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High Impedance Fault Detection Using Neural Networks

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ABSTRACT

This paper presents the detection of the high impedance fault occurring on radial distribution system using neural network. A multilayer perceptron is used for distinguishing the linear and nonlinear high impedance faults by taking the feature vector as input. R.M.S value of third and fifth harmonic components of feeder voltage and feeder current are used as a feature vector obtained by applying the Fast Fourier Transform on the feeder voltage and feeder current. A variety of faults and system conditions have been simulated to evaluate the reliability and sensitivity of the proposed technique.
Keywords: ANN, High Impedance Faults

I. INTRODUCTION

This HIGH Impedance Faults (HIFs) on distribution systems create unique challenge for the protection engineer. HIFs often occur when an overhead conductor breaks down and touches high impedance surfaces (such as asphalt, sand or grass) or where the conductors become in contact with a high impedance object such as a tree. The main purpose in the HIF detection, in contrary to short circuit faults, is not to protect the system, but to protect the human lives and preventing fire hazards due to arcing phenomenon [2]. These faults are characterized by intermittent arc-type nature and very low current rich in low harmonic content and high frequency noise spectra.

High Impedance faults are safety hazard to Humans, Live stocks and Electric Utility Personnel. If left undetected for hours, weeks, and possibly months can prove fatal to humans and animals at typical current level of 50 mill ampere or above.HIFs that occur do not produce enough fault current detectable by conventional over current relays or fuses [5]. So that detection of low-level ground currents using any conventional over-current or ground fault type relays is both difficult and sometimes inaccurate therefore need to develop another method to solve this problem engineering efforts for the development of a reliable method for the detection of high impedance arc-type faults led during the last two decades to important progress in understanding the electrical characteristics of these faults and in the evaluation of several detection concepts [3]. Various techniques of fault detection encompass fractal techniques, expert system, neural networks and dominant harmonic vectors [9, 10]. The use of high frequency harmonics is not feasible in practical relay because of the filtering by the substation current transformers. Other methods that try to reduce the limitation of frequency domain methods include Kalman filtering [11] and wavelet transforms based methods [14]. Among many techniques proposed by different research groups, use of information contained in the low frequency spectral behaviour, in terms of both magnitude and phase, seems to be the most promising approach for the high impedance arc-type faults on a radial distribution system, the Back propagation algorithms such as neural networks has been implemented in our work.

II. HIGH IMPEDANCE FAULT SYSTEM

When a conductor comes in physical contact with the ground but does not draw enough current to operate protective devices is called High Impedance Fault. In an overhead wire breaks and falls to ground. If the phase wire misses the grounded neutral or another ground as it falls, the circuit path is completed by the high impedance path provided by the contact surface and earth. The detail of HIF fault is described in the next section with the help of a radial distribution model of the power system.

A. Single Line Diagram Representation of HIF System

The single line diagram of sample system used for the study of high impedance fault detection shown in figure 1.

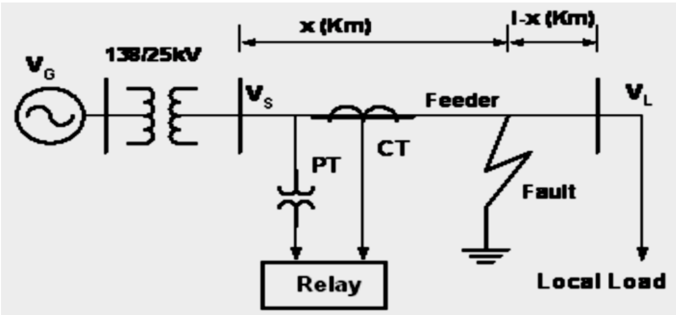


Figure 1. Single Line Diagram Representation Of HIF System

Where V_G = source Voltage

V_f = Voltage at fault point.

V_S = voltage generated after excluding the drop in source.

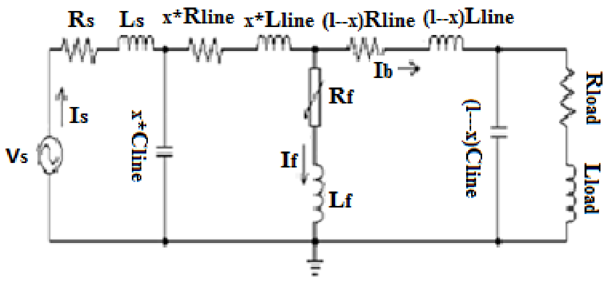
V_L = Load Voltage

l = Feeder length.

X = distance of fault location from the source point.

B. Per Phase Equivalent Circuit Of HIF Model

The per phase equivalent circuit Of the above system is modelled is shown below in figure 2. From figure 2 it's obvious that the transmission line is modelled using nominal pi model which will be used generally for medium length transmission lines.



Here

Vs = Source voltage

Ls = Source inductance

Rs = Source résistance

x*Rline = Resistance of the line up to fault point

x*Lline = Inductance of the line up to fault point

x*Cline = Capacitance of the line up to fault point

L_f = Fault inductance

R_f = Fault resistance

(l-x)*Rline = Resistance of the line beyond fault point and up to load

(l-x)*Lline = Inductance of the line beyond fault point and up to load

(l-x)*Cline = Capacitance of the line beyond fault point and up to load

Rload = Load resistance

Lload = Load inductance

In general the high impedance fault can be linear or nonlinear. In case of linear fault the fault resistance is constant and not a function of any parameter. In case of nonlinear fault the fault resistance is a function of current and is given by $R_f = R_{f0}\ (1+\alpha\ (I_f/I_{f0})^{\beta})$ where α and β are constants.

C. High Impedance Fault Pattern Characteristics

The radial distribution system is subjected to an arc type fault at different locations by varying x, measured from the substation bus. The voltage and current signals at feeder terminals v1 and i1 are used as detection signals as shown in Fig3. The instantaneous values of these detection signals are captured and transformed into frequency domain using one cycle Fast Fourier Transform FFT. The FFT-harmonic vectors v3, i3, v5, and i5 are processed to obtain feature vectors and are used to train the Back propagation network.

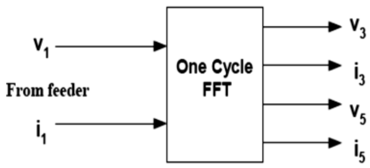


Figure 3. Feature vector extraction

These harmonic components exhibit certain pattern characters using which the linear and non linear high impedance faults can be distinguished. Many cases of linear and nonlinear faults are simulated by varying the fault locations, source impedances and fault resistance. Equal numbers of linear and nonlinear fault cases are simulated. The obtained data is cast into a classification problem by associating half of the samples into linear and the other half into nonlinear cases.

III. BACK PROPAGATION ALGORITHM

A. General Architecture of Neuron

Frank Rosenblatt devised Perceptron that operated much in the same way as the human mind. Perceptron could "learn" - and that was the breakthrough needed to pioneer today's current neural network adjusting of weights to produce a particular output is called the "training" of the network which is the mechanism that allows the network to learn.

A neuron with *R* inputs is shown below. Each input is weighted with an appropriate *w*. The sum of the weighted inputs and the bias forms the input to the transfer function *f*. Neurons can use any differentiable transfer function *f* to generate their output.

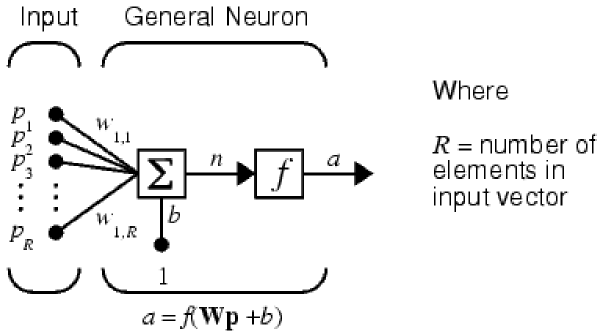


Figure 4. An elementary neuron with R input

The sum of the weighted inputs with bias form the net input to the transfer function f and is given by the following expression.

$$n=w_1, 1p_1+w_1, 2p_2+\ldots +w_1, Rp_R+b$$

Any differentiable transfer function can be used by the neuron to generate the output.

B. Back Propagation Algorithm

1. Start with random weights

2. Repeat

*For each example e in the training set do

a. O=neural net output; forward pass

b. T=teacher output for e

c. Calculate error (T-O) at the output units

d. Computes Δw for all weights from hidden layer to output layer; backward pass

e. Computes for Δw all weights from input layer to hidden layer ;backward pass

Continued

f. Modify the weights in the network

*End

3. Until classified correctly or stopping criterion satisfied

4. Return

IV. RESULT AND DISCUSSION

The training and testing of the feed forward neural network for distinguishing the linear and nonlinear faults is done using back propagation algorithm in Matlab 7.0.4.The first step in training a feed forward network is to create the network object. The function newff creates a feed forward network. Before training a feed forward network, the weights and biases must be initialized. The newff command will automatically initialize the weights. The function sim simulates a network. Sim takes the network input p, and the network object net, and returns the network outputs a. once the network weights and biases have been initialized, the network is ready for training. The network can be trained for function approximation (nonlinear regression), pattern association, or pattern classification. In this thesis training is being done for pattern classification. The training process requires a set of examples of proper network behavior –network inputs p and target outputs t. During training the weights and biases of the network iteratively adjusted to minimize the network performance function net.performFcn. The default performance function for feed forward network is mean square error mse – the average squared error between the network outputs a and the target outputs t.

The implementation of back propagation algorithm updates the network weights and biases in the direction in which the performance function decrease most rapidly – the negative of gradient. One iteration of this algorithm can be written as

$$X_{k+1} = X_k - \alpha_k g_k$$

Where X_k a vector of current weights and biases is, g_k is the current gradient, and α_k is the learning rate. RMS values of third and fifth harmonic components of voltage and current at feeder are found out at each location of the fault. Half of the data is obtained like this is used for training the neural network by using back propagation algorithm and the remaining half is used for testing it. In the present case the neural network is trained to give an output value of 1 for linear fault and 0 for nonlinear fault. We have adapted 3 layer neural network consisting of 4 neuron in each hidden layer and 2 neuron in output layer and the log sigmoid function is used in all layers. Learning rate of 0.565 is used and a momentum factor of 0.585 is used in the training phase of the neural network. Percentage of training and testing samples classified by different back propagation algorithms of the neural network are shown below in table 1.

Table 1.

S.No.	Back propagation algorithm used	Percentage of samples classified in training	Percentage of samples classified in testing
1.	Trainlm	100	97.43
2.	Traingd	100	92.30
3.	Traingda	94.87	79.01
4.	Traingdx	92.87	89.54
5.	Traingdm	100	84.86
6.	Trainb	100	97.54
7.	Trainr	94.87	87.17
8.	Trainrp	100	94.74
9.	Trainbr	100	97.43
10.	Trainoss	100	92.03
11.	Trainbfg	94.87	84.67
12.	Traincgf	100	94.87
13.	Traincgp	100	92.30
14.	Trainscg	97.43	84.61
15.	Traincgb	100	94.87

V. CONCLUSION

The values of feeder voltage and feeder current are obtained for two kinds of fault cases (i.e. linear and nonlinear) by simulating the model of high impedance fault system .The values of third and fifth harmonics are obtained by applying the Fast Fourier Transform.RMS values of these harmonics are used to train the Multilayer Perceptron Neural Network for classification of these two types of faults. It consists of total three layers, two hidden layer and one output layer. Each hidden layer consists of four neuron and one output layer consists of two neuron. This network is trained by using the Back propagation algorithm. Many types of back propagation algorithms are tested and it’s found that trainlm and trainbr are classifying these two kinds of faults more perfectly compared to other algorithms. As well as for selecting the no. of neuron the network is tested for different number of neuron in each layer and it’s found that the network consisting of four neuron in each hidden layer is performing well. The network is tested for different transfer function and it’s found that its performance is good when log-sigmoid transfer function is used in all the three layers or when tan-sigmoid transfer function is used by the neuron in two hidden layer and linear transfer function is used by neuron in output layer.

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