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Simulation Analysis of a Power System Protection using Artificial Neural Network

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Article Info	ABSTRACT
	There has been significant development in the area of neural network based power system protection in the previous decade. Neural network technology has been applied for various protective relaying functions including distance protection. The aim of this Paper is to develop a software module acting as a protective relay using neural network techniques. The Artificial Neural Network (ANN) software developed module employs the back-propagation method to recognize the waveform patterns of impedance in a transmission line. The input waveforms are generated using PSCAD. The generated waveforms then are used as training and testing data for the ANN software. The ANN software is simulated using the Neural Network Toolbox. The design has been tested for different fault conditions including different fault resistances and fault inception angles. The test results show that the relay is able to detect faults in lesser time as compared to conventional relay algorithms.

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1.   INTRODUCTION

Protective relaying of power systems is aimed to safeguard the expensive equipment and also to maintain system integrity that is necessary for continuous and economical supply of electric power to customers [l]. The last decade has seen a significant amount of development of relays from electromechanical and solid state to numerical relays.The technologies used for relay manufacturing have also evolved in the past century. These are related to the implementation of distance relay characteristics. These factors significantly affect the results obtained from a relay. There are essentially four types of numerical relaying algorithms which are used for various protective relaying functions such as measuring phasors, impedance, power flows, frequency, estimate distance of faults etc. These algorithms can be classified as:

i.   Non- Recursive Phasor Algorithms such as Discrete Fourier transform [2] and Walsh functions.

ii.   Recursive Phasor Algorithms such as Kalman Filtering [3] and recursive least squares techniques [4].

iii.   Modeling Algorithms which model transformer and   transmission line in terms of impedance.

iv.   Other alternative algorithms such as pattern recognition and neural networks.

2.   RESEARCH METHOD

ANN-BASED RELAYRelay model shown in Fig.1 is based on a distance relay with twoidenticalthree-phase power sources at both ends. The length of the transmission line (TL) is 100 km.

Figure1.Transmission line model

The relay is intended to protect the protection zone along the 100 km line. The ANN relay was trained to see faults from one side A only, that is the impedance measured is the one facing the relay. The relay on the other side B can use similar relay. The transmission line (Fig. 1) is modeled using PSCAD to get the data for network training and testing. The PSCAD model used to simulate faults is given in Fig 2.
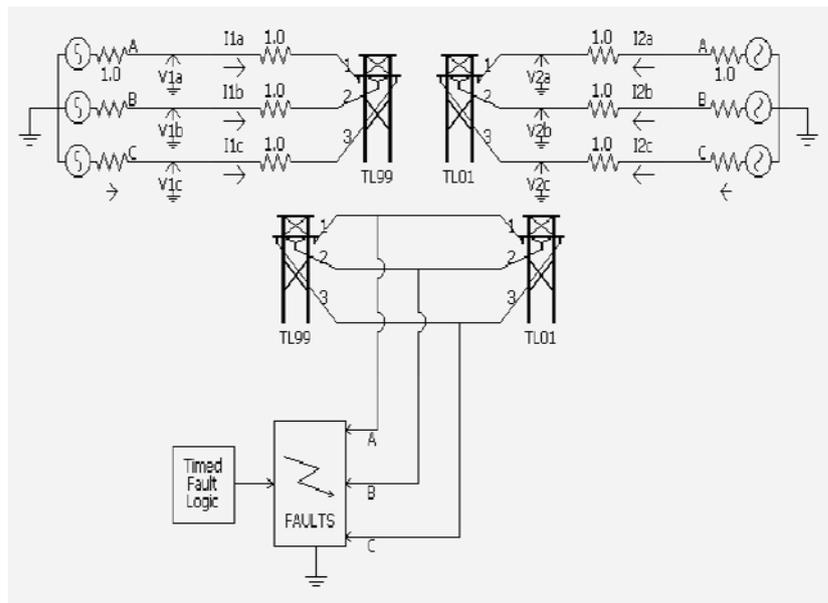

Figure 2. PSCAD transmission line model including faults

The relay is modeled by two three-phase power sources connected by two pairs of TLs. In between the TL pairs, a timed fault is incepted using faults and timed fault logic module. The faults module can generate all types of faults and vary the fault impedance.   The faults module has 4 variables phase A, phase B, phase C, and ground which can be toggled to *'yes'* or *'no'* to make fault and no fault condition.

The consideration taken in using ANN relay to detect faults is what measurable parameters can be taken as ANN inputs. Using voltage and current in the ANN relay requires at least 6 input neurons.. If 10 data window is used then there are 60 inputs required by ANN relay. The size of input layer affects the size of hidden layer needed to map the inputs to output thus affects the size of network and the computing power needed.

There is a tradeoff between the noise resistance and the network size.The distance protection uses voltage and current variables to calculate the impedance of the line.Looking from the relay A during a fault is like a Thévenin circuit with Z_{FA} as the Thévenin impedance. When a fault occurs, the Thévenin impedance will decrease. The magnitude of impedance varies as the location of the fault changes. Using impedance instead of currents and voltages will halve the ANN relay inputs input neurons from 6 to 3 for impedance in each phase.

The ANN relay inputs can be further reduced to 1/3 by using positive sequence impedance (Z_1). For every type of fault, there is a measurable Z_1. Thus, Z_1 can be used to detect fault in the TL for all fault types. The inputs to the ANN relay are further reduced from 3 to 1. Now Z_1 is related to V_1 and I_1using (1).

$$Z_1 = \frac{|V_1|}{|I_1|}(1) \tag{1}$$

The rms voltage and current is defined as (2) and (3)

$$V_{1rms} = \sqrt{\frac{1}{T}\int_a^{a+T} V_1^2(t)\ dt} \tag{2}$$

$$I_{1rms} = \sqrt{\frac{1}{T}\int_a^{a+T} I_1^2(t)\ dt} \tag{3}$$

The rms value of the positive sequence impedance along with the model shown in Figure 3 is used to obtain to the previously shown PSCAD model (Figure 2.).

The ANN used rms positive sequence impedance waveform to detect faults. This is a pattern recognition problem which maps rms positive sequence impedance to trip/no-trip decision
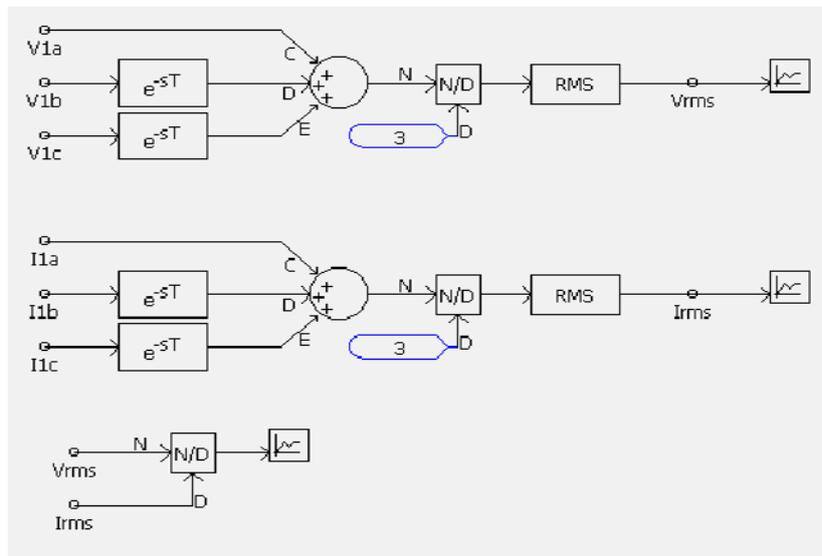

Figure 3.Positive sequence voltage, current and impedance

A. Fault Data Simulated

The distance relay model was simulated to generate different fault types, different fault inception angles and different fault locations.

B. ANN Relay Model
Network Input Layer

As mentioned in (6) the rms value of Z_1, from now on referred as Z, will be the input for the neural network. A data window of 20 samples will be the network input.

The voltage and current are sampled by frequency 20 samples per cycle as mention in Figure 4. The data window consists of 20 samples or 1 waveform. However, it should be noted that after getting the V_{rms} and I_{rms} the frequencies are doubled which double the frequency of Z waveform as well.

The input layer of the ANN relay is fed from the 20-sample data window, which forms a 2 cycles Z waveform pattern.

C. PSCAD Simulation

The fault types were simulated by changing the fault type parameter in the Faults module. The fault inception angle was varied by varying the time to apply fault parameter in the Timed Fault Logic module.

The fault location was varied by changing the length parameter of the transmission line. Each time a TL 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 parameter of 1, 10, 20, 30, 50, 60, 70, 80, 90, and 99 km were saved with different TL names. To simulate a fault located at 20 km, TL batches with length parameter of 20 and 80 were loaded into the circuit configuration. The result of each simulation was saved in a file with distinctive name reflecting its fault case. When a fault case is simulated, the waveform saved includes its transient state. To remove the transient state, the simulation was run from a snapshot file.

  After all the fault cases were collected, data was extracted and organized for training using MATLAB.
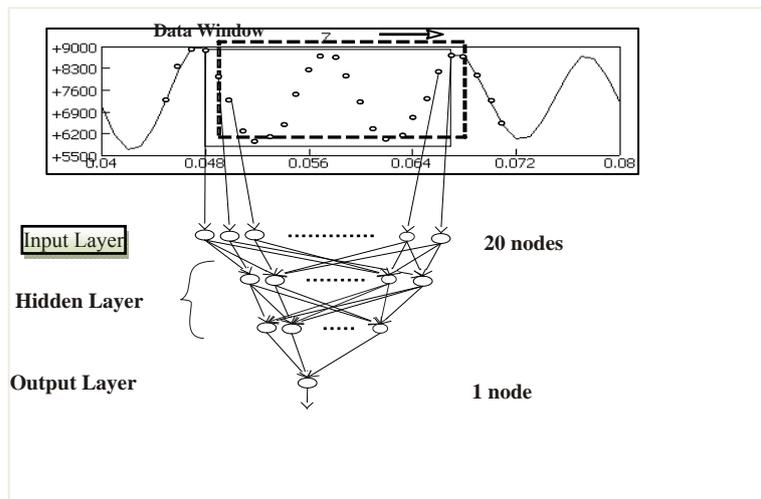

Figure 4.Input data windowing

3. RESULTS AND ANALYSIS

       Discussion from analyzed the waveform pattern for each fault case and the data set for training and testing was chosen. The process continued by training varying network sizes and minimum cost function (mean squared error or MSE) values. The network was then tested using the training and testing data set to see the performance of the network. Upon unsatisfactory performance, the training process was repeated with different network size or different MSE.
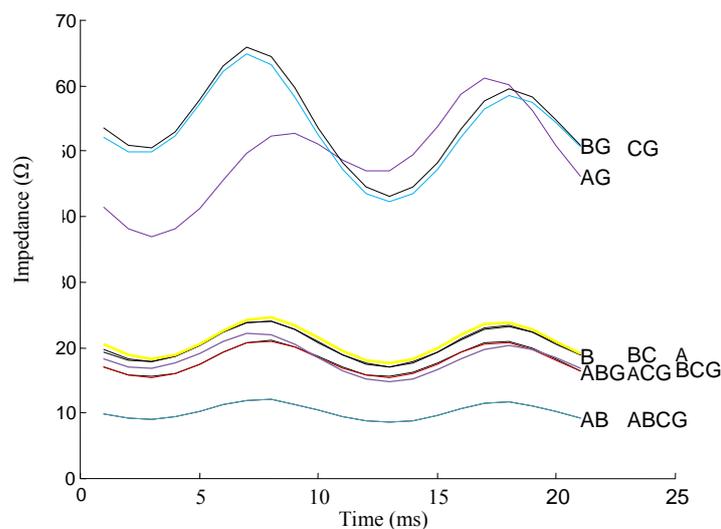

Figure 5. Waveforms of various fault types

A summary of network simulation carried out for different network size and hidden layers with given MSE is shownin Table 1.

Table 1. Network Simulation Summary

Network Size	Final MSE	Epochs	Time (min)	Testing Error			
				Using trained data Set (26,620)		Using untrained data Set (17,600)	
				No	% error	No	% error
[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
[20 155 1]	0.01	15	2	53	0.2	46	0.3
[20 155 1]	0.001	169	17	6	0.02	22	0.1
[20 15 1]	0.001	39	4	15	0.1	20	0.1
[20 5 1]	0.07	200	8	437	9.2	1659	9.4

4. CONCLUSION

This paper has described an ANN scheme that works as a protection relay of transmission lines to implement this scheme a sample transmission line has been modeled along with the positive sequence voltage, current and impedance measure &model and ANN relay model using PSCAD. Simulation investigation were been carried out using ANN software & Neural Network toolbox. The simulation model design has been tested for various fault condition with different fault resistance and fault inception angle. Based on the simulation results obtained it is observed that, by using the proposed methodology it is capable of detecting fault in lesser time as compared to conventional relay algorithms. This immunity to the network changes would make it possible to extend the first zone reach of the transmission line thereby improving the security of the system.

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REFERENCES

[1] S. H. Horowitz and A. G. Phadke, *Power System Relaying,* Great Britain:Research Studies Press LTD.
[2] A.G. Phadke "Synchronized Phasor Measurements in Power Systems"IEEE Computer Applications in Power,Vol. 6, No.2, 1993,(pp 10-15).
[3] M. S. Sachdev, H. C. Wood and N.G. Johnson "Kalman Filtering Applied to Power System Measurements forRelaying" (IEEE Transactions on Power Apparatus and Systems, Vol. PAS-I04, Dec.1985,(pp. 3565- 3573).
[4] M. Nagpal, M.S.Sachdev "A Recursive Least Error Squares Algorithm for Power System Relaying andMeasurement Applications" (IEEE Transactions on Power Delivery, Vol. 6, No.3July 1991).
[5] Sarma, M. & Glover, J.D. 1994, *Power System Analysisand Design,*PWS Publishing Company, Boston. Ch. 9.
[6] Wright, A. &Christopoulos, C. 1993, *Electrical Power System Protection*, Chapman & Hall, London. Ch.4, 5, 11.
[7] Blackburn, J.L. 1993, *Symmetrical Components for Power Systems Engineering*, Marcel Dekker Inc. New York.
[8] Horowitz, S.H. &Phadke, A.G. 1995, *Power SystemRelaying*, 2nd edn. Research Studies Press LTD., Taunton.p. 1, ch. 2. ch. 5.4.