Incipient Fault Detection in Power Transformer Using Fuzzy Technique

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Abstract-One of the main causes of power transformer failures is due to inter turn short circuit faults. It is a challenging problem to the power engineers to detect these faults at an early stage. If these incipient faults are not detected at their inception, they would develop into more severe faults that may result in damage to the transformer. In this paper a physical model of a multiwinding power transformer of 100 MVA, 138/13.8 KV is simulated in a power system using MATLAB/SIMULINK software. Different percentages of turns such as 1%, 3%, 5%, 10%, 15%, and 25% are shorted on primary and secondary sides of the multiwinding transformer to measure the terminals current. The change in the terminals current during fault incidence (inter turn fault) is negligibly small. In order to experience significant changes, negative sequence currents are extracted using symmetrical component approach. The percentage changes in magnitudes of negative sequence currents (%MAG) and the corresponding phase shifts (PS) that occur in the transformer during fault incidence period are evaluated and they are fed as inputs to fuzzy logic.

Here fuzzy logic is employed not only to monitor the condition of the transformer but also to improve the sensitivity of the proposed scheme. The two variables (%MAG & PS) are fed as inputs to fuzzy logic. Depending on the data obtained, the inputs are assigned with three membership functions each namely low, medium, and high. A fuzzy inference engine is built with nine fuzzy rules based on the knowledge gained from the system behavior. Here the process of defuzzification is carried out by using centroid calculation method. The output variable is named as transformer condition (TC), Which is assigned with three membership functions such as Incipient fault (IF), Minor fault (MF), and Severe fault (SF)

1.INTRODUCTION

Power transformer online monitoring methods became popular now-a-days because their outages result in loss of revenue and also effect the service to the consumers. Recent reports on transformer failures show that about 70% of transformer failures are only due to transformer inter turn short circuits. If these faults are not detected at an early stage, they develop into more serious faults even to repair. Due to this reason, an increasing effort has been put for detection of inter turn faults in the recent years.

There are numerous techniques reported in the literature to detect inter turn faults in a power transformer such as acoustic and partial discharge analysis, dissolved gas analysis (DGA), transfer function techniques etc. But these techniques possess the limitations of high cost, long operating time and in some cases they cannot monitor these faults online. On the other hand the traditional differential protection scheme fails in detecting such a low incipient faults as the current measured at the transformer terminals is negligibly small.

DGA can be used for online online monitoring of incipient fault with the help of an instrument called gas chromatograph th.at is connected to the transformer in service [1]. However, the instrument is more expensive and also it is not suitable for all industries. Another approach based on

the principle of Hydran is proposed in [2]. Due to the variability of gas data the DGA is not sensitive in detecting incipient faults to a better degree. Also this technique is not suitable for air forced, naturally cooled, and dry-type transformers.

Frequency response analysis (FRA) is also proved to be one of the successful diagnostic in transformer fault diagnosis. In FRA the admittance is measured over a wide range of frequencies and the results are compared with a reference set. Any deviation in these two sets of measurements indicates a fault in the transformer winding. In general this method is adopted to assess the mechanical deformation of transformer winding under the influence of short circuits. Although it is a popular method, it requires additional instruments for fault detection and also it always needs an evidential reasoning (ER) approach [3].

Combined Artificial Intelligent (AI) techniques with wavelet transforms is proposed in [4-5] for power transformer fault diagnosis. However these methods need much computation and more memory requirement and hence they require large number of processors and instruments. In [7], a review on fuzzy-logic method is proposed for power transformer fault diagnosis based on DGA of mineral oil. This review shows that various fuzzy-logic techniques for power transformer fault detection have been developed inorder to reduce operating costs, enhance operational reliability and improve power and services of customers. Some disadvantages of fuzzy-logic methods are that membership functions must be determined according to practical experience or expert advice and an efficient fuzzy-logic system requires complete knowledge provided by human specialists. Some inaccuracy is always associated with lab DGA measurements of transformer oil, which may affect the gas ratios, concentrations differences and other calculations [8].

The afore mentioned limitations have lead the power engineers to develop more sensitive, low-cost, fast, and online monitoring protective schemes. In this research article a new online monitoring inter

turn fault detection method based on fuzzy logic is presented.

A physical model of a multiwinding power transformer is simulated in a power system using MATLAB/SIMULINK software. Different percentages of turns are shorted on primary and secondary sides of the multiwinding transformer to measure the terminals current. The change in the terminals current during fault incidence (inter turn fault) is negligibly small when compared with steady state conditions. Inorder to experience significant changes, negative sequence currents are extracted using symmetrical component approach. The percentage changes in magnitudes of negative sequence currents (%MAG) and the corresponding phase shifts (PS) that occur in the transformer during fault incidence period are evaluated. Here fuzzy logic is employed to monitor the condition of the transformer and also to improve the sensitivity of the proposed scheme. The two variables (%MAG & PS) are fed as inputs to fuzzy logic. Depending on the data obtained, the inputs are assigned with three membership functions each namely low, medium, and high. A fuzzy inference engine is built with nine fuzzy rules based on the knowledge gained from the system behavior. Here the process of defuzzification is carried out by using centroid calculation method. The output variable is named as transformer condition (Tc), Which is assigned with three membership functions such as Incipient fault (IF), Minor fault (MF), and Severe fault (SF).

The organization of the paper as follows: In section 2 a brief introduction of Fuzzy logic is presented. Section 3 depicts the system under consideration and its simulation. The results and discussion are presented in section 4. Section 5 concludes the paper.

2. FUZZY LOGIC

Fuzzy sets were developed by Lotfi A. Zadeh and Dieter Klaua in the year 1965. These are extended version of classical sets for dealing with uncertainty events. The application of fuzzy logic for power system problems was introduced in 1979 [6]. Fuzzy

set theory is a nothing but a generalized classical set theory. In classical set theory each element of universe of discourse either belongs to the set or does not belong to it. So the degree of associated element is crisp. Fuzzy set is a mapping from the universe of discourse to the closed interval {0, 1}. In this theory the correlation of an element will be continuously varying.

As fuzzy logic uses expert knowledge and experience, it is very helpful while solving decision making problems. Fuzzy set is an effective tool to analyze uncertain events and relations between them. A fuzzy system is used to deal without data loss when there is vagueness in the input data. In this context fuzzy logic is employed to assess the severity of inter turn fault. Steps involved in fuzzy system are
A. Fuzzification
B. Inference mechanism
C. Defuzzification

A. Fuzzification

Fuzzy logic uses linguistic variables in place of numerical values. In other words Fuzzification is the method of converting real numbers into fuzzy numbers. In the proposed scheme the variables R1 and R2 are used as fuzzy inputs. Depending on the range of data obtained for each variable, these are divided into three membership functions each (low, medium, and high). The output variable (transformer condition) is also divided into three membership functions such as IF, MF, and SF.

B. Inference method

The proposed scheme makes use of vigorous rules to describe the operating condition of the transformer. In this article, to perform a mathematical operation, the Mamdani method is used from MATLAB software. In the proposed scheme 12 rules were used.

C. Defuzzification

The combination of a fuzzy set includes a range of output values and so it must be defuzzified in order to determine a single output from the set. The most accepted defuzzification method is the centroid method, which returns the centre of the area under the curve. There are other methods like centroid, middle of maximum, smallest of maximum, largest of maximum, bisector methods are also available. In this work centroid method is adopted.

3. POWER SYSTEM UNDER CONSIDERATION

A physical model of multiwinding transformer of 100 MVA, 138/13.8 KV, Y-Y shown in Figure1 is simulated using MATLAB/SIMULINK software.
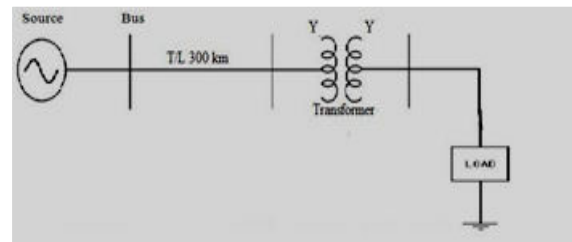

Fig. 1. One line diagram of power system model.

4. RESULTS AND DISCUSSION

The power system considered for simulating transformer inter turn short circuits is shown in Figure 1. This includes a physical model of a multi-winding transformer with 100 turns on the secondary that is simulated using MATLAB/SIMULINK software. Using symmetrical component approach negative sequence currents are extracted when 1%, 3%, 5%, 10%, 15%, and 25% of the turns are shorted on the secondary winding in phase C. Figures 2 and 3 show the magnitude variations of negative sequence currents during fault incidence.
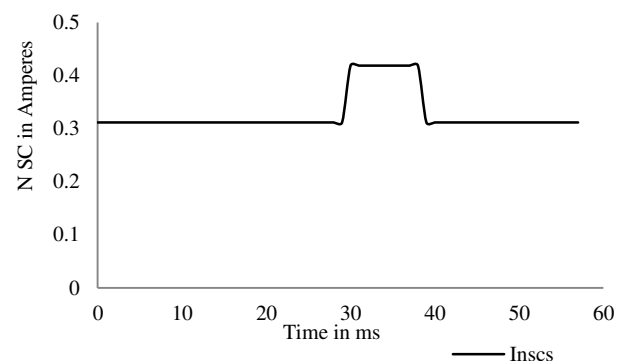

Fig. 2. Negative sequence current magnitudes on secondary for 1% shorted turns on secondary in phase C.
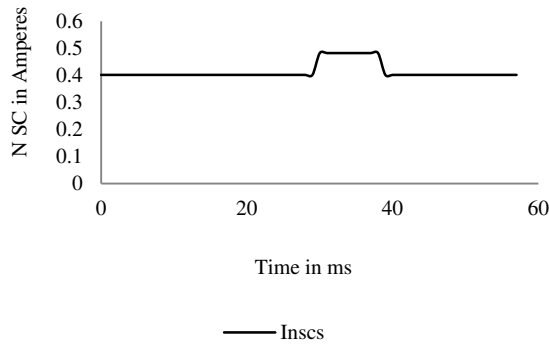
Fig. 3. Negative sequence current magnitudes on secondary for 3% shorted turns on secondary in phase C.

Table I shows percentage changes in the negative sequence currents in secondary, phase C for different number of shorted turns.

TABLE I

Sl. no	% of shorted turns in secondary of phase C	Magnitude of steady state current	Magnitude of negative sequence current	% change (%MAG)
1	1	0.3115	0.321	3.04
2	3	0.4013	0.4145	3.289
3	5	0.4085	o.4264	4.38
4	10	0.6839	0.725	6.839
5	15	0.8773	0.941	7.26
6	25	1.5346	1.682	9.605

The phase angle variations of negative sequence currents on both sides of the power transformer during different percentages of shorted turns are measured and the phase variations during 1% and 3% shorted turns are shown in Figures 4 & 5.
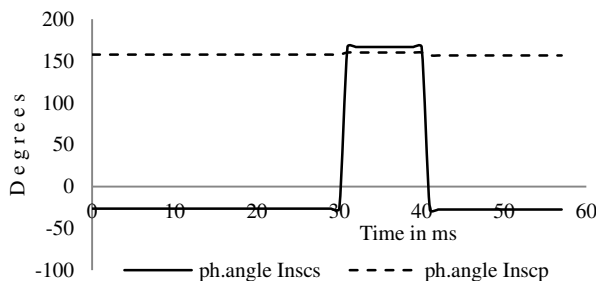

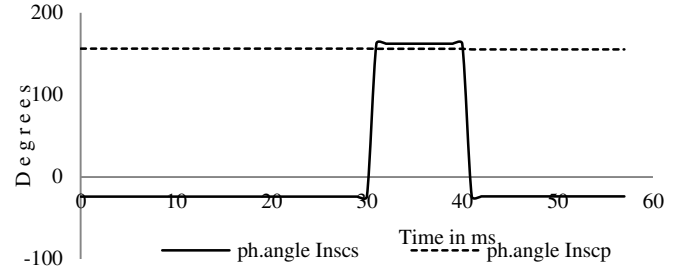Fig. 4. Phase shift between Inscs to Inscp when 1% turns are shorted

Fig. 5. Phase shift between Inscs to Inscp when 3% turns are shorted

Theoretically, the phase angle between two phasors of negative sequence currents has to be 0 degrees during internal short circuit. But in reality there are some other arbitrary phase angle shift caused by the quite high current in the shorted turns as shown in figures. The phase shift during different percentages of shorted turns on primary and secondary sides of power transformer is shown in the Table II.

TABLE II

Sl. No.	% of shorted turns	Phase angle of Inscs	Phase angle of Inscp	Phase shift (PS)
1	1	156.64	151.12	5.51
2	3	160.19	154.63	5.55
3	5	162.33	156.11	6.21
4	10	159.11	152.83	6.28
5	15	166.84	160.27	6.57
6	25	160.63	152.40	7.80

%MAG and PS are fed as inputs to the fuzzy logic. For building membership functions %MAG and PS are divided into three parts each namely low, medium, and high. The three membership functions of %MAG and PS are represented by trapezoidal membership functions with their respective ranges as shown in figures 6 and 7.
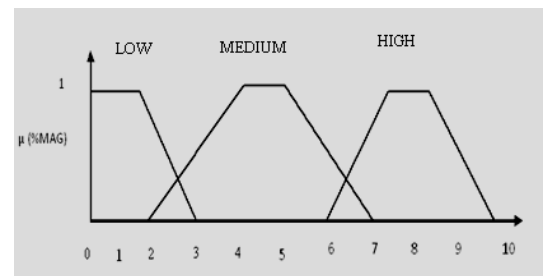

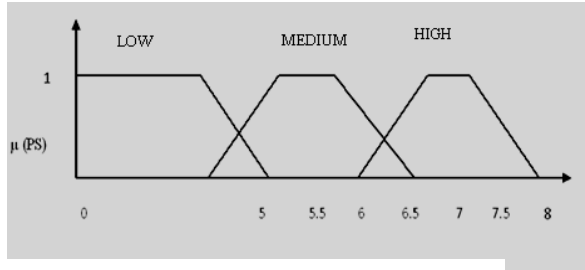Fig. 6 Membership functions of %MAG
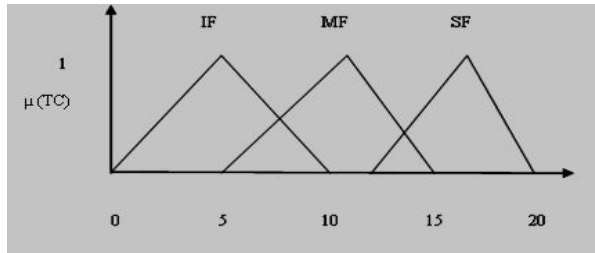
Fig. 7 Membership functions of PS

Fig.8 Membership functions of output

The fuzzy IF-THEN rules are given in Table III

TABLE III

% MAG / PS	LOW	MEDIUM	HIGH
LOW	IF	IF	IF
MEDIUM	IF	MF	MF
HIGH	IF	MF	SF

By using a Fuzzy Logic tool box in the MATLAB environment the rule viewer at an instant is obtained as shown in Figure 9.
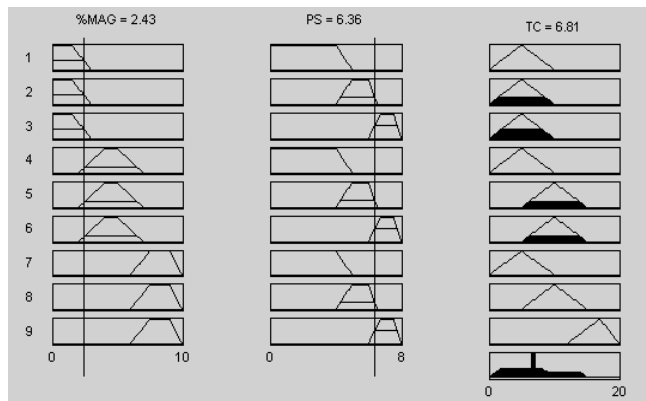

Fig. 9 Rule viewer

5. CONCLUSION

The proposed scheme overcomes the limitations of the traditional power transformer differential protection scheme in detecting low-level inter-turn faults. Hence, it is found to be a very good compliment to the existing power transformer fault detection methods. This research work presents the detection and severity of incipient fault in a power transformer by monitoring the magnitude and phase shift associated with negative sequence currents during fault inception. The relative variations in the negative sequence currents are found to be significant in both magnitude and phase. The proposed fuzzy based technique is quite simple, robust, and able to detect the incipient faults at an early stage.

ABOUT THE AUTHORS

K. RAMESH received B. Tech degree from JNTU, KAKINADA in the year 2001. He obtained M. Tech degree in the year 2008 from the same university. Currently he is pursuing Ph. D. He is working as Assistant professor in Bapatle Engineering College, Bapatla. His research interests include digital protection of electrical power systems and electrical machines.

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