ISSN 2229-5518

Protective Relay for Transmission Line Using Artificial Neural Network

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Abstract— Electricity is a naturally occurring force that exists all around us. Its necessity is increasing day by day because of supply quality electrical power continuously for business, industrial and also residential usage. It might result in discomfort to many residential areas while failure to supply electricity and will result in loss of productivity by discontinuing the supply of business and industrial areas. It is all about the power supplier to maintain the supply of electricity while occurs disturbances. The main goal of this project is to develop a software module which acts like a protective relay using natural network techniques. To recognize the waveform patterns of impedance in a transmission line, the back-propagation method has been employed by the ANN software module which produces a trip signal if a fault waveform is recognized and no trip signal otherwise. The waveform patterns are generated for unsymmetrical and symmetrical faults that occur on a varied distance in the transmission line. After that the generated waveforms are used as training and testing data for the ANN software. The ANN software is simulated using the neural network toolbox of MATLAB version 2013a.

Index Terms— Artificial Neural Network (ANN), Protective Relay, Transmission Line Faults, Fault Analysis, MATLAB, PSCAD, Network Simulation.

1 Introduction

The Electricity is a set of physical phenomena associated with the presence and flow of electric charge. Electricity permits the creation and reception of electromagnetic radiation such as radio wave. The movement of electric charge is known as an electric current or supply of electricity. The supply of electricity to users requires a complex network of power system where faults due to natural causes, equipment or operator failure are prevalent. The fault of power system is not only the cause of disconnected supply, but also they can damage the power system equipment and that is costly to replace. It also can create many problems in supplying electricity. It is fortunate that those faults can be isolated and detected earlier before the further damage to the equipment.

2 Overview of The Technology

In the power system network protective relay acts a vital component to protect the transmission line from thermal damages caused by network faults. In this thesis a neural network based protective relay detecting faults in the three phase transmission line is devised. The protective relay recognizes the faults in transmission line by using ANN.

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3 Background and Motivation

In most cases power stations are located remote area to keep the carbon emissions away from the residential place. The majority of faults occur in transmission lines. When the current rises above the normal operating current and voltage .This causes thermal damage to electrical components. To reduce the adverse effects of faults, protective relays are included as part of a power system. Protective relays detect faults in the power conditions and return the power system to normal operative conditions (Horowitz, 1995) [1]. The relay activates the circuit breaker to isolate the fault after detecting faults in the relay protection zone. When multiple loads are connected, the supply will discontinue until the problem causing the fault is fixed. It is a common practice to use network of power systems where multiple sources are available in connections for multiple loads [2].

3.1 Proposed Block Diagram

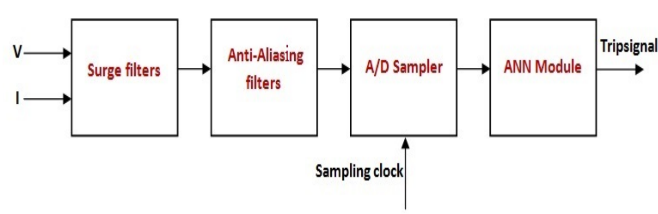

Fig. 1: Block Diagram for ANN based relay

The ANN uses back propagation method to recognize the faults waveform patterns of a transmission line. Figure 1 shows the block diagram of ANN based relay elements.

3.2 Objectives of the Thesis

The aim of the project is to develop an Artificial Neural Network (ANN) model acting as a protective relay. The input waveforms are generated by PSCAD. The generated waveforms are used as training and testing data for the Artificial Neural Network (ANN) module. The ANN module is simulated by using Neural Network Toolbox of MATLAB.

4 Theoretical Background

4.1 Artificial Neural Network

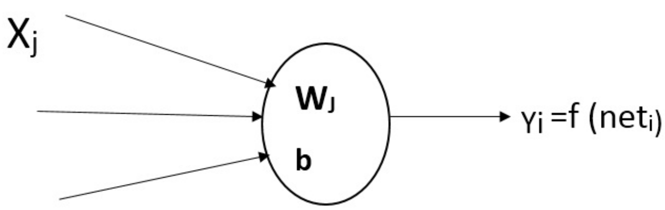

Fig. 2: Neural Network

Each node has inputs connected to it while weights corresponding to each input. Figure 2 shows Neural Network. Each node only has one output and above neuron is called neuron i. It has j inputs X_j and one bias b. Each input corresponds to a weight W_{ij}, thus there are j weights in the neuron. The output of the neuron yi is produced by a function of net_i where

$$Net_i = \sum_j w_{ij} x_i + b \qquad (1)$$

Every neuron can be interconnected to other neurons by using the output of neurons as inputs to other neurons. The interconnection of neurons forms layers of neural network. A neural network consists of three types of layer, input layer, hidden layer, and output layer.

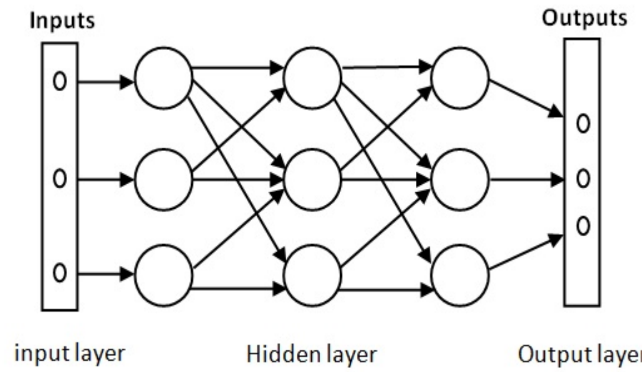

Fig. 3: ANN Layers

The number of inputs in a neural network is equal to the number of nodes in the input layer. Similarly, the number of outputs in the neural network is equal to the number of nodes in the output layer. The number of hidden layers and the number of nodes in the hidden layer are varying depending on its application [3]. Figure 3 shows ANN Layers.

4.2 Protective Relay

The necessity of transmission line is so much important part in power system. In transmission line two types of transmission are used. One is overhead and another is underground. Overhead transmission lines are commonly used. The reason of overhead transmission lines is susceptible to faults caused by short circuits between phases or between phase and ground. In the power system majority of faults occur in the transmission line [4]. In faulty condition current increase above the normal level for that reason thermal damage happened to all electrical equipment. For reducing this type of faults, protective relays are used in power system. It detects an abnormal condition and shutdown the circuit breaker or returns the power system to normal condition. Basically, it actives the CB and isolates the faults. The line disconnected until the problem solve. To reduce blackout, it is helpful to use network of power system where multiple connections are connected with multiple loads [4].

5 Software Simulation

For thesis simulation MATLAB and PSCAD was used and the software was provided by the university. For generating faults PSCAD and for network simulation MATLAB was used [5].

ISSN 2229-5518

5.1 PSCAD Software

PSCAD is a general-purpose time domain simulation tool for build, simulate, and modeling of electrical networks. The fault cases occurred in transmission line was simulated by using PSCAD.

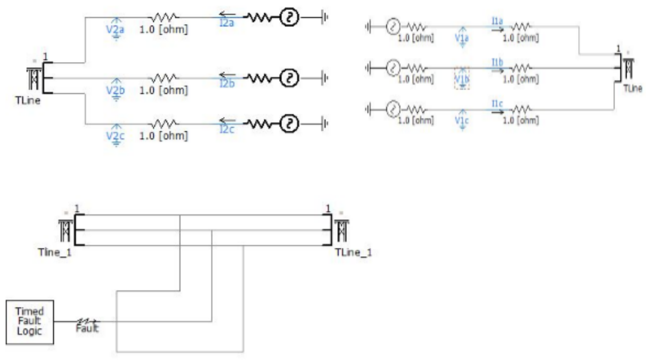

Fig. 4: PSCAD model

By changing the fault type parameter, the fault types were simulated in PSCAD model. The fault inception angles were varied by varying the time to apply fault parameter in the Timed Fault Logic module. The fault location of the transmission line was varied by changing the length parameter. For each time, parameter is changed, the TL constants have to be solved and the TL batch has to be saved. In simulating various fault locations, TL batches with length parameters were saved with different Transmission Line. To simulate a fault located within 25 km, Transmission Line batches with length parameter of 25 and 85 were loaded into the circuit diagram [6].

5.2 MATLAB Simulation

MATLAB (**mat**rix **lab**oratory) is a multi-paradigm numerical computing environment and fourth-generation programming language. Although MATLAB is intended primarily for numerical computing, An additional package, Simulink, adds graphical multi-domain simulation and Model-Based Design for dynamic and embedded systems. The MATLAB Version 2013a was used for simulation. The MATLAB codes used are listed below.

6 Network Simulation and Result analysis

6.1 Data Extraction

By using PSCAD, all of faulty data has been stored and the data needed for training. The data in A column, needs to be extracted by MATLAB. The function, written as aeditdata.m does this task. This aeditdata.m function takes the data produced by PSCAD as input value.

6.2 Data Windowing

After files containing (A) data were extracted, they have organized into a data window by samples. The file extracted by function aeditdata.m acts as the input for the function getann.m. The output of getznn.m function is a file containing an Rx20 matrix of data. This file is used as input to the neural network.

6.3 .Neural Network Simulation

To train the network, the input file to the neural network needs its output pair. The function aoutp.m examines each row of the input file and write as 0/1 to the output file.

The neural network is trained by using anntrain.m. This function calls Artificial Neural Network functions which included in the MATLAB Neural Network Toolbox. These functions are called as newff.m and train.m. The newff function returns a network object and creates a feedforward network. The train function trains the network created by PSCAD.

After the training has finished, the anntrain.m back to its trained network object. The network then tested by calling asimnver.m function. This function simulates the network by using data file given in the function parameter. Then finally compare the output of the function with the desired output data to get the performance error of the network.

7 Experimental Data and Result Analysis

After the sampled faulty case collected by running PSCAD, the data were formed into 20-sample data window for network input using MATLAB functions. The fault cases gathered is given here as Fault types of BG, CG, AG ABG, ACG, BCG, ABC, AB, AC, BC, a Fault inception angles 0°, 30°, 70°, 110°, 150°, 180°, 210°, 250°, 280° and 320°. Fault location measured 1, 15, 25, 35, 45, 55, 65, 75, 85, 95, and 100 km.

7.1 Training Data

From the Figure 5 we can see, some fault types have a similar waveform pattern. Given below are the waveform patterns for various faulty types with constant fault distance of 25 km with the fault inception angle of 0°. The following graph shows the faulted section of the waveform.

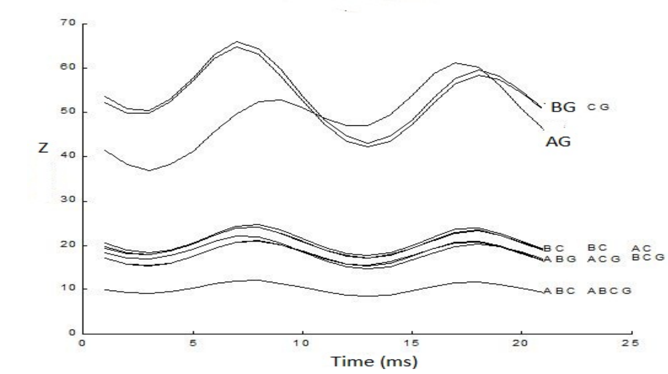

Fig. 5: Waveform of the sampled faults

From the above graph, various types of waveforms with various fault types have been seen.

7.2 Network Simulation analysis

After training the data, the network architecture then trained it using learning algorithm. The size of the input and output has given already, only the hidden layer size was measured. The training started with higher size of network and then gradually reduced to smaller size if network testing gave satisfactory result.

7.2.1 Network 1 [20 20 10 1]

The first network trained which had two hidden layers of size [20 20 10 1]. The learning rate was 0.7 and momentum was 0.8. The target MSE=0.001. The training algorithm used was Gradient Descent with Momentum (GDM).

The learning curve is shown below in Figure 6.

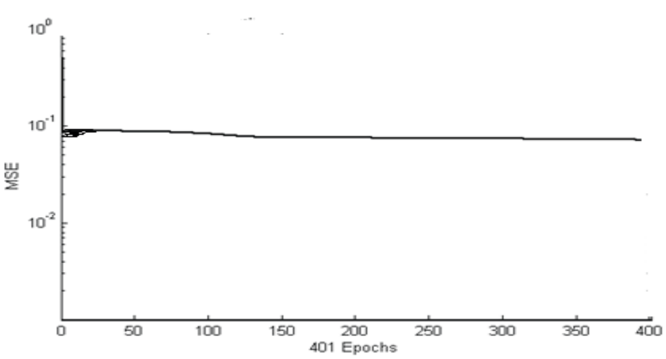

Fig. 6: Learning Curve [20 20 10 1]

On the graph shows that gradient descent suffers from slow convergence.

7.2.2 Network 2 [20 20 10 1]

The second neural network trained which had two hidden layers of size 20 and 10. The learning rate was 0.7 and momentum was 0.8. The MSE was 0.001. The learning method used here was Scaled Conjugate Gradient (SCG). This time the learning curve converged faster. Figure 7 shows the corresponding curve.

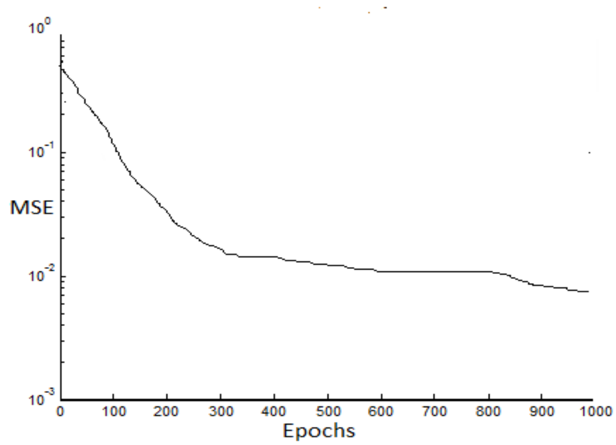

Fig. 7: Learning Curve of network [20 20 10 1]

7.2.3 Network 3 [20 15 5 1]

The network size was further reduced by reducing the network size [20 15 5 1] in each hidden layer. Third network architecture trained had two hidden layers of size 15 and 5. The learning rate was 0.7 and momentum was 0.8. The learning method used was same as before. The learning curve is shown in the Figure 8.

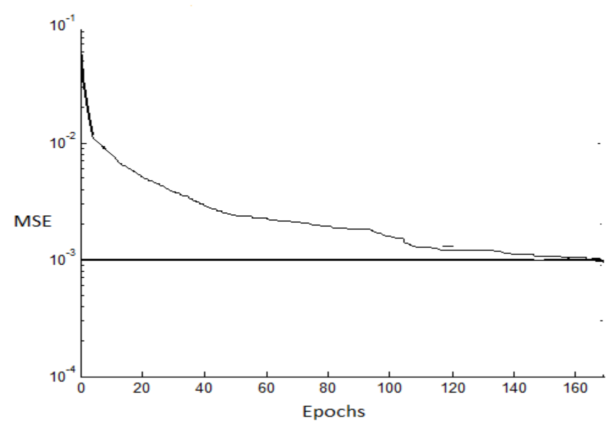

Fig. 8: Learning Curve of Network [20 15 5 1]

This time the learning curve converged faster and had better performance.

7.2.4 Network 4 [20 5 1]

Further reducing the hidden layer size to five nodes did not improve the learning rate and the performance. The network of this size cannot map the input from the training data to desired outputs. Figure 9 shows the Learning Curve of Network [20 5 1].

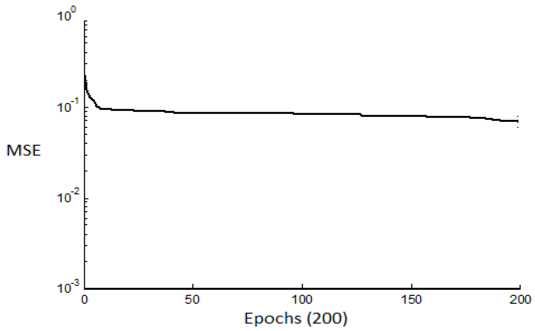

Fig. 9: Learning Curve of Network [20 5 1]

The network of this size cannot map the input from the training data to desired output.

7.3 Simulation Results

All the results of the training and testing are given here for convenience.

Table 1: Network Training and Testing Result

Network Size	Final MSE	Epoch(s)	Time	Testing Error			
				Trained Data Set		Untrained Data Set	
				No	%	No	%
[20 20 10 1]	0.07	401	29	N/A	N/A	N/A	N/A
[20 20 10 1]	0.007	1000	126	26	0.1	30	0.2
[20 15 5 1]	0.001	169	17	6	0.02	22	0.1
[20 5 1]	0.07	200	8	2437	9.2	1659	9.4

By analyzing the above data, the network with sizes of [20 20 10 1] and [20 5 1] are either bigger or smaller. Both of them cannot map the training data with output satisfactorily. The smaller network hardly converged anymore when it reached MSE by 0.07, thus the performance of the network suffered greatly with about 9.4%.
The network architecture [20 15 5 1] had better performance and faster convergence. Both networks [20 15 5 1] and [20 15 1] are good choices for the ANN module for training time and performance data. The numbers of errors occur in both networks is insignificant. Calculating the error performance, the [20 15 1] network has advantages of smaller network size and faster training time compared to [20 15 5 1] network. It does not show any evidence of its capability of escaping from local minima value, but one cannot assume that it is not capable of doing that as well. The network [20 15 5 1] is chosen over the network [20 15 1] because of the performance.

8 Conclusion

In this project artificial neural network relay performance was tested with various data structures. In performance or simulation, some network showed the faulty condition classify in six (6) and (22) patterns and also describe how to detect it.

9 Future Work

In the future, data and function can be improved. It will be added more functionality and data which will tested with more faults and fault off with varying resistance and capacitance. Functional data like faulty location can also include with same network or another network.

Appendix

MATLAB Coding

```
aeditdata.m
function aeditdata(fn1)
numline=100;

%fn1 column
%col1head='t';
col2head='V';
col3head='I';
col4head='Z';
getann.m
[FID,MSG]=fopen(ifn,'rt');
input=fscanf(FID,'%f');
fclose(FID);

inpCol=20;
A=[];
for i=1:(length(input)-inpCol+1),
  B=input(i:i+inpCol-1);
  A=[A;B'];
end
```

Partial Coding has given above.

Acknowledgment

The authors acknowledge the department of Electrical and Electronic Engineering, American International University–Bangladesh for giving permission to access equipments and work in Power system protection Lab, Control System Lab and Computer Lab and also express their special thanks to the faculty members of American International University–Bangladesh (AIUB).

REFERENCES

[1]. Blackburn, J.L. 1993, Symmetrical Components for Power Systems Engineering, Marcel Dekker Inc. New York

[2]. Blackburn, J.L. 1987, Protective Relaying: Principles and Applications, Marcel Dekker, Inc., New York.

[3]. Browne, A. (ed) 1997, Neural Network Analysis, Architectures and Application, Institute of Physics Publishing, Philadelpia.

[4]. Coury, D.V. and Jorge, D.C. 1997, 'The Back-propagation Algorithm Applied to Protective Relaying', IEEE International Conference on Neural Networks, vol. 1, pp. 105–110.

[5]. MATLAB Version 2013.00, Release 13, list help.

[6]. Vazquez, E., Altuve, H.J. and Chacon, O.L. 1996, 'Neural Network Approach to Fault Detection in Electric Power Systems', IEEE International Conference on Neural Networks, vol. 4, pp. 2090–2095.

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He started his professional career as an Assistant Engineer (Electrical/Instrument) in Bangladesh Chemical Industries Corporation (BCIC) from September, 1988, became an Executive Engineer in 1997. During his job in BCIC, he also completed Postgraduate Diploma in Industrial Management (PGDIM) in 1990 from Bangladesh Management Development Centre, Dhaka, Bangladesh. He also completed many training courses on different types of process control instrumentations including programmable logic controller (PLC) and programmable instruments during his job in BCIC from 1988 to 2003.

After having the Dr. of Engineering degree, he started his teaching career as an Assistant Professor in Electronic and Telecommunication Engineering (ETE) Department of Daffodil International University, Dhaka, Bangladesh in May, 2008 and he worked there till August, 2008. On September, 2008, he joined as a Faculty member of Electrical and Electronic Engineering (EEE) Department under Engineering Faculty, American International University-Bangladesh (AIUB). On May, 2009 he was appointed as an Assistant Professor of EEE Department, Faculty of Engineering, AIUB. Currently he is an Assistant Professor at the American International University-Bangladesh (AIUB). He is also a Member of the Institution of Engineers Bangladesh (IEB). He is the author and co-author of several papers and contributes at prominent journals and international conferences. His present research interest includes Plasma science, Nanotechnology, Solid state electronics, Materials science, Power system, Renewable energy, Optoelectronics.