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Transmission Line Fault Detection and Classification using Artificial Neural Network

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Abstract–**Electrical power systems suffer from unexpected failures due to various random causes. The functions of the protective systems are to detect, then classify and finally determine the location of the faulty line of voltage and/or current line magnitudes. Then at last, for isolation of the faulty line the protective relay have to send a signal to the circuit breaker. The ability to learn, generalize and parallel processing, pattern classifiers is applications of Neural Network used as an intelligent tool for detection.**

The features of Neural Networks, such as their ability to learn, generalize and parallel processing, among others, have made their applications for many systems ideal. The use of neural networks as pattern classifiers is among their most common and powerful applications. The use of back-propagation neural network architecture as an alternative method for fault detection, classification and isolation in a transmission line system. The main goal is the implementation of complete scheme for distance protection of a transmission line system. In order to perform this, the distance protection task is subdivided into different neural networks for fault detection, fault identification (classification) as well as fault location in different zones. Three common faults were discussed; single phase to ground faults, double phase faults and double phase to ground faults. The result provides a reliable and an attractive alternative approach for the development of a protection relaying system for the power transmission systems.

Keywords –**Neural Networks, ORPD, Transmission Line.**

I. Introduction

In power systems, the transmission losses are always a major concern across an electric power network. Present condition of markets demands enormous power in a continuous manner. In power system operation, minimizing the power loss in transmission lines and/or minimizing the voltage deviation at the load buses by controlling the reactive power is referred to as optimal reactive power dispatch (ORPD). The security of a power system is under threat when it is operated at stressed conditions and may result in voltage instability. Nowadays voltage instability has become a new challenge to power system planning and operation. Insufficient reactive power availability or non-optimized reactive power flow may lead a power system to insecure operation under heavily loaded conditions [1]-[2]. By reallocating reactive power generations in the system by adjusting transformer taps, generator voltages and switchable VAR sources, the problem can be solved to a far extent.

Transmission power losses have been an important topic of study in recent decades. Low power transmission has been recognized as a factor for efficient system operation. A reliable system has the benefits to users and the industry as minimum wastage can increase efficiency. To achieve this aim a highly reliable and cost effective long term investment technology is required. Power limits can define transfer capability. Also in a complex interconnected system, power has a great impact to increase the reliability and the profits. Although this interconnection gives the system a complicated dynamic. It has advantages such as reduced spinning reserves and a lower electricity price. To achieve these benefits, appropriate control is required to synchronize the machines after a disturbance occurs.

An overhead transmission line is one of the main components of electric power system. The transmission line is exposed to the environment and the possibility of experiencing faults on the transmission line is generally higher than that on other main components. Line faults are the most common faults, they may be triggered by lightning strokes, trees may fall across lines, fog and salt spray on dirty insulators may cause the insulator strings to flash over, and ice and snow loadings may cause insulator strings to fail mechanically. When a fault occurs on an electrical transmission line, it is very important to detect it and to find its location in order to make necessary repairs and to restore power as soon as possible. The time needed to determine the fault point along the line will affect the quality of the power delivery. Therefore, an accurate fault location on the line is an important requirement for a permanent fault. Pointing to a weak spot, it is also helpful for a transient fault, which may result from a marginally contaminated insulator, or a swaying or growing tree under the line.

The research done in the field of protective relaying of power systems concentrates on transmission line fault protection due to the fact that transmission lines

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are relatively very long and can run through various geographical terrain and hence it can take anything from a few minutes to several hours to physically check the line for faults. The automatic location of faults can greatly enhance the systems reliability because the faster we restore power, the more money and valuable time we save. Hence, many utilities are implementing fault locating devices in their power quality monitoring systems that are equipped with Global Information Systems for easy location of these faults.

The goal of this paper is to detect and identify the type of fault in the line and to determine which zone (segment) of the line has become faulty. Back-propagation neural network approach is studied, implemented and modified to perform these three tasks. To identify the existence of faults in the system voltage and current signals of a line are observed. These signals are also used to specify the fault type and location. The simulation models of the transmission line system are constructed and the generated information is then channelled using the MATLAB.

II. Losses in Transmission Lines

Power generated in power stations pass through large and complex networks like overhead lines, transformers, cables and other equipment and reaches at the end users. It is fact that the single unit of electric energy generated by Power Station does not match with the units distributed to the consumers. However, some percentage of the units is lost in the distribution network.

$$\text{Transmission and Distribution Losses} = \frac{(\text{Energy Input to Feeder (Kwh)} - \text{Billed Energy to consumer (Kwh)})}{\text{Energy Input Kwh}} \times 100 \quad (1)$$

There are two types of technical losses:

- Fixed Losses
- Variable Losses

Main Reason for Technical Losses

1. ***Lengthy Distribution Lines:*** This results in high line resistance and therefore high I^2R losses in the line.
2. ***Inadequate Size of Conductors of Distribution Lines:*** The size of conductors should be adequate but are generally varied in rural areas.
3. ***Installation of Distribution transformers away from load centers***: This again leads to higher line losses.
4. ***Low Power Factor of Primary and secondary distribution system:*** A low Power Factor contributes towards high distribution losses.
5. **Feeder Phase Current and Load Balancing:** One of the easiest loss savings of the distribution system is balancing current along three-phase circuits.
6. Load Factor Effect on Losses.
7. Transformer Sizing and Selection
8. Balancing 3 phase loads
9. Switching off transformers
10. Other Reasons for Technical Losses
    - Unequal load distribution among three phases in L.T system causing high neutral currents.
    - Leaking and loss of power
    - Over loading of lines.
    - Abnormal operating conditions at which power and distribution transformers are operated.
    - Low voltages at consumer terminals causing higher drawl of currents by inductive loads.
    - Poor quality of equipment used in agricultural pumping in rural areas, cooler air-conditioners and industrial loads in urban areas.

III. Proposed Methodology

Modeling of the Power Transmission Line System

A 500 kV transmission line system has been used to develop and implement the proposed strategy using ANNs. A one-line diagram of the system that has been used throughout the research. The system consists of two generators of 500 kV each located on either ends of the transmission line along with a three phase fault simulator used to simulate faults at various positions on the transmission line. The line has been modelled using distributed parameters so that it more accurately describes a very long transmission line.

Figure 1: Power transition model

This power system was simulated using the SimPowerSystems (Simscape Power Systems) toolbox in Simulink by the MathWorks. A snapshot of the model used for obtaining the training and test data sets, ZP and ZQ are the source impedances of the generators on either side. The three phase V-I measurement block is used to measure the voltage and current samples at the terminal A. The transmission line (line 1 and line 2 together) is 300 km long and the three-phase fault simulator is used to simulate various types of faults at varying locations along the transmission line with different fault resistances.

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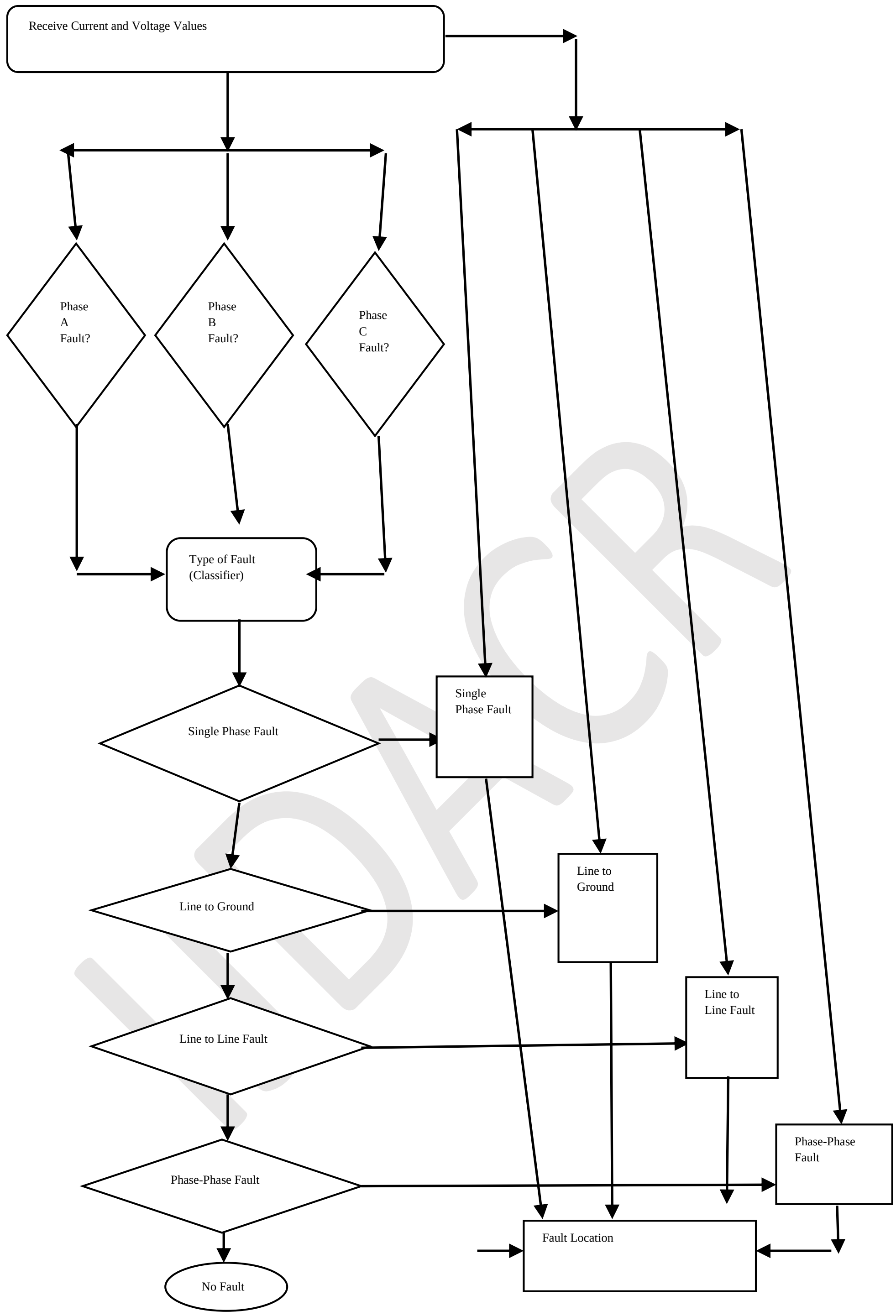

Figure 2: Flow chart of proposed approach

Training Procedure

The back propagation learning rule used in perhaps in over 80-90% of practical application. In the first stage which is the fault detection phase, the network takes in six inputs at a time, which are the voltages and currents for all the three phases. Here the value we take for no fault and single line to ground fault condition. The output of the neural network is that target value is equal to with the input or not. When target and input values are same that shows the power system is healthy. If any changes in the target value it shows that any transmission line fault has

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occur on the system. The input layer, 20 neurons in the hidden layer and 6 neuron in the output layer. This figure called as the performance plot of the neural network. Selecting the right structure size of the network reduces not only the training time but also significantly impacts the generalization and representational capabilities of the trained network. The no of hidden layer and neuron in these layers are important factor in determining the optimal size and structure of the network. The network presented here represents only a sample of those that we modelled and correspond to the 'best' results that were obtained after extensive trial and error procedure.

Overview of the Training Process

Two important steps in the application of neural networks for any purpose are training and testing. The first of the two steps namely training the neural network is discussed in this section. Training is the process by which the neural network learns from the inputs and updates its weights accordingly. In order to train the neural network we need a set of data called the training data set which is a set of input output pairs fed into the neural network. Thereby, we teach the neural network what the output should be, when that particular input is fed into it. The ANN slowly learns the training set and slowly develops an ability to generalize upon this data and will eventually be able to produce an output when a new data is provided to it. During the training process, the neural network's weights are updated with the prime goal of minimizing the performance function. This performance function can be user defined, but usually feed forward networks employ Mean Square Error as the performance function and the same is adopted throughout this work.

The outputs, depending upon the purpose of the neural network might be the fault condition, the type of fault or the location of the fault on the transmission line. For the task of training the neural networks for different stages, sequential feeding of input and output pair has been adopted. In order to obtain a large training set for efficient performance, each of the ten kinds of faults has been simulated at different locations along the considered transmission line. In view of all these issues, about 100 different fault cases for each of the 10 kinds of faults have been simulated.

Apart from the type of fault, the phases that are faulted and the distance of the fault along the transmission line, the fault resistance also has been varied to include several possible real-time fault scenarios.

- The fault resistance has been varied as follows: 0.25 ohm, 0.5 ohm, 0.75 ohm, 1 ohm, 5 ohm, 10 ohm, 25 ohm, 50 ohm.
- Fault distance has been varied at an incremental factor of every 3 km on a 300 km transmission line.

Neural Network

The methods of neural network based recognition have been studied for several years in order to achieve performance close to those observed in humans. Such neural networks are composed of several elements (or cells) for calculating operating in parallel and arranged in the manner of biological neural networks. The strength of neural networks is their ability to generate a decision region of any shape required by a classification algorithm, the price of integration of additional cell layers in the network type multilayer perceptron with learning by back propagation of the error gradient.

The general Neural Network approach contains following steps:

- Neural network creation.
- Configuration
- Training
- Simulation

Neural Network accept the features of training signals and test signal as an input a predefined target value has been set to perform feed forward neural network with gradient descent back propagation neural network algorithm in the presence of supervise learning, this algorithm is used to reduce the overhead and increase the accuracy of network and we use sigmoid transfer function to perform calculation at output layers. With the help of these all function desired output is generated. The functionality of Artificial Neural Network is performed is explained as follows:

Artificial Neural Network (ANN) is dealt with as an intelligence data processing framework that is motivated by the method for working of biological nervous systems of human, for example, mind and process data. The structure of data processing framework made out of countless interconnected processing components called neurons constantly in attempting to take care of particular issues. ANNs, is much the same as individuals, learn by case. There are numerous application region of ANN, for example, pattern recognition or information arrangement, through a learning procedure. Adapting in biological nervous systems includes alterations of synaptic associations that work between the neurons. This is valid for ANNs too that Neural networks, with their wonderful capacity to extract meaning from convoluted information, can be utilized to concentrate and despise examples and patterns that are so complex to be perceived by either ordinary

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people or other traditional computerized methods. A trained neural network can be dealt with as a master framework in the class of data it has been given to analyze to give suitable outcome [7].

Neurons

A class of statistical models is generally recognized as "Neural" if they possess following characteristics:

a. Consisting the set of adaptive weights or numerical parameters tuned by learning algorithm
b. Capable of approximating non-linear functions of their inputs.

The training mode of neurons (Figure 3) sources n number of inputs in parallel manner. The teaching input provides sufficient arguments to a neuron for generating specific output. In this mode the neurons are trained to fire for particular fashion. In case if input pattern does not resemble the taught list of patterns, firing rules takes the decision of firing or holding the inputs.

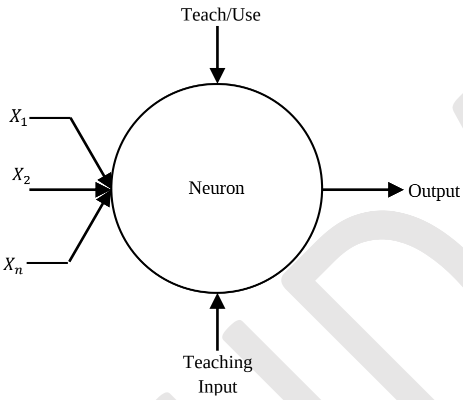

Figure 3: A simple Neuron [7]

Layers

The organization of Neural Network is a pattern of interconnected nodes that contain 'activation function'. The patterns are provided to 'input layer' that communicates with one or more hidden layers (Figure 4) for processing via weighted connections. The connection among the hidden layers and output layer delivers the required answers. The functions of three layers in NN can be defined in following statements:

- *Input Layer:* This layer accepts the patterns as input. The firing decision for further process is positive if the test input match with the training input.
- *Hidden Layer:* Dependent on the weights of connection with input and the related activities the operations at hidden layer are determined.
- *Output Layer:* The behaviour is directly proportional to hidden layer(s) activity and weight of connections among both output and hidden layer(s).

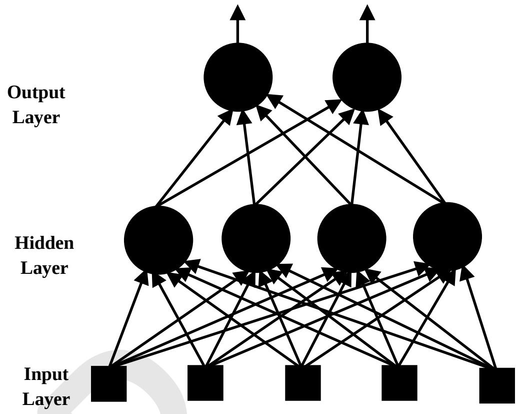

Figure 4: An example of a simple feed-forward network [7]

IV. SIMULATION RESULTS

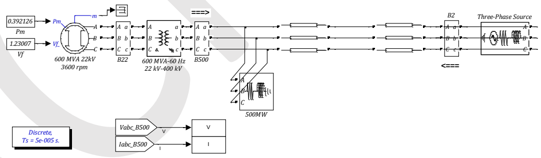

Figure 5: Transmission System

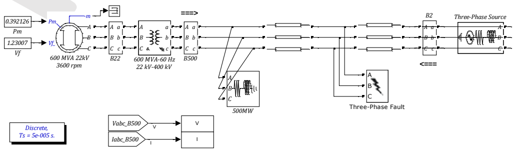

Figure 6: Transmission System AB

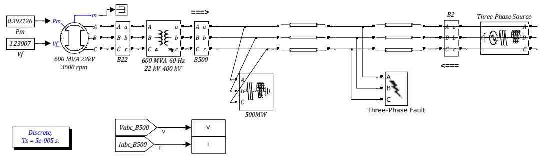

Figure 7: Transmission System ABG

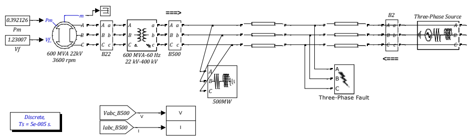

Figure 8: Transmission System AG

CASE-1

Select a Fault for system:

1. AG
2. AB
3. ABG
9. No Fault

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Enter Your Choice: 2
Enter the fault distance (KM) from sending end (d < 300): 200
Result:
Fault Type: L-L
Fault Location: zone3 (200KM < d<= 300 KM)

CASE-2
Select a Fault for system:
1. AG
2. AB
3. ABG
9. No Fault

Enter Your Choice: 2
Enter the fault distance (KM) from sending end (d < 300): 15
Result:
Fault Type: L-L
Fault Location: zone1 (d <= 100KM)

CASE-3
Select a Fault for system:
1. AG
2. AB
3. ABG
9. No Fault

Enter Your Choice: 1
Enter the fault distance (KM) from sending end (d < 300): 250
Result:
Fault Type: L-G
Fault Location: zone3 (200KM < d<= 300 KM)>>

CASE-4
Select a Fault for system:
1. AG
2. AB
3. ABG
9. No Fault

Enter Your Choice: 3
Enter the fault distance (KM) from sending end (d < 300): 240
Result:
Fault Type: L-L-G
Fault Location: zone3 (200KM < d<= 300 KM)>>

V. Conclusion

In this paper we have studied the application of artificial neural networks for the detection and classification of faults on a three phase transmission lines system. The method developed utilizes the three phase voltages and three phase currents as inputs to the neural networks. The inputs were normalized with respect to their pre-fault values respectively. The results shown in the paper is for line to ground fault only. The other types of faults, e.g. line-to-line, double line-to-ground and symmetrical three phase faults can be studied and ANNs can be developed for each of these faults. All the artificial neural networks studied here adopted the back-propagation neural network architecture. The simulation results obtained prove that the satisfactory performance has been achieved by all of the proposed neural networks and are practically implementable. The importance of choosing the most appropriate ANN configuration, in order to get the best performance from the network, has been stressed upon in this work. The sampling frequency adopted for sampling the voltage and current waveforms in this research work is 1,000 Hz.

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