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Distance Protection Scheme For Protection of Long Transmission Line Considering the Effect of Fault Resistance By Using the ANN Approach

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Abstract **-** Traditional electromechanical distance relays used for protection of transmission lines are prone to effects of fault resistance. Each fault condition corresponds to a particular pattern. So use of a pattern recognizer can improve the relay performance. This paper presents a new approach, known as artificial neural network (ANN) to overcome the effect of fault resistance on relay mal-operation. This method is based on pattern recognition and classification. The scheme utilizes the magnitudes of resistance and reactance as inputs. Once trained with a large number of patterns corresponding to various conditions, it can classify unknown patterns. It also has the advantage that it can adapt itself with the changing network conditions.

Keywords*- artificial neural network,distance relay, fault resistance, MATLAB*

I. INTRODUCTION

Distance relays have been successfully used for many years as the most common type of protection of transmission lines. The development of electromechanical and solid state relays with mho characteristics can be considered as an important factor in the wide spread acceptance of this type of protection at different voltage levels all over the world. Zone 1 of distance relays is used to provide primary high speed protection, to a significant portion of the transmission line. Zone 2 is used to cover the rest of the protected line and provide some backup for the remote end bus. Zone 3 is the backup protection for all the lines connected to the remote end bus. The implementation of distance relays requires understanding of its operating principles, as well as the factors that affect the performance of the device under different abnormal conditions [1].

The setting of distance relays should ensure that the relay is not going to operate when not required and will operate, only when it's necessary. Distance relays effectively measures the impedance between the relay location and the fault. If the resistance of the fault is low, the impedance is proportional to the distance from the relay to the fault. A distance relay is designed to only operate for faults occurring between the relay location and the selected reach point and remains stable (or inoperative) for all faults outside this region or zone. In a time stepped distance scheme this ensures adequate discrimination for faults that may occur between different line stations [2].

However it is seen that the relay performance gets affected when the fault involves resistance. To overcome this problem, this paper presents a new approach based on Artificial Neural Networks (ANN). This is because the majority of power system protection techniques are involved in defining the system state through identifying the pattern of the associated voltage and current waveforms measured at the relay location [3]. This means that the development of adaptive protection can be essentially treated as a problem of pattern recognition and classification. ANN is powerful in pattern recognition and classification. They possess excellent features such as generalization capability, noise immunity, robustness and fault tolerance. Consequently, the decision made by an ANN-based relay will not be seriously affected by variations in system parameters.

The paper is arranged in VII sections. Section II presents the proposed single machine infinite model (SMIB) developed in MATLAB. Section III describes the filtering scheme to remove the DC bias and harmonics from measured signals, so that the input to the neural network consists of fundamental components of voltage and current. Section IV explains algorithms and activation functions which are popularly used in ANN technique. Section V and VI describe the programming and results obtained.

II. SYSTEM SIMULATION-SMIB MODEL

Fig. 1 shows a typical 400 kV transmission line with series compensation used for the simulation [4]

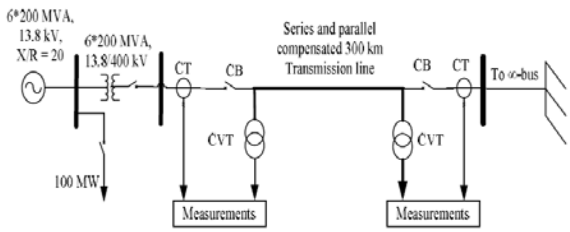

Figure 1: Single line diagram of model

The model shown in Fig. 2 is set up in Simulink and simulated by generating several faults. The faults are generated at different locations with variable fault resistance and fault duration. Throughout the simulation, ground resistivity is taken to be 100 Ωm which is practically acceptable.

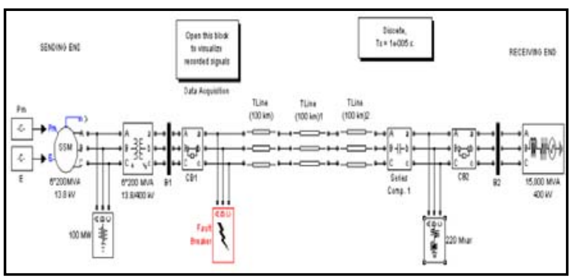

Figure 2: Simulink model used in simulation.

A three phase to ground fault is simulated at the bus 1 (fig. 3) and corresponding impedance locus is shown on R-X plane (fig. 4). Fault voltage and current signals are taken from measurements at the sending end side of the line.

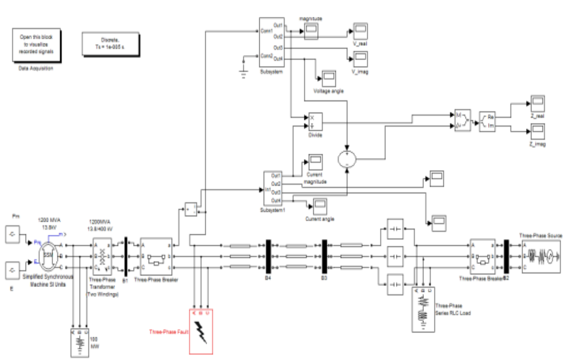

Figure 3: Three phase to ground fault simulated at bus 1.

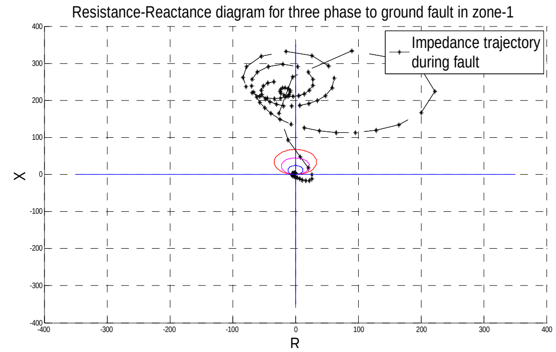

Figure 4: Fault trajectory on R-X plane.

III. FILTERING (PRE-PROCESSING) :

The pre-processing stage can significantly reduce the size of the neural network based distance relay, which in turn improves the performance and speed of the training process. The fault voltage and current signals are often noisy. In addition, when a fault occurs on a transmission line, voltage and current signals develop a decaying DC offset component whose magnitudes depends on many factors that are random in nature. Thus, the input data should be pre-processed before being fed to the network.

The block diagram of a typical numerical relay filtering scheme and it's realization in MATLAB is shown in fig. 5 and fig.6 [5].

Input signal Low pass filter A/D

Discrete Fourier Digital filter Converter

Figure 5: Block diagram of a typical numerical relay filtering scheme

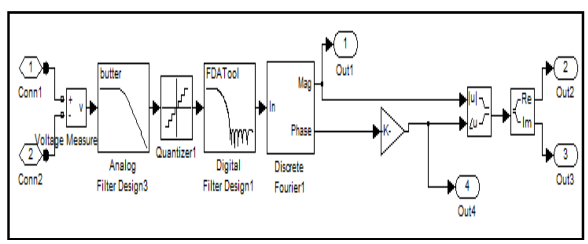

Figure 6: Implementation of filtering scheme in MATLAB

The signal is passed through low pass filter to remove the effects, on the voltage and current signals, of the travelling waves instigated by the fault. The input filtered signals then passed through A/D convertor. The output signal becomes ready to be used by the Discrete Fourier Transform. Here complete cycle discrete fourier transform is used.

The discrete Fourier transform (DFT) is a digital filtering algorithm that computes the magnitude and phase at discrete frequencies of a discrete time sequence. Fast Fourier transforms are computationally efficient algorithms for computing DFTs. FFTs are useful if we need to know the magnitude and/or phase of a number individual or band of frequencies. The DFT is ideal method of detecting the fundamental frequency component in a fault signal.

III. ANN BASED PROCESSING

In this section work done in implementation of ANN method in the field of distance protection is discussed.

Once trained, a network response can be, to a degree, insensitive to minor variations in its input. This ability to see through noise and distortion to the pattern that lies within is vital to pattern recognition in a real world environment [6]. Fig. 7 shows a simple model of a neuron characterized by a number of inputs P1,P2, ..., Pn, the weights W1, W2, ...Wn, the bias adjust b and an output a. The neuron uses the input, as well as the information on its current activation state to determine the output a, given as in equation (1),

$$a = \sum_{k=1}^{n} W_k P_K + b \quad \text{......... (1)}$$

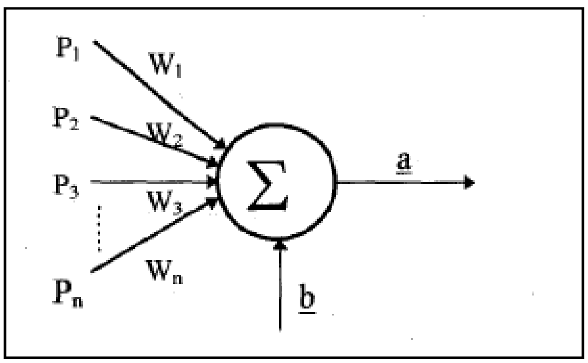

Figure 7 : Perceptron representation

The neurons are normally connected to each other in a specified fashion to form the ANNs. These arrangements of interconnections could form a network which is composed of a single layer or several layers. The ANN models must be trained to work properly. During training each input vector is assigned a particular target value. The algorithm adjusts weights so that the output response to the input patterns will be as close as possible to the respective desired response. In other words, the ANNs must have a mechanism for learning. Learning alters the weights associated with the various interconnections and thus leads to a modification in their strength.

Literature shows that most of the ANN based schemes use 2 hidden layers structure with backpropagation algorithm and Levenberg-Marquardt (ML) algorithm for training purpose. The backpropagation algorithm applied is discussed in brief in this paper.

A. The backpropagation method:

The backpropagation algorithm is central to much current work on learning in neural networks. The backpropagation method works very well by adjusting the weights which are connected in successive layers of multi-layer perceptrons. The algorithm gives a prescription for changing the weights in any feed-forward network to learn a training set of input-output pairs. The use of the bias adjust in the ANNs is optional, but the results may be enhanced by it. A multilayer network with one hidden layer is shown in Fig. 8.

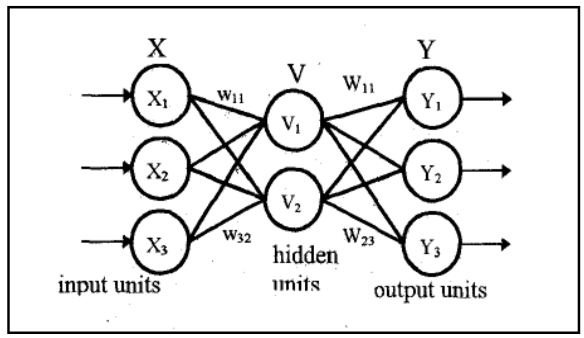

Figure 8: Multilayer Perceptron representation

This network consists of a set of N input units (X_i, i = 1,... N), a set of p output units (Y_p, p= 1,...,P) and a set of J hidden units (V_j, j = 1 ,... J). Thus, the hidden unit V_j receives a net input and produces the output:

$$V_j = F\left\{\sum_{k=1}^{N} W_{jk} X_k\right. \quad \text{...…….(2)}$$

where j=1,…,J

Final output is then produced

$$Y_p = F\left\{\sum_{m=1}^{J} W_{pm} V_m\right. \quad \text{……………..…...(3)}$$

where p=1,…..P.

F[.] is a non-linear transfer function which can be of various forms. Backpropagation networks often use the logistic sigmoid as the activation transfer function. The logistic sigmoid transfer function maps the neuron input from the interval (-∞,+∞) into the interval (0,+1). The logistic sigmoid, shown in (4), is applied to each element of the proposed ANN.

$$F[.]=\text{logsig}(n,b)=\frac{1}{1+e^{-(n+b)}} \quad \ldots\ldots\ldots\ldots\ldots(4)$$

Where, n - summation output& -bias adjust

The usual error measure or cost function for the process is:

$$E[w]=\frac{1}{2}\sum_{i=1}^{n}[Y_i - Y_{i-target}]^2$$

and now becomes,

$$E[w]=\frac{1}{2}\sum_{p=1}^{n}[F(\sum_{m=1}^{J} W_{pm}F(\sum_{k=1}^{n} w_{jk}X_k)) - Y_{i-target}]^2$$

This is clearly a continuous differentiable function of every weight, so we can use a gradient descent algorithm to learn appropriate weights. Since the weight errors are successfully back-propagated from the output layer, this specific training algorithm is known as error backpropagation.

IV. DISTANCE PROTECTION IMPLEMENTATION USING ANN

This section describes how a neural network can classify faults in a particular zone, once it is trained properly. The results show how an ANN based relay distinguishes itself from electromechanical relay. The ANN relay is supposed to identify the zone in which fault has occurred correctly even if the fault involves resistance and resultant trajectory settles outside the corresponding zone, having the magnitudes of the resistance and reactance corresponding to the postfault fundamental frequency as inputs.

Concerning the ANN architecture, parameters such as the number of inputs to the network as well as the number of neurons in the input and hidden layers were decided empirically. This was done by observing network response to various configurations.

To create a feed-forward network suitable for back-propagation algorithm 'newff' instruction from MATLAB [7] is used. It provides flexibility to vary the number of hidden layers and neurons in particular hidden layers. It also allows user to change the training algorithm easily.

In the algorithm, only 1 hidden layer is used. It has 30 neurons with Logsig as activation function .Purelin activation functions is used for output layer. The network is trained Levenberg-Marquardt algorithm.

The instruction newff is used as shown below;

net=newff(p,t,[30], { ' logsig ' , ' purelin ' } , ' trainlm ' , 'learngdm')

V. RESULTS

While training the network, patterns corresponding to various conditions such as fault resistance, fault initiation time, series compensation, etc. are used (Table I). Target vector is assigned value 1 or 0 according to the network condition. Threshold is set at 0.5, i.e., values above 0.5 are treated as 1 and values below 0.5 are treated as 0. Once performance goals are met, an unknown pattern is applied to verify whether the network is trained properly or not. It is as tabulated below :

TABLE : 1 - TRAINING PATTENRS

Network condition	Input pattern name	Assigned target value
No fault with different percentage of Series compensation	C_NF1, C_NF2 , C_NF3, C_NF4	[1; 0; 0; 0]
Three phase to ground fault in zone 1 with different fault initiation timings and fault resistance	C_F1, C_F2, C_F3, C_F4, C_F5, C_F6, C_F7	[0; 1; 0; 0]
Three phase to ground fault in zone 2 with different fault initiation timings and fault resistance	C_F21, C_F22, C_F23, C_F24, C_F25, C_F26, C_F27	[0; 0; 1; 0]
Three phase to ground fault in zone 3 with different fault initiation timings and fault resistance	C_F31, C_F32, C_F33, C_F34, C_F35, C_F36, C_F37	[0; 0; 0; 1]

Out of these patterns, some patterns are used for training the network using Levenberg-Marquardt algorithm. The unknown patterns are used for testing purpose. The training and testing results are as follows:

A. *Training details:*

The training GUI invoked is as shown below.

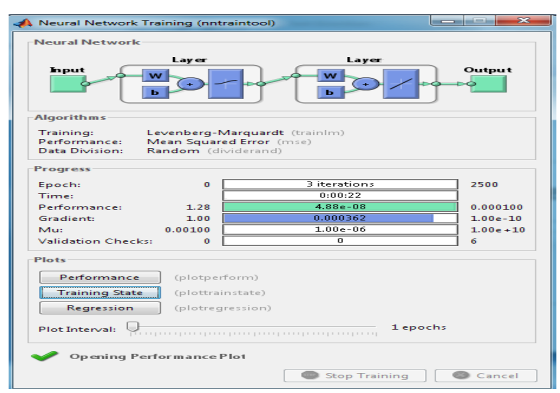

Figure 9: Multilayer Perceptron representation

B. Testing results:

While testing the network, patterns not used during testing are used. Results are tabulated below (Table II):

TABLE-II : TESTING RESULTS

Network condition	**Input pattern name**	**Resultant output value**
No fault with different percentage of Series compensation	C_NF2	[**0.92**; -0.11; -0.18 -0.01]
Three phase to ground fault in zone 1 with different fault initiation timings and fault resistance	C_F3	[-0.0038 **0.9633** -0.0118 0.0091]
Three phase to ground fault in zone 2 with different fault initiation timings and fault resistance	C_F25	[-0.0011 0.0003 **0.9995** 0.0001]
Three phase to ground fault in zone 3 with different fault initiation timings and fault resistance	C_F31	[0.0055 -0.0030 0.0087 **0.9953**]

It can be seen that, depending on input pattern conditions, the corresponding target neuron has a value close to 0 or 1.

VI. CONCLUSION

The use of an ANN as a pattern classifier to improve the performance of distance relay is discussed in this paper.The developed neural network is able to detect whether the pattern corresponds to fault or no fault condition. In addition to this, if there is a fault condition, network is also able to determine the zone of operation.

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