

Adaptive Method for Inrush and Internal fault Current Discrimination of Power Transformer

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Abstract: Power transformer plays a significant role in electrical power system network. It is required in all types of substation for transmission & distribution purpose. It is very expensive and vital device which always remains in service after installation, except under the breakdown or maintenance condition. Hence transformer protection against internal faults and other disturbances which occurs in the power system is necessary to maintain continuity of supply. Buchholz relay is used to provide security against all types of internal fault but it is convenient only for oil immersed transformer, that too for small & medium power rating transformers. It is not inherent sensitive for detecting faults and due to sluggish behavior of relay operating time of relay is also more, hence reliability is a serious concern. So at present differential protection is widely used for protection of large power transformer using differential relay. The major problem with differential relay is that, it sometime fails to differentiate among inrush and internal fault current samples. Hence this paper provides a novel solution to this problem by using artificial intelligence tools to discriminate between inrush and internal fault in order to avoid the mal-operation of differential relay.

Keywords: inrush current; internal fault; ; differential relay; Back Propagation Neural Network

1. Introduction

Transformer is a static device which is used to transfer the power from one circuit to another circuit. It changes the voltage level from primary circuit to secondary circuit as per desired condition. It is installed in all types of transmission and distribution substations for supplying the electrical energy. In generating stations, step up transformers are used to raise the voltage level at sending end. At receiving end substation, step down transformers are used. Earlier actuators and relays were used to protect the transformer from faults within protection zone, but in present scenario these are replaced by electronic circuits and microprocessor based relay. The static relays also keep the record of fault occurrence for further analysis and investigation.

This paper proposed an algorithm that is designed to discriminate these two current samples. Waveform identification method uses ANN to distinguish between inrush and fault current. The techniques i.e. BPNN is used in the present work for correct classification of current samples.

2. Simulation of Power Transformer

For the analysis of the transformer Simulation of the different operating conditions of the transformer was done on the software package called PSCAD/EMTDC™. PSCAD (i.e. Power System Computer Aided Design) is a software package which is used for simulation of power system network. This software is developed by Manitoba HVDC Research Center [5]. In this software package

different operating conditions of transformer can be simulated.

Simulation is done for normal and faulty condition of transformer in PSCAD and records all these signals are used for interfacing these signals with MATLAB to analyze all conditions and build an algorithm for transformer protection. Various transformers are taken for training and testing purpose for simulating in PSCAD at different switching angle and different types of fault which occur in transformer. Various operating conditions of transformer are performed as follows:

1. Normal Operating condition :- In normal operating condition of transformer rated or less current flow through it and average value of differential current is zero i.e. $I_d = I_1 - I_2 = 0$. So relay will not operate in this condition. Fig.1 shows the simulation model of normal operating condition of transformer.

The basic principle of operation of the differential protection for calculate the difference between current entering and leaving the protection zone of transformer.[9].

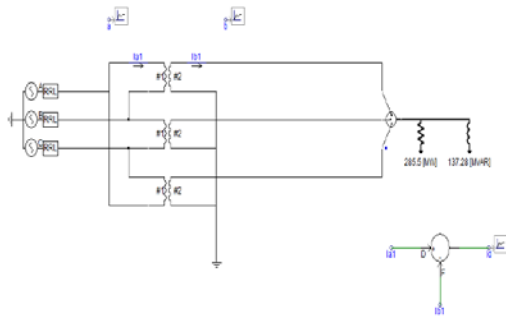


Figure 1: Simulation model of power transformer under normal operating condition

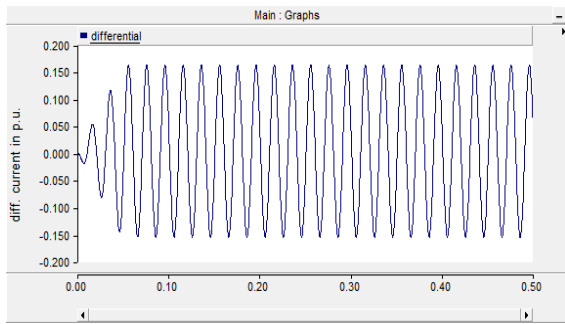


Figure 2: Differential current waveform under normal operating condition of power transformer

2. Magnetizing Inrush Current: - When a transformer is energized from fault recovery or during the time of commissioning, a large amount of current flows through the primary winding these currents are called inrush currents. When a transformer is first energized, a transient current up to 8-10 times larger than the rated transformer current flows for several cycles.

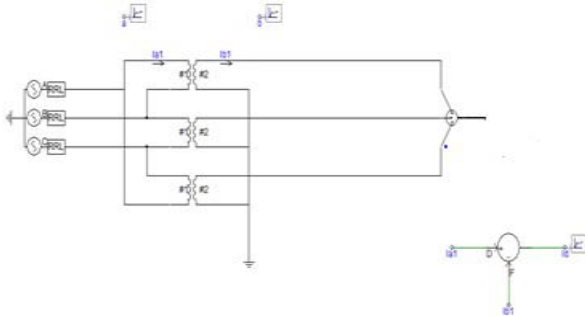


Figure 3: Simulation diagram of Power Transformer for inrush current

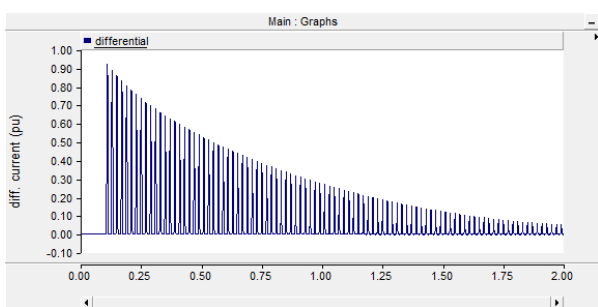


Figure 4: Differential current waveform under inrush condition at switching angle 0°

3. Internal Fault Condition: - The fault occurs inside the Protected zone of the Transformer is called Internal Fault. These types of fault are most critical they can cause huge damage to transformer and disturb the continuity of power supply. Hence differential relay must be operating for this type of faults and tripping is mandatory in case of internal fault. There are various types of internal fault which are as follows :-

a. Phase to phase fault: - The fault which occurs from one of the winding to another of winding is called Phase to phase fault as shown in Figure 5. These types of faults are rare in transformer. If phase to phase occur in transformer, it will give rise to substantial current to operate the instantaneous over current relay on the primary side as well as the differential relay.

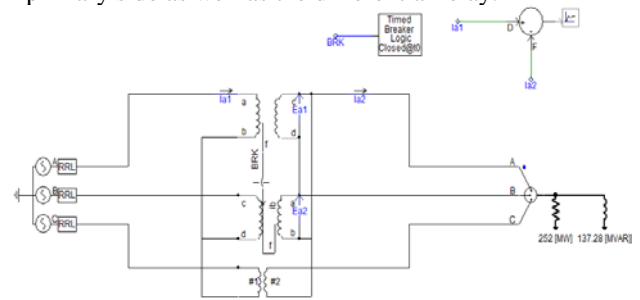


Figure 5: Simulation diagram of differential power model for Phase to phase fault of transformer

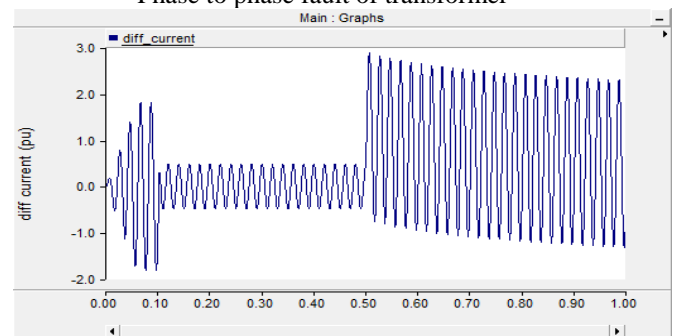


Figure 6: Differential current waveform for phase to phase fault condition at 25% fault location

b. Phase to ground fault: - The fault which occur when one of the phases directly contact to ground or any metallic part. This types of faults are called Phase to ground fault. The Fig.7 for phase to ground are as follows :

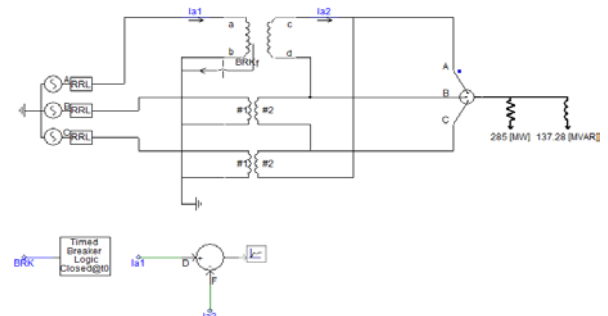


Figure 7: Simulation diagram of differential power model for Phase to ground fault of transformer

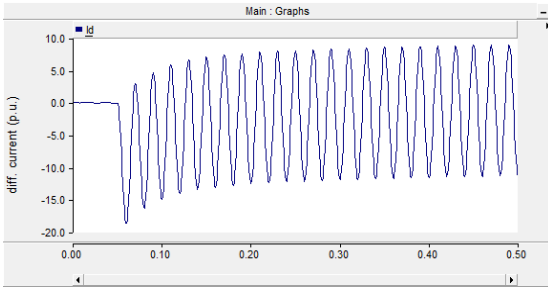


Figure 8: Differential current waveform for phase to ground fault condition at 25% fault location

3. Back Propagation Neural Network

Back propagation is multilayer feed forward network given by McCulloch and Pitts. It consists of input layer, hidden layer and an output layer. It is trained by the forward-backward method; the weights are updated by forwarding and then backward, and it again updates itself for error minimization. The output layer consists of only 1 neuron because we need to get only two conditions to satisfy at the output, i.e., inrush current and the internal fault current. For classification neural network toolbox is utilized from MATLAB [7].

Training process for BPNN

1. Initialization of weights with randomly selecting initial values.
2. Calculate the output for all input sampled values.
3. Calculate the mean squared error (MSE) and sum squared error (SSE), stop if MSE is below the desired values.
4. Follow the loop till it reaches the MSE goal; return to step 2 till the goal reaches or up to the maximum iteration completed.

Samples/cycle is calculated by taking 800µs channel plot step time in PSCAD

$$\frac{25ms}{800\mu s} = 25 \text{ samples / cycle} \quad 3.1$$

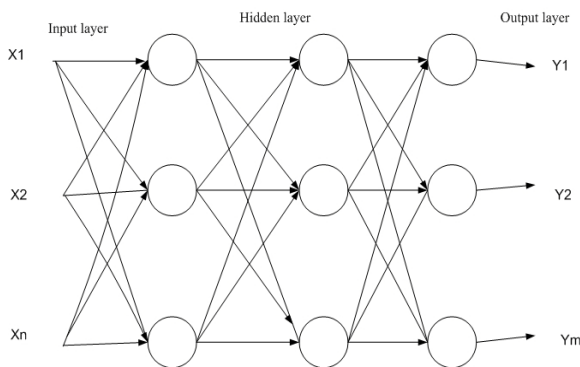


Figure 9: Basic structure of Back propagation neural network architecture

4. Training and Testing, Formation of Matrix

4.1 Training and Testing

Before training a feed forward network, weights and biases must be initialized. Weights are initialized by the `rand` (twister) command or can be done by `init`.

Input layers are the input sample values which are given to the BPNN network hidden layer neurons and are decided by checking in which case the error is minimum (empirically by trial and error method) so the convergence of the training will be faster and with higher accuracy.

It is trained by the forward-backward method and weights are updated by forwarding and then backward; it again updates itself for error minimization. The output layer consists of only 1 neuron because of the necessity to get only two conditions for satisfying at the output, i.e., inrush current and the internal fault current.

4.2 Formation of Matrix

Now we make an input matrix in the same manner for both cases for internal and inrush current until all the elements up to 3 cycles have been used. So we form the matrix for inrush and internal fault cases and for the training purpose more no. of patterns are required for testing of transformer.

Hence all training matrix contains for both inrush and internal fault cases. So the complete input matrix consists of 1000 patterns and corresponding 1000 target values are given to the input matrix in which 500 patterns are for inrush and remaining 500 are for fault case.

These include various patterns for inrush at no load at different switching conditions and different fault conditions, i.e., phase to phase and phase to ground fault at different fault locations.

The training matrix has been constructed in this manner that BPNN has been trained to provide output as ‘0’ for inrush and ‘1’ for internal fault.

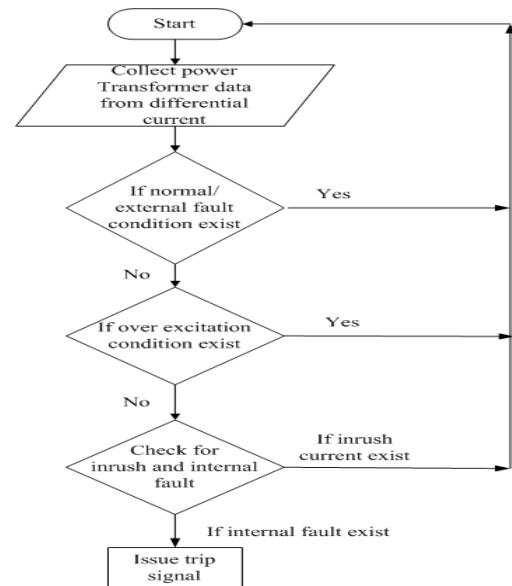


Figure 10: Flow chart of ANN based algorithm

Here from all five operating conditions of the transformer out of these the normal and internal fault can be differentiated by comparing of both peak-to-peak values for the two cycles and also by comparing the sampled values for each cycle.

The training process for BPNN has been shown in figure 11

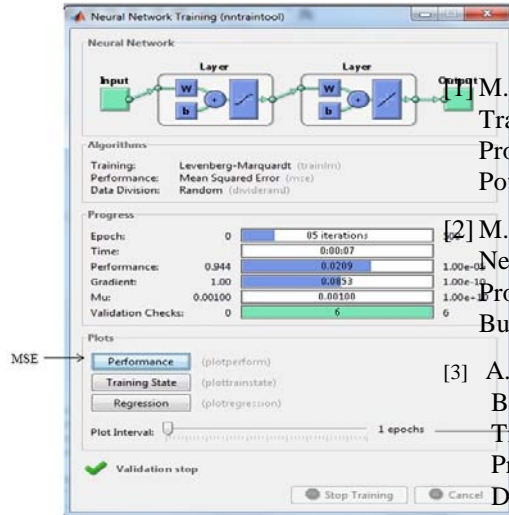


Figure 11: Training process of BPNN based algorithm

The main issue to discriminating the internal fault and inrush case is that these two are classified by BPNN using ANN technique. These two conditions come same in case of small amount of internal fault and inrush. The internal fault which is less than 2% for shorted winding those of inrush both replicate the same so it is complicated to distinguish between these two currents i.e. internal fault and inrush. So we use ANN technique for successfully classified and allow to trip signal if internal fault occur in the system.

5. Result and Discussions

An algorithm is designed to discriminate the inrush current and fault current by using artificial neural network technique. Simulation is done to perform various operating condition of transformer in PSCAD software. To perform various operating condition of power transformer different rating of power transformer is taken for simulating purpose respectively 315MVA, 180MVA and 150MVA. In which by varying the various switching angle different output is taken from PSCAD. Switching angles are respectively 0^o, 30^o, 60^o, 90^o, 120^o, 150^o, 180^o, 240^o, 300^o, 360^o etc. Similarly for fault condition phase to phase fault and phase to ground fault are performed and output is taken at various condition respectively for 5%, 25%, 50%, 75%, 90%, 95%, 99% etc.

Table 1:- Classification accuracy in BPNN

| Training Transformer in MVA | Testing Transformer in MVA and % accuracy in BPNN | | |
|-----------------------------|---|------|-----|
| | 315 | 180 | 150 |
| 315 | 98% | 87% | 94% |
| 180 | 88% | 100% | 85% |
| 150 | 84% | 88% | 98% |

6. Conclusion

In this chapter algorithm has been implemented to recognize between the inrush current and fault current which occur in transformer. The absolute classification accuracy obtained by BPNN technique is 94% for 25 samples/second with 1000 patterns, t is set as target.

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