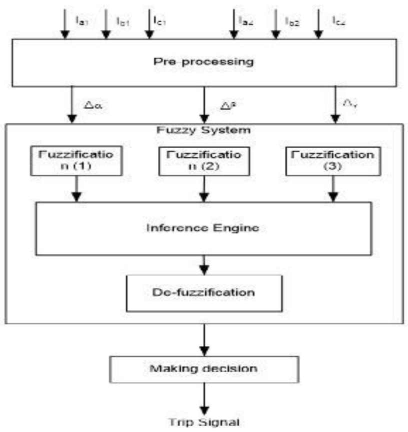


Fig. 3 Block diagram of proposed system

A. Pre-Processing :

After acquiring the data, a pre-processing stage was executed, obtaining the uncoupled signals for the fuzzy system. This pre-processing can be carried out by Clarke's transform and further the fuzzy controller takes a decision based on inference/knowledge based system.

Clark's Transformation: In Electrical Engineering the α-β-γ transformation is a mathematical transformation employed to simplify the analysis of three-phase circuits. It is conceptually similar to d-q-0 transformation. One of the useful application of the α-β-γ transformation is the generation of the reference signals used for various control techniques. The α-β-γ transformation is

$$I_{\alpha\beta\gamma}(t) = T * I_{abc}(t) = \frac{2}{3}\begin{bmatrix} 1 & -\frac{1}{2} & -\frac{1}{2} \\ 0 & \frac{\sqrt{3}}{2} & -\frac{\sqrt{3}}{2} \\ \frac{1}{2} & \frac{1}{2} & \frac{1}{2} \end{bmatrix}\begin{bmatrix} I_a(t) \\ I_b(t) \\ I_c(t) \end{bmatrix} \ldots\ldots\ldots (3)$$

Where,

( ) = Three phase current sequence. ……………… (5) ……………... (6)

( ) = corresponding current sequence given by transformation T. ……………... (7)

Power invariant transformation:

As the transformation matrix T is not the unitary matrix, the active and reactive powers of the system changes. Thus to avoid this the transformation matrix is written as,

$$I_{\alpha\beta\gamma}(t) = T * I_{abc}(t) = \sqrt{\frac{2}{3}}\begin{bmatrix} 1 & -\frac{1}{2} & -\frac{1}{2} \\ 0 & \frac{\sqrt{3}}{2} & -\frac{\sqrt{3}}{2} \\ \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} \end{bmatrix}\begin{bmatrix} I_a(t) \\ I_b(t) \\ I_c(t) \end{bmatrix} \ldots\ldots (4)$$

Which, is unitary matrix and the inverse coincides with its transpose.

Clarke's transform could be applied to both instantaneous values as well as the phasors [4]. The main idea of usingClarke's transformation is to carried out in a pattern-recognition process to discriminate certain conditions of transformers, such as magnetizing inrush, and energization. The proposed method uses the differential − − components of the current, such as,

Where,

1, 1, 1, *I* 2, *I* 2, and *I* 2 are α-β-γ-components of the primary and secondary currents of a transformer. The output of this preprocessing is then provided to the fuzzy system as the input.

B. Fuzzy Logic:

Fuzzy inference is a process that makes a decision in parallel. Because of this property, there is no data loss during the process and so final fault detection will be more precise than that of conventional relaying techniques [1]. Fuzzy system involvesfollowing steps,

Fuzzification:
In Fuzzy logic, linguistic variables are used instead ofnumerical variables. In general, the measured quantities are real numbers i.e. crisp values. Thus the process of converting these numerical variables into a linguistic variable or fuzzy variables is called —fuzzification□ . Here the classification of

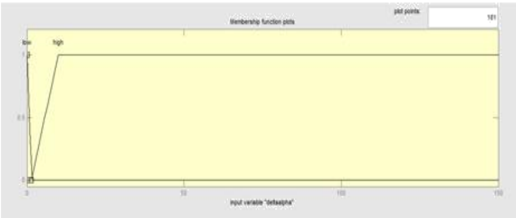


Fig (a)

input data into suitable linguistic variables are given as follows,

Three inputs are taken in the fuzzy system as 1)α; 2) Δβ; and 3) γ. These variables are obtained from equations (5)-(7).

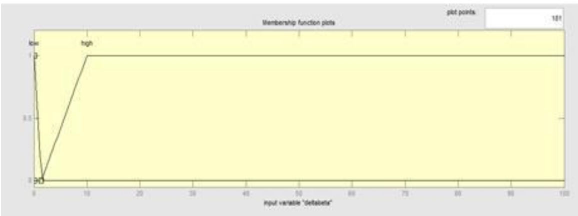


Fig (b)

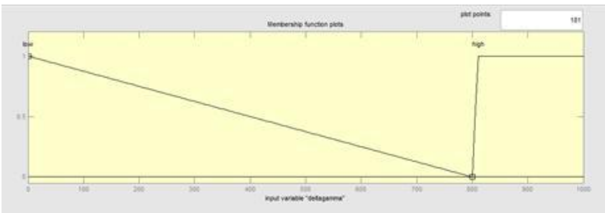


Fig (c)

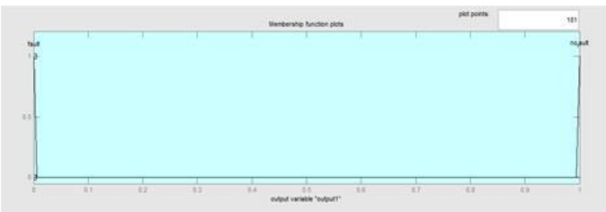


Fig (d)

Fig. 4 Membership functions. (a) Input variable α. (b) Input variable β
(c) Input variable γ. (d) Output variable.

Figs. 4(a)–(d) show the membership functions of the inputs and the output variables. For fuzzification of a defined input variable from equation (5), a range is set between 0 and 150 and the membership values range from 0 to 1. The input variable from equation (6), a range is set between 0 and 100. The other input variable from equation (7) is in the range from 0 to 1000. The output variable is shown in Fig. 4(d) ranging from 0 to 1 for two membership functions that determine trip signals.

2. Inference method:

The proposed scheme uses rules to discriminate two operating conditions: inrush current condition and faulty conditions. For this paper, in order to perform a mathematical operation, the Mamdani method is used. 8 rules are used in this proposed scheme.

3. De-fuzzification:

The method needed a crisp value for control purposes. The technique applied a centroid in accordance with [4].

$$Output = \frac{\sum_{j=0}^{N} y_j \ \mu_F(y_j)}{\sum_{j=0}^{N} \ \mu_F(y_j)} \ \ldots\ldots\ldots\ldots\ldots (8)$$

ere, is the value of each point on a domain of a final output fuzzy set and ( ) is the membership value at each point.

IV. SIMULATION AND RESULTS

A Three phase power transformer rated 100MVA 220KV/66 KV, 50Hz is simulated in MATLAB software. Simulation model is shown in Fig. 4 which is having the pre-processing block and Fuzzy Inference System. The pre-processing block consists of Clark's transformation block shown in Fig. 6

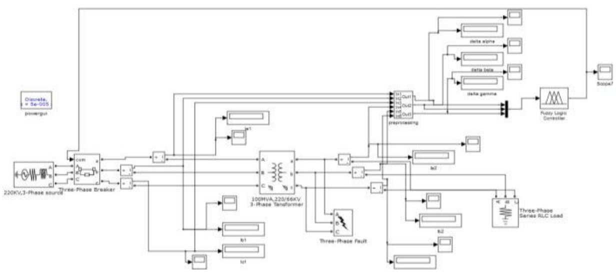


Fig. 5 Simulation model for power transformer in MATLAB.

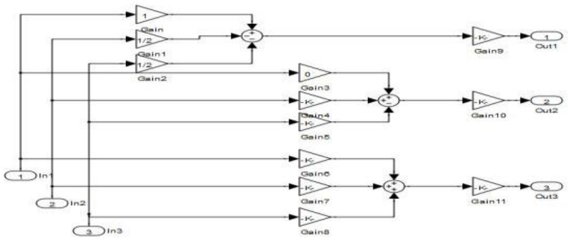


Fig. 6 Clark's Transformation block

The results of the simulation are shown below under healthy condition, under inrush current condition and under faulty conditions.

A. Under healthy condition:

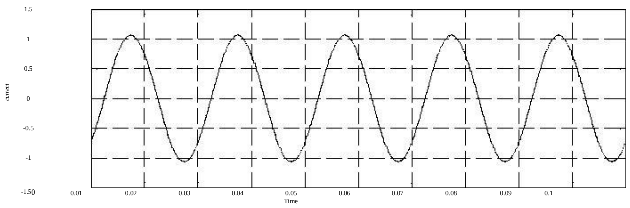


Fig. 7 Primary current I_{a1}

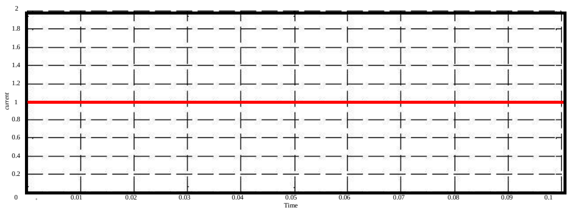


Fig. 8 Fuzzy output —1 .

Fig. 7 and Fig. 8 show the primary current and fuzzy output under normal condition. The fuzzy output is 1 since there is no fault.

B. Under inrush current condition:

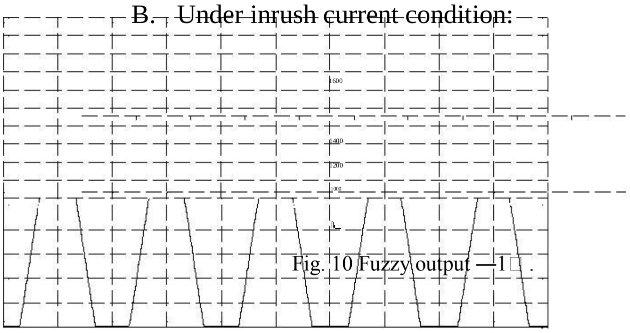
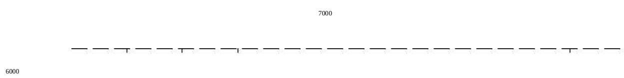


Fig. 10 Fuzzy output —1 .

Fig. 8 and Fig. 10 show the primary current and fuzzy output under inrush current condition. The fuzzy output is 1 since it is not the faulty condition.

C. Energization under faulty (3L-G) condition:



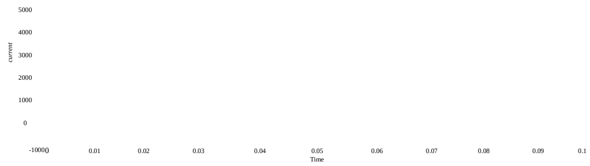
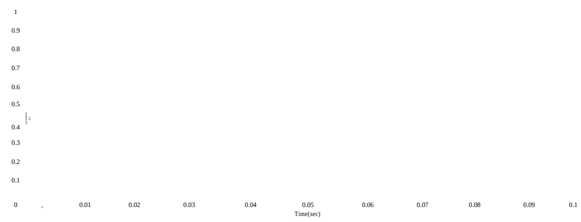


Fig. 11 Primary current I_{a1}



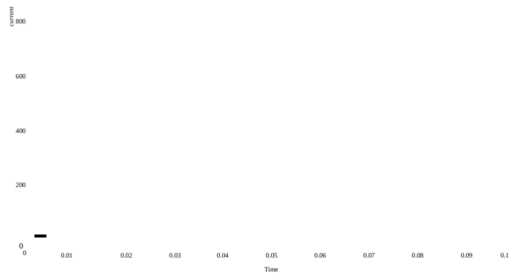
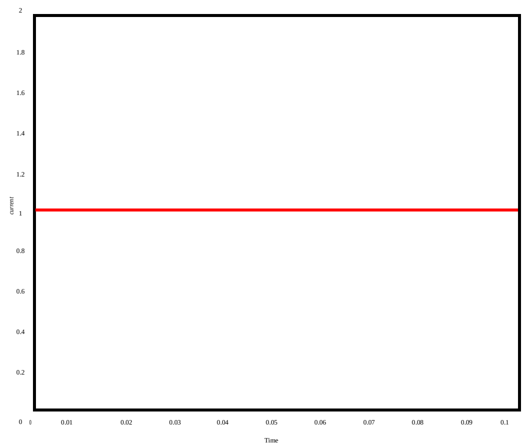
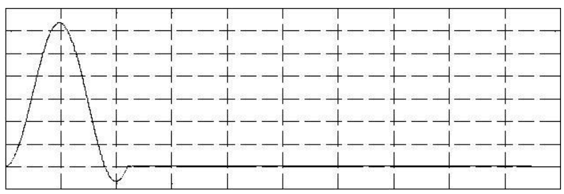


Fig. 9 Primary current I_{a1} simulated for 0.1 sec





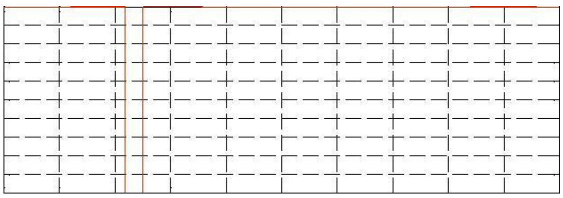


Fig. 12 Fuzzy output

Fig. 11 and Fig. 12 shows the primary current and fuzzy output for energization under faulty condition.

Similarly various faults can be simulated in the system and results are obtained.

Table1

Results:

Various cases	Output
Inrush current	No trip
Under fault	Trip
No-fault	No trip

V. CONCLUSION

The paper presents a method differential protection power transformer based on fuzzy logic and application of Clarke's transform shows improved performance over conventional techniques. The obtained result shows that the proposed fuzzy based differential relay avoids the tripping of the protection scheme during inrush current condition and trips the protection scheme during the faulty condition. Thus the use of fuzzy logic with Clarke's transform can make it possible to increase reliability and sensitivity of differential relays for power transformer.

REFERENCE.

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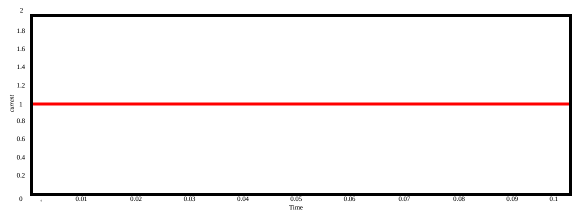
[5] Ramsis S. Girgis, Ed G. teNyenhuis, ―Characteristics of Inrush Current of Present Designs of Power Transformers□ ,IEEE, 1-4244-1298-6/07/$25.00 ©2007 IEEE.

[6] S. Jamali Arand, M. Saeedi, S. Masoudi,□ Transformer inrush current mitigation using controlled switching and magnetic flux shunts□ , International Journal of Energy and Power Engineering, April 2, 2013.



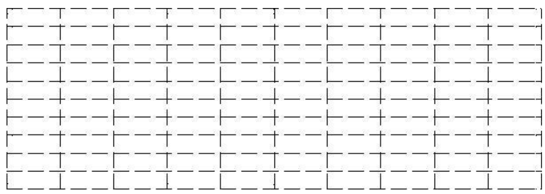


Fig. 8 Fuzzy output ―1□ .

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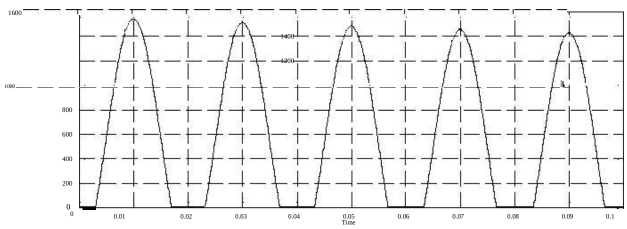
B. Under inrush current condition:



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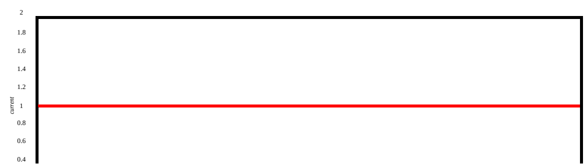

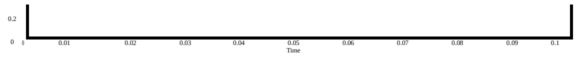

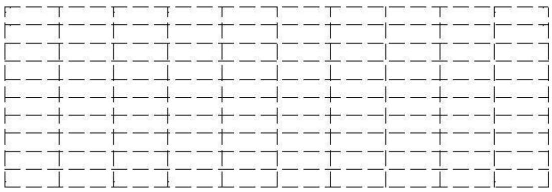

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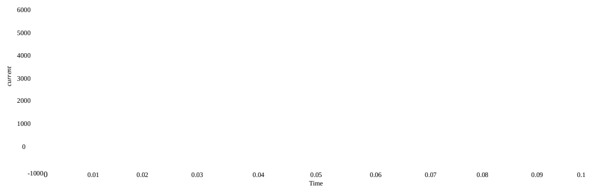
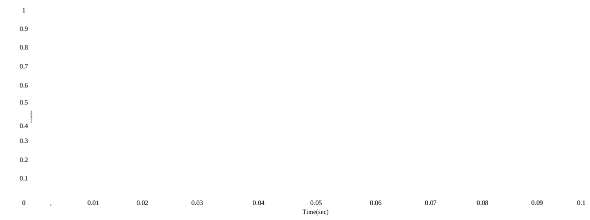
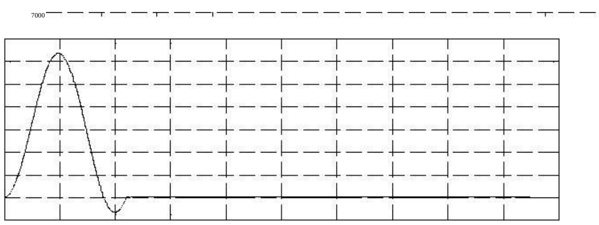
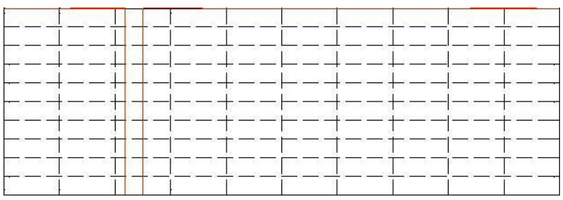


Fig. 11 Primary current I_{a1}







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[13] and Power Engineering, April 2, 2013. [14] Fig. 12 Fuzzy output