Scientific Journal of Impact Factor (SJIF): 3.134
e-ISSN (O): 2348-4470
p-ISSN (P): 2348-6406
International Journal of Advance Engineering and Research Development
Volume 2, Issue 12, December -2015

To Avoid Malfunction due to Inrush current Using Neural Network Fitting Tool

Vinay Barhate

Department of Electrical Engineering, Shri Ramdeobaba College of Engineering and Management, Nagpur

Abstract— *The growing power system demands a speedy and reliable protection module for Transformer which is its one of the important link to maintain uninterrupted power supply. The protective module should quickly initiate the tripping during internal faults and should not allow the tripping during magnetizing inrush. The work reported in this paper demonstrates the use of Neural Network fitting tool to be incorporated in association with differential relay operation in the protection scheme. The ANN based algorithm is trained to recognize the waveform pattern which permits the Relay Trip operation only during short circuit conditions due to internal faults and not for inrush current. Modelling of ANN using feed forward Levenberg-Marquardt Back propagation techniques is used for implementation. The performance of the Neural Network has been tested with simulated signal which proved to be the technique having accuracy and fast classification.*

Keywords— *Transformer protection, Differential Protection Scheme, Inrush current, Artificial neural network, Neural Network Fitting Tool*

I. INTRODUCTION

Transformer is the most essential part of power system and its protection not only becomes necessary but also the selection of method used for protection. The protection for any internal fault is now universally provided by the differential protection scheme. But this protection sometimes fails for the excitation of the transformer at no-load due to inrush current in the primary circuit, which is generally three to four times the normal load current. Hence, to avoid the tripping of the relay during this condition, it is necessary to distinguish between the short circuit current and the inrush current.

It is reported that since 1960 the research scholars have shown interest in this area of protection of transformers. Many different techniques were used by the researchers for discrimination between internal faults and inrush current. The second harmonic restraint method is the most common one used by various relay manufacturers and application engineers [1] to analyse factors affecting the second harmonic ratio in inrush current, and described various harmonic restraint methods and compared their performance.

Second Harmonic restrain and Fifth Harmonic blockade technique [2], is based on the fact that the inrush current has a second-harmonic component of the differential current which is much larger in the case of inrush than for a fault, and the over-excitation current has a larger fifth harmonic component. And as the use of digital protection offers the advantage to implement complexes algorithms such as DFT to ensure better extraction of fundamental and other harmonic components, then the use of the second and the fifth harmonics for restraining and blocking, by the differential protection will give a possibility to discriminate between the faulty and the normal state of power transformer.

The wavelet Packets (WPT) algorithm approach [3] for determining different types of currents for power transformer was evaluated. The use of WPT as feature extraction naturally emphasizes the difference between fault, non-fault and inrush currents as generated by MATLAB/SIMULINK, since their frequencies are very different. The results of simulation showed that the algorithm successfully distinguish between fault, non-fault and magnetizing inrush currents condition in less than 1/5 cycle. The classification scheme is powerful and need simple calculation.

Differential power transformer protection using fuzzy logic concept [4] reports that fuzzy based algorithm consisting flux differential current derivative curve, harmonic restraint and percentage differential characteristic curve. The following advantages can be concluded from the papers mentioned above on fuzzy logic based approach: That the fuzzy based relaying algorithm prevents mal operation of relay in the event of magnetizing inrush with low second harmonic component and internal faults with high second harmonic component. This results in improved accuracy and robustness against the change of condition in power system. And also the Relays obtain high sensitivity to the fault detection and operate with tripping time of within half cycle, which is reliable and speedy.

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 [5] wherein the extensive simulation study shows that the symmetrical components can provide adequate inputs for classification of magnetizing inrush current and internal fault current. This new approach had shown a vastly improved performance over conventional techniques.

Under ANN, one strong method to discriminate between inrush and internal fault current is Probabilistic neural network (PNN) [6],[7].

The architecture of adaptive fuzzy network [8] has been utilized as a new inrush detector algorithm for differential protection of power transformer based on the fuzzy-neuro method.

An extensive C program code for Back propagation Algorithm was used in model of 78 Neurons input representing input current of Magnetising and short circuit samples for identification of Magnetising inrush current by training the data for short circuit. Experimental set up for small transformer with differential protection scheme [9] was tested. A review of literature survey of Transformer protection [10] is done since it is critical issue in power system when accurate and rapid discrimination of magnetizing inrush current from internal fault current is required. The use of Clark's transform with Fuzzy Logic[11] identifies the inrush current and avoids the Tripping of relay but while simulation of internal faults it takes care to issue trip signal.

In present paper, Neural Network Fitting Tool is used for identification of Magnetizing Inrush and Internal Fault currents in Transformer. This approach has been used due to its better classification accuracy, low computational burden, and fast response of the relay. A brief introduction of ANN is mentioned first.

II. ARTIFICIAL NEURAL NETWORK

The architecture of Artificial Neural Network with Levenberg-Marquardt back propagation algorithms is represented in Figure 1 which consists of five components. The x_i input neurons with W_{ii} weights, summation of weighted inputs, activation function and O_j output. Information enters the input neurons from external world, initially the weights are assigned and then weights are values that express the outcome of an input set or another process element in the preceding layer. Sum function calculates the net input that approaches to a neuron having effect of inputs and weights.

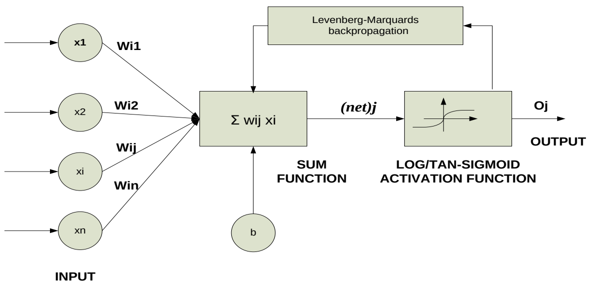

Figure 1. Architecture of ANN with LMBP

The weighted sums of the input components *(net)j* are calculated using (1) as follows:

$$(net)_j = \Sigma^{n}_{i=1} W_{ij} x_i + b \qquad (1)$$

where *(net)j* - is the weighted sum of the jth neuron for the input received from the preceding layer with n neurons

W_{ij} - is the weight between the jth neuron in the previous layer

x_i - is the output of the ith neuron in the previous layer.

b - is a fix value as internal addition and represents sum function. Activation function is a function that processes the net input obtained from sum function and determines the neuron output. In general for multilayer feed-forward models, the sigmoid activation function is used.

The output of the jth neuron *Oj* is computed using (2) with a sigmoid activation function as follows:

$$Oj = f(net)j = 1/(1+ e^{-\alpha(net)j}) \qquad (2)$$

where α- is constant used to control the slope of the semi-linear region. The sigmoid nonlinearity activates in every layer except in the input layer 3. The sigmoid activation function represented by (2) gives outputs in (0,1). If it desired, the outputs of this function can be adjusted to (-1,1) interval. As the sigmoid processor represents a continuous function it is particularly used in non-linear descriptions. Because its derivatives can be determined easily with regard to the parameters within *(net)j* variable.

III. NEURAL NETWORK FITTING TOOL

Whenever a Neural network is used to solve pattern fitting problems, a mapping between data sets of numeric inputs and a set of numeric target is required to be done.

A Neural Network Fitting Tool (nftool) is useful to select data and to create and train a network. It provides a graphical user interface for designing and training a feed forward neural network for solving fitting problems. The network can be evaluated for its performance by mean square error and regression method. A single, double and multidimensional mapping problems can fit arbitrarily into a two layer feed forward network with sigmoid hidden and linear output neuron which gives consistent data and enough neurons in its hidden layers. The training algorithm is Back propagation based on a Levenberg-Marquardt minimization method (LMBP) which is often the fastest available back-propagation algorithm, and is highly recommended as a first-choice supervised algorithm, although it requires more memory than other algorithms.

The learning process is controlled by a cross-validation technique based on a random division of the initial set of data in 3 subsets:

- For training (weights adjustment),
- For learning process control (validation) And
- For evaluation of the quality of approximation (testing).

The quality of the approximation can be evaluated by Mean Squared Error (MSE), which expresses the difference between to correct outputs and those provided by the network; the approximation is better if MSE is smaller i.e. closer to 0.

IV. SIMULATION

This section describes the simulation of Magnetizing Inrush and Short circuit current in a saturable core transformer. The simulation is done using MATLAB.

Figure 2 shows the Simulink diagram of power system comprising of a three phase AC source with chosen Power Transformer out of various samples shown in Table 1 .This system is shown feeding a connected three phase Load. There is a provision for simulating a desired fault in the system. The function block of Neural Network Fitting Tool (nftool), which is trained for Short circuit waveform, is connected at the primary side of power transformer. A real time data is given as an input to ANN which would be having a pattern of either a Magnetising Inrush current or a short circuit current. Based on the type of input i.e. Short circuit or Inrush current, it will take a decision whether to issue a trip signal to relay or not. It is designed suitably to issue trip signal/ Logic 1 for relay only in case of Short circuit fault and shall remain stable for avoiding mal functioning during Inrush current.

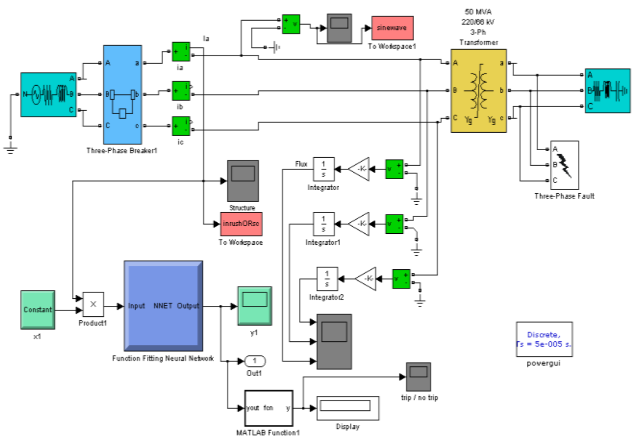

Figure 2. Simulink model of the simulated power system

The system is simulated for various sample Power Transformers under protection say 50MVA, 100 MVA, 150MVA and 200 MVA as shown in Table 1. For each transformer, both the input patterns, one for magnetizing inrush and another for short circuit during fault, are simulated for obtaining the waveform patterns. Figure 3 shows a pattern of Magnetizing Inrush Current for phase 'a' of 50 MVA transformer and subsequently the pattern for other phases are also recorded for training

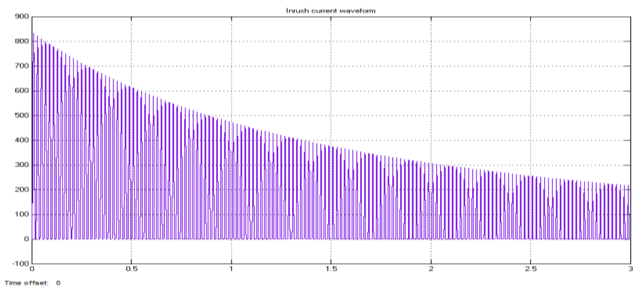

Figure 3. Magnetizing inrush current of 50 MVA transformer

The magnitude of Inrush current is 840 Amps at the first instant, which is about 4 times the rated current and Relay is likely to Trip under malfunction. The main objective here is to avoid this tripping for Magnetising Inrush current and using nFtool it should take a decision by giving No Trip / Logic 0 accordingly.

Another pattern of Waveform in Figure 4 shows the Short circuit current when L-L-L-G fault occurs at the load side. It is expected to take a decision of issuing Trip signal/ Logic 1 within no time for such a high magnitude of short circuit current.

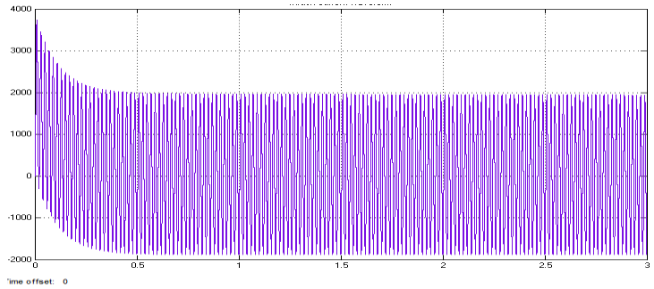

Figure 4. Short circuited current waveform of 50 MVA transformer

The Short Circuit Current (LLL-G) fault has a magnitude of 3750 Amps initially and it continues to have 2000 Amps, even after 1 seconds, flowing into system if not protected. Many such samples for each Power transformers are taken and stored to analyse for Training and testing with nftool.

V. TRAINING

The Artificial Neural Network is trained using neural network fitting tool (nftool) available in MATLAB; for the power system model under simulation shown in Figure 2. The network is trained for Short circuit current having pattern of sinusoidal waveform with DC offset as shown in Figure 5 which is taken as a reference. This training pattern is obtained for 40 milliseconds (i.e. 2 cycles) which is nothing but a part of sample shown in Figure 6 out of waveform window of more than 3 seconds This is more than sufficient window to train the Neural network. In fact it requires hardly one cycle to take a decision for issue of Trip signal once trained.

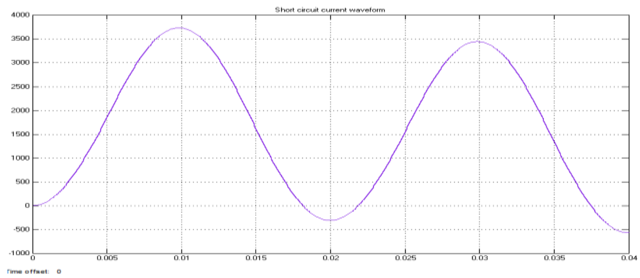

Figure 5. Training pattern for neural network

For training the neural network, instantaneous values are required. Hence, from this Short Circuit current waveform shown in Figure 5, the values, i.e. total 801 samples, have been collected in the Workspace with the help of SIMOUT block. The training has been done for Short circuited waveform as a reference.

After the completion of training of Neural Network a Simulink diagram of Function Fitting Neural Network has been formed as shown in Figure 6. It consists of two layers Feed Forward Neural Network and for evaluation of performance it uses Mean Square Error and regression analysis.

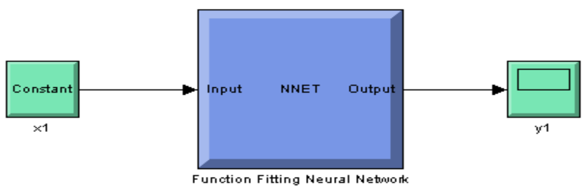

Figure 6. Simulink diagram of trained neural network

The subsystem of Function Fitting Neural Network is shown in Figure 7. The first is Hidden layer having Neurons with sigmoid activation function and the other is output layer with linear activation function neurons. The network is trained with Levenberg-Marquardt Back Propagation Algorithm. The Output of Trained network is then compared with the Average value of patterns for actual Short circuit and Inrush currents input while testing.

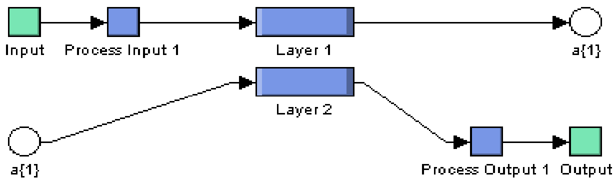

Figure 7. Subsystem off function fitting neural network

The 801 input samples collected till 40 milliseconds of short circuit current under training is feed-forward through two layers. It is observed that the training has been completed within 1000 epochs. Figure 8 shows the output of trained neural network.

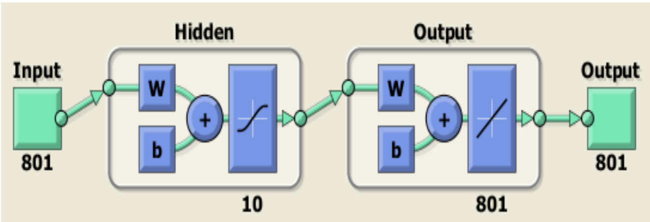

Figure. 8. View showing output of trained neural network

VI. TESTING AND RESULT OF NFTOOL

Testing is performed and the desired results have been obtained for the chosen sample of Three phase, 50 Hz, 220/66 KV, 50 MVA transformer with saturable core and having specified initial fluxes. Table 1 shows other transformers having rating of 100 MVA, 150 MVA and 200 MVA, with corresponding winding parameters which are also tested.

Table 1. Sample power transformers under test

Sr. No.	Rating of power Transformer	Winding parameters	
		R1 (pu)	L1(pu)
1	50 MVA	0.001	0.0049
2	100 MVA	0.1732	0.000845
3	150 MVA	0.17318	0.000732
4	200 MVA	0.17319	0.001134

The testing of network is done for both the inputs separately i.e. short circuit and Inrush currents. When it was tested by applying the Magnetizing Inrush current as an Input, the testing pattern is simulated for 40 milliseconds as shown in Figure 9. Apparently it is distinguished than the already trained pattern under short conditions shown in Figure 5.

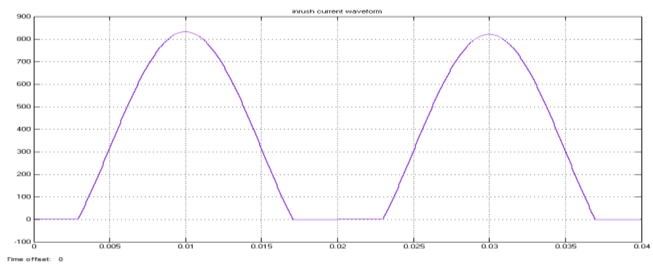

Figure 9. Testing pattern

Figure 10 shows the program flow chart in the MATLAB function block given in Figure. 2. This program takes a decision whether the Inrush current has occurred or a short circuit in the system and accordingly the tripping of relay takes place.

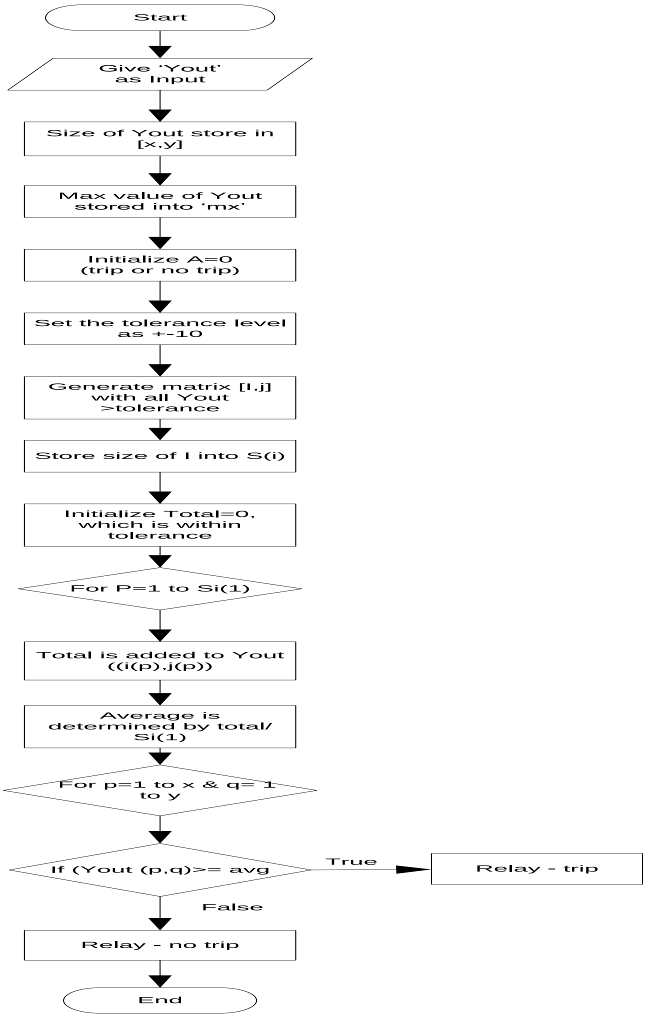

Figure 10. Program flow chart for trip or no- trip

A. Testing for Short Circuit

After running the power system model with 50 MVA power transformer shown in of Figure 2, for LLL-G fault, it issues trips signal, At the point of time when index at Y_{OUT} (p,q) is greater than or equal to threshold Average of target then it results into TRIP. It is found that with Y_{OUT} (p = 54;q = 216) it results to 1.0393e+04; and the threshold Average value was equal to 1.0393e+04.

Above result which is simulated for LLL-G fault, it is seen that the value at index (p,q) is (54, 216) is just equal to the threshold average value, here the average value is 1.0393e+04 and the value at this index is same as the average value, hence the relay gets trip signal at this instant.

It is also tested for all ratings mentioned in Table 1 for various internal faults and found reliably works to issue trip signal.

B. Testing for Inrush Current

For Inrush current, first at no load condition, without any fault, it's tested and it works reliably for the simulation model having 50 MVA transformer shown in Figure 2. The relay doesn't trip since the Y_{OUT} (p,q) has been never greater than or equal to Average hence the system will not issue trip signal.

It is also tested for all ratings of Transformer mentioned in Table 1 and found working reliably for not to issue trip signal and ultimately avoids a malfunction of employed differential protection scheme.

C. Interfacing MATLAB environment to Trip Relay

The output of Simulink model in MATLAB environment is interfaced successfully to the outside world using Com port, RS 232 with USART Max 232, Microcontroller AT89C2051 and relay with driver circuit. This relay trip circuit is designed and implemented on PCB. The block diagram for the relay trip circuit is shown in Figure 11.

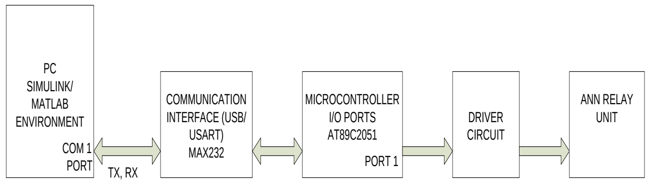

Figure 11. Interface MATLAB output to issue trip signal in real world

The trip signal from MATLAB is given to the hardware circuit through serial port RS-232. The USART interface MAX232 converts signals from RS-232 serial port to signals suitable for use in TTL (transistor-transistor logic) compatible to digital logic circuits for communication between serial port and microcontroller. Microcontroller AT89C2051 is programmed using AVR studio to activate the driver circuit using transistor and the relay coil is energized to trip. This part is referred as ANN relay unit which is proposed to be used in association with Differential Protection unit.

D. ANN Relay unit in association with Differential Relay Unit

The ANN Relay unit can be connected in association with existing percentage differential Relay unit protection of the Transformer. The single line diagram for this arrangement is shown in Figure 12. There are two Relay coils in Normally Open (NO) contact mode connected in series, one responding to Differential protection unit and the other responding to ANN unit. The Trip coil of Circuit Breaker shall be energized only in case of closing of both the relay units.

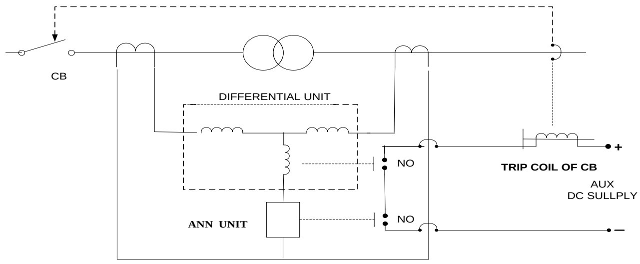

Figure 12. Schematic showing ANN unit in association with differential unit

Operation of circuit breaker occurs only when there is fault current due to internal fault. Table 2 explains the condition of Trip and No trip of Circuit Breaker under various simulation conditions and shows the operation of Relay coils of ANN unit in association with Differential unit with reference to Single Line Diagram connection shown in Figure 12.

Table 2. Trip conditions of circuit breaker

Simulation condition	**current**	**Relay Operation**		**Trip coil of Circuit Breaker**
		ANN Unit	**Differential Unit**	
No Load & No Fault	Inrush	Remain Open	May be Closed (malfunction)	No Trip
No Load & Internal fault	Inrush & Fault Current	Closed	Closed	Trip
Full Load & Internal fault	Fault current	Closed	Closed	Trip
External Fault	Fault current	May be Closed	Remain open	No Trip

VII. CONCLUSION

This new approach in differential protection for power transformer based on Artificial Neural Network Fitting Tool had shown a vastly improved performance over conventional techniques. The LM-back propagation algorithm minimizes an average sum squared error term by doing a gradient descent in the error space during training. A program for the flow chart shown in Figure.10 written in C has taken care of Trip or No trip condition of ANN relay unit. An attempt of interfacing MATLAB environment and hardware circuit on PCB to issue Trip signal to ANN relay unit worked accurately once the index reaches to equal or above threshold value. The obtained results showed that the proposed Neural Network fitting Tool avoids the malfunction of differential Protection scheme.

This ANN Relay shall be used in association with Differential Relay unit, Table 2 shows that it promises good selectivity to differential protection of power transformer having ability of not to trip during the occurrence of Inrush Current but at the same time ensuring tripping under Internal faults

REFERENCES

[1] Jialong Wang, "Analysis of transformer inrush current and comparison of harmonic restraint methods in transformer protection" Protective Relay Engineers, 2008 61st Annual Conference 1-3 April 2008.

[2] Ouahdi Dris, Farag. M. Elmareimi and Rekina Fouad, "Transformer differential protection scheme with internal faults detection algorithm using second harmonics restrain and fifth harmonics blocking logic", Electrical Engineering Portal.

[3] Iswadi HR, Redy Mardiana, "Differential power transformer protection techniques using the wavelet packet transform approach" Proceedings of the International Conference on Electrical Engineering and Informatics Institute Teknologi Bandung, Indonesia June 17-19, 2007.

[4] Ahmed Abdulkader Aziz, Prof. Dr. Abduladhem, Dr. Abbas H. Abbas Abdulkareem Ali, "Power Transformer Protection by Using Fuzzy Logic" Iraq J. Electrical and Electronic Engineering Vol.5 No.1 2009.

[5] Venkateshan and M. Senthil Kumar, "Power transformer differential protection with neural network based on symmetrical component" International journal of communication and Engineering, Vol 06 No.6 2012.

[6] Manoj Tripathy, R P Maheshwari and H K Verma, " Power Transformer Differential Protection based on optimal probabilistic Neural Network" IEEE transactions on power Delivery, Vol 25, No 1, 2010.

[7] Manoj Tripathy, R P Maheshwari and H K Verma, "Improved transformer protection using probabilistic neural network and power differential method", international journal of Engineering science and technology. Vol 2 No. 1 2010.

[8] H. Khorashadi Zadeh, Mr Aghaebrahimi, "A neuro- fuzzy technique for discrimination between internal faults and magnetizing inrush currents in transformer" Iranian Journal of Fuzzy Systems Vol. 2, No. 2 (2005).

[9] Mudita Mathur, Vinay Barhate, "ANN based technique for discrimination between Magnetizing Inrush and Internal Fault Currents in Transformer," International Journal of Science and Research, Vol. 2, Issue 1, January 2013.

[10] Vinay Barhate, "A review of distinguishing schemes for power transformer's magnetizing inrush and fault currents", International Journal of Electrical and Electronics Engineering Research, Vol. 3, Issue 2, June 2013.

[11] Rupanjali Umre, Vinay Barhate, "Power Transformer Protection using Clark's transformation and Fuzzy Logic, International Journal of Engineering Research and Application", special issue/ICIAC 12-13, April 2014.

