Extraction Of Features To Discriminate And Detect Transformer Inrush Current And Faulty Condition Using ANN.

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***Abstract*— The inrush current occurs when transformers are initially energized at no load, which lead to mal-operations of protective relays and issues of power quality. However, it is very necessary to discriminate between inrush condition and faulty condition for modern protection of power transformer. This paper presents an alternative approach of using artificial neural network for discrimination and detection of transformer inrush current and faulty condition by extracting features. In this paper, second harmonics ratio (SHR), peak value of inrush current and mean deviation are the features extracted which are used as input to ANN for discrimination between inrush and faulty condition.**

***Keywords*— Artificial neural network (ANN), transformer, inrush current, transformer faults, harmonics, SHR.**

I. Introduction

Transformers are the most important device in a power system. So it is very necessary to avoid any mal-operation of required protective system, otherwise continuity in power delivery can be seriously disrupted. Protection system contains the differential relay, which operates for all types of internal faults and it is supposed to block due to inrush current. However, a simple detection of faulty condition from other condition is not sufficient to discriminate between them as they also produce such currents. Some of these situations may occur during current transformer saturation, initial energising of transformer (inrush current), or other situations which may cause incorrect tripping of protection system. Therefore, it is very important to discriminate this condition such as inrush current and faulty condition to avoid mal- operation of protective relay [1].

On no load, when power transformer is energised caused inrush current due to the saturation of magnetized core. This inrush current usually contain second harmonics component [2]. Due to this inrush current second harmonics contain, total harmonics distortion (THD) also increases. This harmonics current is always reactive. Due to this, voltage drop takes place across the network and the power system becomes unstable [3]. The other effect of inrush current are fast aging of transformer winding due to heating of winding, also it give rise to harmonics and insulation failure. In this paper second harmonics ratio (SHR) is used to discriminate faulty current from inrush current. The second harmonics component to the fundamental component of differential current in inrush current condition is greater than the ratio in the faulty condition [4]. This condition is used to discriminate inrush and faulty current. Along with SHR, peak value of inrush current during inrush and faulty condition and mean deviation are also used for discrimination.

For improving selectivity and operation of differential relays, new methods are approach such as neural network and fuzzy logic, have been studied recently [5].

This paper presents alternate approach using artificial neural network (ANN) for extraction of features to discriminate and detect transformer inrush current and faulty conditions. ANN is used because there is no need to develop external algorithm, it develops its own algorithm and have decision making capability which is better than conventional method. An Artificial neural network is an information-processing paradigm that is inspired by the way of biological nervous system, such as the human brain, processing system [6]. An ANN is configured for a particular application, like data classification or pattern recognition, through a learning process. ANN gives better accuracy than conventional methods, better classification, low computation burden and fast response to protective system [7].

MATLAB based simulation circuit is used to generate input for ANN. These inputs are used for training as well as testing the proposed approach. This new methodology gives encouraging results which are shown in following sections.

II. Transformer Inrush Current and ANN

A. *Transformer Inrush Current*

Inrush Current in transformer arises initially when it is first energized; the magnitude of inrush current is 10 to 15 times higher than the rated current of transformer. The instantaneous

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value of steady state flux is not matched with the residual flux which causes non-linear characteristics of magnetization curve, this saturates the transformer core. During this inappropriate amount of MMF is needed to generate magnetic flux which leads to rise in winding current which is 10 to 15 times greater than the initial rated current. Fig 1 shows the inrush current occurring in transformer when it is first energized [8].

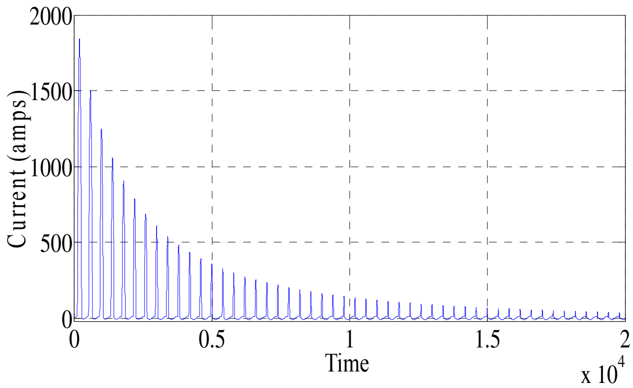

Fig. 1 Transformer Inrush Current

Mathematically the amplitude of inrush current is given by

$$i(t) = \frac{\sqrt{2}V_m}{zt} * Kw * Ks * \left(\sin(\omega t - \varphi) - e^{\frac{-(t-to)}{\tau}} * \sin\alpha \right) \qquad (1)$$

Where, Vm is the maximum applied voltage, Zt is the total impedance during inrush condition, φ is the energization angle, t is time, t0 is the time when core saturates, τ is time constant of transformer winding under inrush conditions, α is function of t0, Kw & Ks are the accounts for three phase winding connection and short circuit power of network [9].

The switching of supply at different angles gives different magnitudes of inrush currents. Fig 2 shows the switching of supply at 0, 45, 90 and 135 degrees. This shows that the inrush current is minimum at 90 degrees.

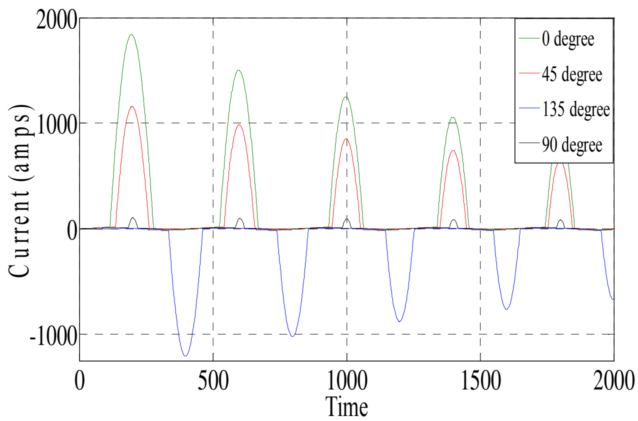

Fig. 2 switching of circuit breaker at different angle.

B. *Artificial Neural Network*

ANN basically consists of inputs which are multiplied with weights and then computed by a mathematical function which determines the activation of the neuron. The output of artificial neurons is computed by another function. By applying neural network techniques a program can learn by examples and create its own internal structure of rules to classify different inputs. Fig 3 shows the basic operation of artificial neural network. Inputs are given to the network and which are stored as activation function in the neurons which are used to classify and give the output more accurately [10].

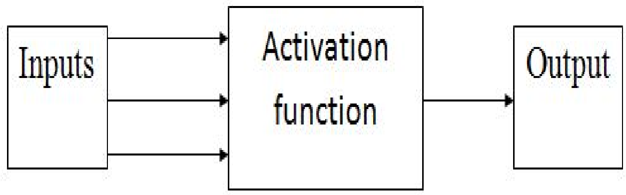

Fig. 3 Working of ANN.

Training of ANN consist of three stages, First stage is initial training: in this stage the inputs are fed to the ANN according to which the neurons get trained by recognising the pattern of the input. Second stage is validation: this stage is used to measure network generalization and it determines when to stop the training in order to get maximum efficiency. Third stage is testing: at this stage the neurons which are trained at first stage is tested in order to measure the performance of the network.

III. Feature Extraction

In this section features are extracted in order to classify the transformer inrush current and faulty condition properly. The simulations of inrush current and faulty conditions are done using MATLAB. Fig 1 and fig 4 shows the signals having inrush current and faulty condition. Then the features are extracted at different switching angles of supply to the transformer. The features are explained below.

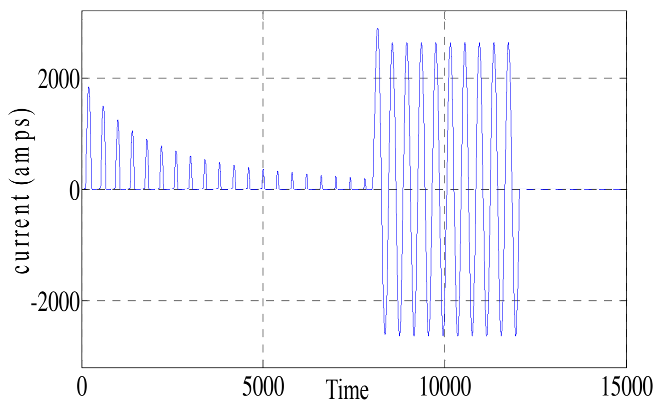

Fig. 4 Inrush with faulty condition

A. Second Harmonic Ratio (SHR)

Fast Fourier Transform (FFT) is used to get this feature. The FFT of the inrush and faulty condition are taken and the ratio of magnitude of 2nd harmonics to the fundamental is calculated. Mathematically FFT is calculated using (2)

$$a_n = \frac{I_m}{\pi}\left[\frac{1}{n+1}\sin\left((n+1)\alpha\right)+\frac{1}{n-1}\sin\left((n-1)\alpha\right)-\frac{2}{n}\sin\left(n\alpha\right)\cos\alpha\right] \quad (2)$$

Using the above equation the magnitude of fundamental and second harmonic is found and the ratio of both gives SHR. Fig 5 shows the value of SHR at different angles for inrush as well as faulty conditions [11].

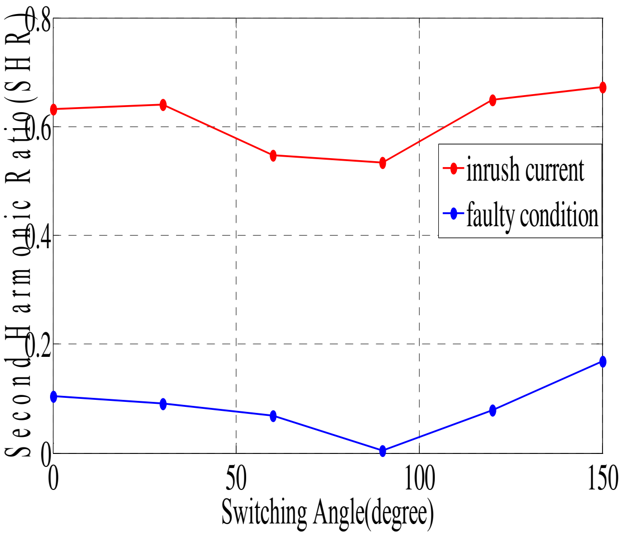

Fig. 5 SHR at different angles.

B. Peak Value

The feature is found by taking out the maximum value of the current flowing through the system. Mathematically it is represented as

$$A = Max(x) \quad (3)$$

Where, A is the peak value of the signal x. Fig 6 shows the peak values for inrush as well as faulty condition at different angles.

C. Mean deviation

The mean of a signal is found using equation (4). The average or mean deviation is the summation of the deviations of all individual samples which is divided by the number of samples

$$z = \frac{1}{n}\sum(x-\mu) \quad (4)$$

Where, is the signal having either inrush or faulty condition and is the mean of the signal. Fig 7 shows the mean deviation at different angles for inrush and faulty condition.

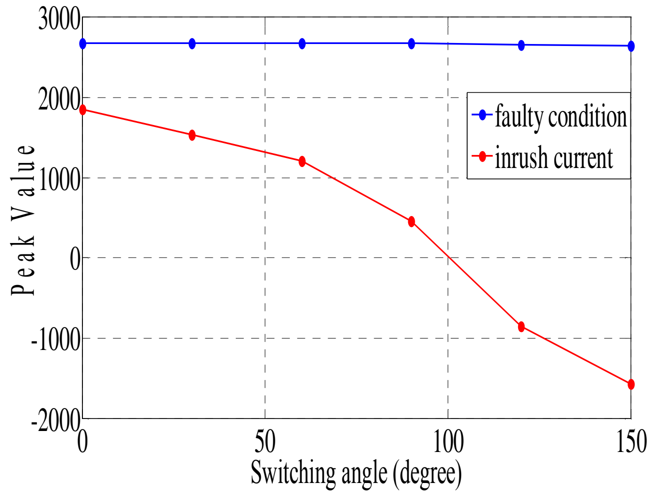

Fig. 6 peak value at different angles.

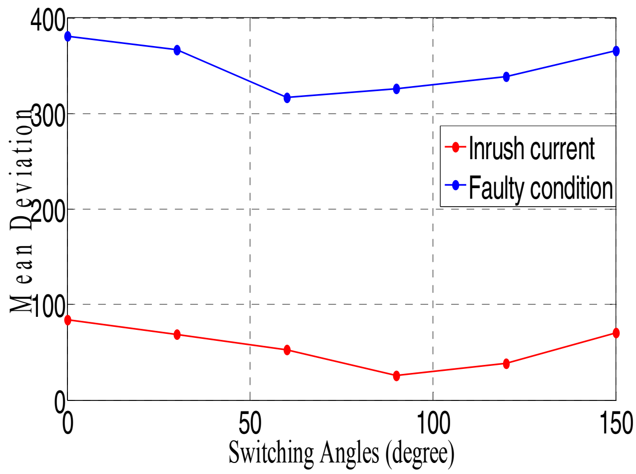

Fig. 7 Mean deviation at different angles.

From fig 5, 6 & 7 it is seen that the features extracted in this paper are very appropriate to discriminate between the faulty condition and inrush current of transformer.

IV. RESULTS AND DISCUSSIONS

The faulty condition and transformer inrush current are obtained using MATLAB simulation. Since inrush current have second harmonics FFT of primary current is taken in order to calculate SHR for faulty and inrush conditions. Similarly the peak value and mean deviation of the current signals are taken in order to classify the conditions properly. These features extracted as shown in above section are given as input to the ANN. The features are calculated for different current signals which are obtained by varying the switching angle. Total 100 signals are used to feed ANN as input by extracting features.

The training of ANN is divided into 3 parts, training in which 70% of signals are used, validation in which 15% signals are used to validate the training and last testing in which 15% signals are used to test the network. The numbers of neurons which are trained are 20 these neurons take the extracted features as input and get trained according to the pattern of the features. 10 hidden layers are used for this purpose. Fig 8 shows the MATLAB simulation of ANN used to discriminate the inrush and faulty condition.

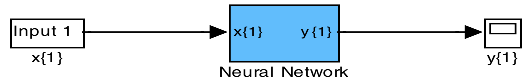

Fig. 8 MATLAB simulation of ANN.

Fig 9 shows the output of ANN here it is seen that the 20 neurons are sufficient to classify the Inrush current and faulty condition accurately the efficiency of ANN is found to be 100% which shows that the features which are used to feed ANN are best and can be used to classify the inrush and faulty conditions. The first and second row indicates the inrush current and faulty conditions, and first and second column indicates the output of individual condition. From fig 9 it is seen that the ANN is able to classify the inrush and faulty condition accurately and the accuracy of ANN is found to be 100%.

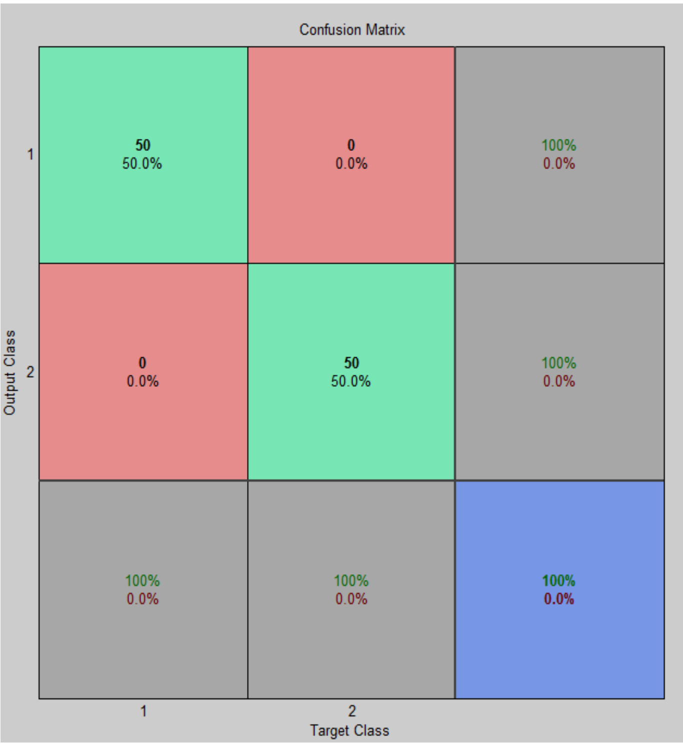

Fig. 9 Output of ANN.

Since total 100 signals were used to feed the ANN the 20 neurons used can classify the conditions accurately i.e. 50 signals were classified accurately as inrush current and remaining 50 signals are classified as faulty conditions. As seen from fig 9 first row and first column shows that 50% signals are classified as inrush current and from second row and second column it is seen that 50% signals are classified as faulty conditions, Which shows that the accuracy of features which were used to classify the conditions is 100%.

Table I & II shows the values of SHR, peak value and mean deviation for different angles.

TABLE I

FEATURES AT DIFFERENT ANGLES FOR INRUSH CURRENT

Angle (degree)	*Features*		
	SHR	*Peak value*	*Mean deviation*
0	0.6311	1849.2	84.05
30	0.6410	1534.7	68.55
60	0.5470	1211.6	52.89
90	0.5340	462.55	25.38
120	0.6490	-851.6	38.07
150	0.6718	-1569.6	70.24

TABLE II

FEATURES AT DIFFERENT ANGLES FOR FAULTY CONDITION

Angle (degree)	*Features*		
	SHR	*Peak value*	*Mean deviation*
0	0.1032	2680.99	380.77
30	0.0900	2680.99	366.99
60	0.0690	2679.31	317.02
90	0.0050	2680.62	326.17
120	0.0790	2657.45	338.59
150	0.1687	2651.00	366.13

V. CONCLUSIONS

In this paper, a new methodology using ANN is used for discrimination between inrush current condition and faulty condition for protection of transformer from mal-operation of protective system or relay. MATLAB simulation is used for obtaining inrush current and faulty condition. By extracting different features such as SHR, peak value and mean deviation and comparing with different switching angle of circuit breaker i.e. 30degree, 60degree, 90degree etc. and by using these features as an input to ANN, the author predict accurately inrush and faulty condition which can be used to restrain the operation of relay during inrush condition while operating it in faulty condition. The accuracy of ANN is 100%

i.e. 50% signal have been detected as inrush and 50% as faulty condition accurately.

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