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ARTIFICIAL NEURAL NETWORK BASED PROTECTION FOR COMPENSATED TRANSMISSION LINE

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I. INTRODUCTION

Transmission lines connect various parts of the power system network. Their main purpose is to transmit the power from power stations to the consumers. Transmission lines are exposed to the environment therefore they are subjected to various types of faults due to effect of harsh environmental conditions. The possibility of faults in transmission line is higher than the other elements of power system. Table 1 gives an approximate idea of fault statistics.

Element	% of Total faults
Overhead Lines	50
Underground Cables	9
Transformers	10
Generators	7
Switchgears	12
Control Equipments, etc.	12

Table 1 Percentage distribution of faults in various elements of power system

From Table 1, the importance of protection of transmission line can be understood because maximum faults occur in transmission lines. Transmission lines are made of bare conductors. Whenever these conductors are shorted together because of wind, ice and falling trees, there is a possibility of faults. Overvoltage occurs because of lightning and switching surges. When fault occurs in transmission line it is necessary to detect the fault, classify it and find its location to make necessary repairs. Detection of fault means whether it is continuous or momentary transient, whether it is in the protection zone or outside the zone. As far as protection of transmission line is concerned, fault classification means to determine that fault belongs to which of eleven possibilities such as from 3-LG, 3-LL, 3-LLG, LLL & LLL.

Types of Faults	Fault Symbol	% of Total Faults
Line to Ground	LG	85
Line to Line	LL	8
Double Line to Ground	LLG	5
Three Phase	3-ø	2

Table 2 Frequency of occurrence of faults in transmission line

Table 2 shows the frequency of occurrence of different types of faults on overhead lines. From the table it is seen that line to ground faults are more frequent than any other type of fault. After the classification of fault, tripping signals are sent to the circuit breakers. The series compensation schemes have been proven to be an important component in long transmission line. This is because of the low cost of series compensation compared to the cost of building a new transmission line. Series capacitors reduces inductive reactance and increases the transfer capability, reducing the losses associated with transmission lines, controlling the load flow between parallel circuits and improving transient and steady state stability margins. Due to these reasons, series compensated transmission lines have become common in locations where distance between load centres is great and large transmission investments are required. The addition of series compensation in the transmission circuit could impose several problems in designing. One of these problems is due to protection system elements; the distance relays are adjacent to server incorrect operations. The reason is the distance relays are sensitive to line length or in other words, to the amount of impedance of the line. The conventional or numerical distance relays have fixed settings for a particular transmission line which is to be protected. But, the Electrical Power System or to be precise, Transmission line is the varying element of Power System. The network conditions are changed many times for example; a new line is added to the existing electrical network or a line taken out of service for maintenance or repair. These changing network conditions affect the reach of distance relays and sometimes they malfunction. Also, the effect of arc resistance and power swings affects the relay operation and hence special care has been taken while implementing them in distance protection. Artificial Neural Networks, because of their generalizing and mapping abilities are capable of processing of such non linear inputs and may work as relay that can operate correctly, maintaining the reach during different fault conditions and in changing network configurations. The artificial neural networks provide a very interesting and valuable alternative for the protection of series compensated transmission lines because they can deal with most situations, which are not defined sufficiently for deterministic algorithms to execute.

II. BASIC CONCEPTS OF ANN

Artificial neural networks are a form of computation inspired by the structure and function of the brain. Various learning mechanisms exists to enable neural network acquire knowledge. Neural network architectures have been classified into various types based on their learning mechanisms and other features. Some classes of neural network refer to this learning process as training and the ability to solve a problem using the knowledge acquired as inference. Neural networks are simplified imitations of the central nervous system, and obviously therefore, have been motivated by the kind of computing performed by the human brain. The structural constituents of a human brain termed neurons are the entities, which perform computations such as cognition, logical inference, pattern recognition and so on. Hence, the technology which has been built on a simplified imitation of computing by neurons of a brain has been termed Artificial Neural Networks.

A. Biological Neuron

The brain is made up of a vast network of neurons, which are coupled with receptors and effectors. The neuron is the fundamental unit of the nervous system, particularly the brain. Considering the microscopic size, it is an amazingly complex biochemical and electrical signal processing factory. From a classical viewpoint, the neuron is a simple processing unit that receives and combines signals from many other neurons through filamentary input paths called dendrites. Dendrites are bunched into highly complex dendrites trees which have an enormous total surface area. Dendritic trees are connected with the main body of the nerve cell, the soma. The soma has a pyramidal or a cylindrical shape. The dendrites conduct signals to the soma or cell body (Fig. 1). Extending from a neuron's soma, at a point called axon hillock is a long fibre called the axon, which generally splits into a very small branches constituting the axonal arborisation. The interior of the cell is filled with the intracellular fluid, and the outside with extracellular fluid. When excited above a certain threshold, the neuron fires. It transmits an electrical signal, the axon potential, along an axon. The tips of axon branches impinge either upon dendrites, somas, or axons of other neurons or upon effectors. The axon-dendrite contact between the end bulb and the cell it impinges upon is called a synapse. In other words, the connection or junction between a neuron's axon and another neuron's dendrite is called a synapse.

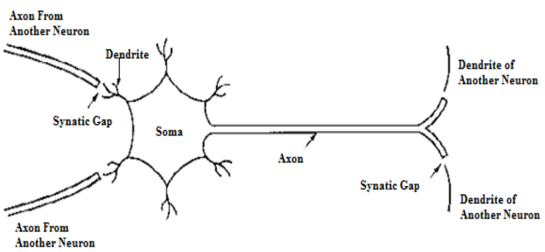


Fig 1. A Biological Neuron

The signal in a neuron flows from the dendrites through the soma converging at the axon hillock and then down the axon to the end bulbs. A single neuron may have 1000 to 10000 synapses and may be connected with around 1000 other neurons. All the synapses are not excited at the same time. When the action potential reaches the axionic endings, chemical messengers known as neurotransmitters are released. Neurotransmitters are stored in tiny spherical structures called vesicles and are responsible for the effective communication of information between neurons; they either accelerate or retard the flow of electrical charges. The fundamental actions of the neurons are chemical in nature. The neurotransmitter fluid produces electrical signals that go to the soma of the neuron. All integrated fluid produces electrical signals that go to the soma of the neuron. All integrated signals are combined at the soma, and if the amplitude of the combined signal reaches the threshold of the neuron, a firing process is activated and the output signal is produced. The signal is transmitted along the cell's axon to the axonic endings.

B. Artificial Neuron

An artificial neuron is an information processing unit that is fundamental to the operation of neural network. Fig. 2 shows the schematic representation of an artificial neuron. It consists of a set of synapses or connecting links, each of which is characterised by a weight or strength of its own. The input signals are x0, x1, x2, ..., xn. These signals are the continuous variables, not the discrete electrical pulses that occur in brain. Specifically, a signal xj at the input of synapse j connected to neuron k is multiplied by the synaptic weight Wkj. The first subscript refers the neuron and the second subscript refers to the input end of the synapse to which the weight refers. Unlike a synapse in the brain, the synaptic weight of an artificial neuron may lie in a range that includes negative as well as positive values, corresponding to the acceleration or inhibition of the flow of electrical signals. The processing element consists of two parts. The first part consists of adder for summing up the input signals, weighted by the respective synapses of the neuron, and the second part consists of an activation function, in that it squashes the permissible amplitude range of the output signal to some finite value. The normalized amplitude of the output of a neuron lies within the closed unit interval [0, 1] or [-1, 1].

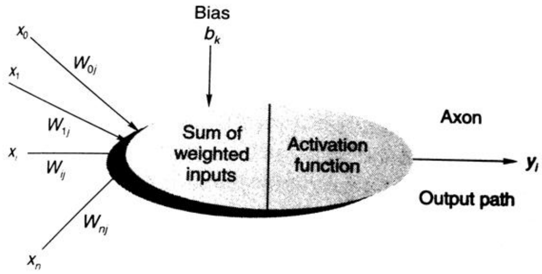


Fig 2. An Artificial Neuron

An external bias bk is also applied to the neuron. It has the effect of raising or lowering the net input of the activation function, depending on whether is positive or negative, respectively. The activation function is denoted by $\emptyset(I)$, defines the output of the neuron in terms of the individual local field I. The threshold function passes information only when the output of the first part of artificial neuron exceeds the threshold value T.

C. Neural Network Architectures

Single layer feed forward network consists of two layers; the input layer and the output layer. The input layer consists of input neurons which receive the input signals and the output layer consists of output neurons which receive the output signals. The synaptic links carrying the weights connect every input neuron to the output neuron. In this network not a single output neuron is connected to input neuron. Fig. 3 illustrates the example of feed forward network. Such a network is said to be feed forward in type or acyclic in nature.

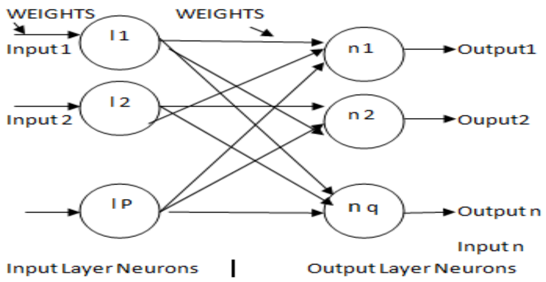


Fig. 3 Single layer feed forward network

Multilayer feed fordward network is made up of multiple layers. In addition of input layer and output layer, it also has one or more intermediary layers called hidden layers. The computational units of the hidden layers are also known as hidden neurons or hidden units. The hidden layers perform useful computations before directing the input to the output layer. The input layer neurons are linked to the hidden layer neurons and the weights on these links are referred to as input-hidden layer weights. The hidden layer neurons are linked to the output layer neurons and the corresponding weights are referred to as hidden-output layer weights.

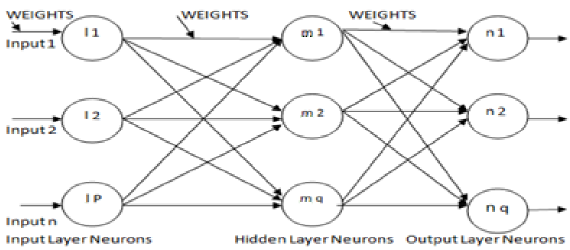


Fig. 4 Multilayer feed forward network

Recurrent neural networks differ from feed forward network architectures in the sense that there is at least one feedback loop. Thus, in these networks, for example, there could exist one layer with feedback connections as shown in fig. 5. There could also be neurons with self-feedback links, i.e. the output of a neuron is fed back into itself as input.

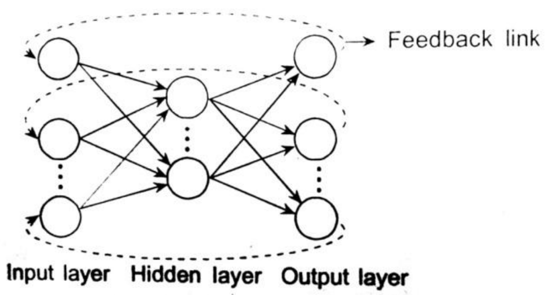


Fig. 5 Recurrent neural networks

Modern neural network architectures are listed below:

- ADALINE
- Associative Memory
- Hopfield Network
- Adaptive Resonance Theory
- Back propagation Network
- Perceptron
- Boltzman Machine
- Self Organizing Feature Map

D. Back propagation Networks

Rumelhart, Hinton and Wilham (1986) presented a clear and concise description of the backpropagation algorithm. Parker (1982) has also shown to have anticipated Rumelhart's work. It was also shown elsewhere that Werbos (1974) had described the method still earlier. Back propagation is a systematic method for training multilayer artificial neural network. It has a mathematical foundation that is strong if not highly practical. It is a multilayer forward network using extend gradient-descent based delta learning rule commonly known as back propagation (of errors) rule. Back propagation provides a computationally efficient method for changing the within Feed forward network, with differentiable activation function units, to learn a training set of input-output examples. The network is trained by supervised learning method. The aim of this network is to train the network to achieve a balance between the ability to respond and the ability to provide good responses to the input that are similar. During training, each input is forwarded through the intermediate layer until outputs are generated. Each output is then compared to the desired output to get the errors that will be transmitted backwards to the intermediate layer that contributes directly to the output. Based on these errors, the weights are updated. This process is repeated layer by layer until each node in the network has received an error signal that describes its relative contribution to the total error. The gradient descent algorithm suffers from slow training time. Some other fast algorithms such as Levenberg-Marquardt, Quasi-Newton, and conjugate gradients algorithms have been used to optimise the learning rules in BPN.

III. MATLAB SIMULATION

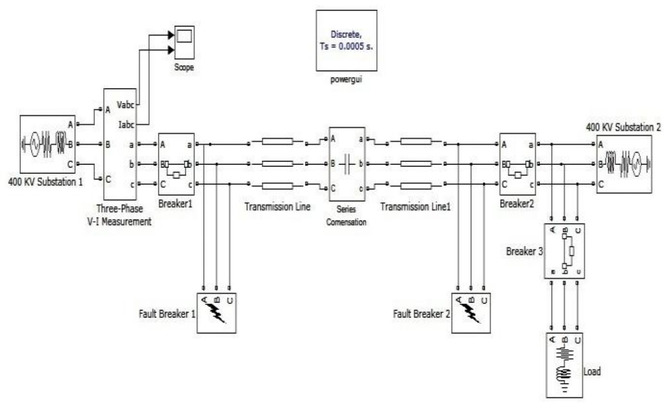


Fig. 6 MATLAB simulation model for 400kv transmission line

The MATLAB simulation model is shown in fig. 6. A 400 KV, 300 km long transmission line is fed from two substations; 400 KV Substation 1 & 400 KV Substation 2. Fault Breaker 1 creates fault at the sending end & Fault Breaker 2 creates fault at the receiving end of the transmission line. 3-Phase load is connected at the receiving end of the transmission line. Series compensation is applied at the middle of the transmission line. For different conditions the fault data is to be collected for training of Neural Network. Fig. 7 describes the fault data collection method.

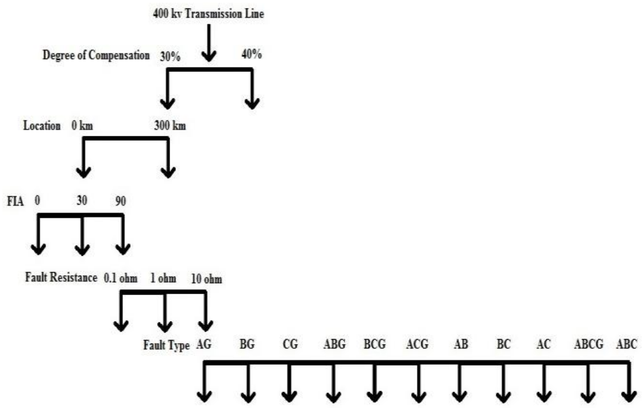


Fig. 7 Fault data collection scheme

A. Training of ANN

A module of ANN is trained for fault detection. The collected fault data are fed for training ANN with predefined targets such as for fault sample (Va, Vb, Vc, Ia, Ib, Ic) the target set is 1 else 0. The neural network will give output = 0 for no fault condition and it will give output = 1 for fault condition. The training parameters are shown in Table 3.

Training Parameters	
Type of Neural Network	Neural Network Fitting Tool
Method Adopted for Training ANN	Backpropagation
Training Algorithm	Levenberg- Marquardt
Number of Inputs	6 (V_a, V_b, V_c, I_a, I_b, I_c)
Total Samples Used	16638
Samples Used for Training	70 % (16646 samples)
Samples Used for Validation	15 % (2496 samples)
Samples Used for Testing	15 % (2496 samples)
Number of Input neurons	6
Number of Hidden neurons	20
Number of Output neurons	1

Table 3 Training Parameters

As shown in fig. 8, the input layer neurons receive all the 6 inputs and associate them with randomly generated weights. Input layer produces net sum of product of inputs and corresponding weights of each input layer neuron. The hidden layer neurons receive the net sum produced by input layer which is associated with hidden layer weights. The output of each hidden layer is passed through Tansigmoidal transfer function. Similarly, output layer neuron receives the output produced by hidden layer neurons. The output of output layer neuron is passed through Purelinear transfer function.

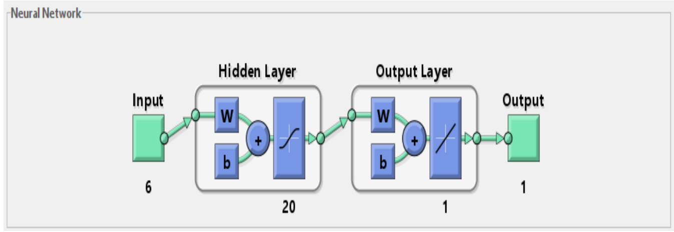
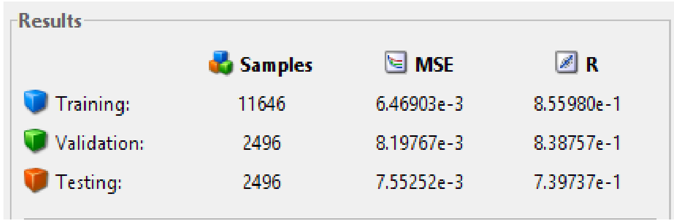


Fig. 8 ANN fault detection module

Fig. 9 shows the results of the training. Ideally, the Mean Squared Error (MSE) should have been 0. The Mean Squared Errors obtained after training are close to zero value. Regression values (R) shows how closely the outputs and targets are related. Regression R=1 shows close relationship between the output produced by ANN and the targets assigned. After training, the regression values obtained for different training stages (Training, Validation and Testing) are found to be close to 1.



Results

	Samples	MSE	R
Training:	11646	6.46903e-3	8.55980e-1
Validation:	2496	8.19767e-3	8.38757e-1
Testing:	2496	7.55252e-3	7.39737e-1

Fig. 9 Mean squared error & regression value

B. Simulation Results

For simulating different faults, the fault conditions such as location of fault occurrence, fault inception angle and fault resistance were different than those which had been used during training. One example of fault conditions taken into account during testing of ANN module of fault detection is as follow:

Fault Inception Angle: 0; Fault Resistance Rf = 8 Ohm.

The following figures show ANN output for no fault and different fault conditions.

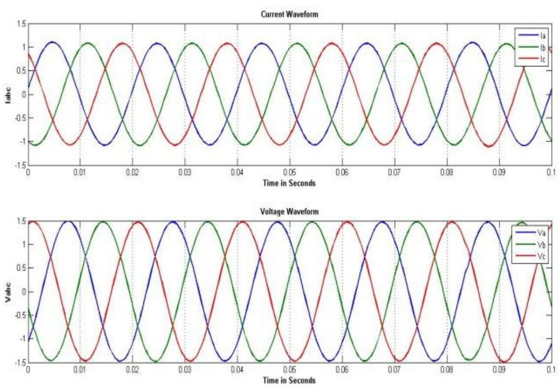


Fig. 10 Voltage & current waveforms for no fault condition

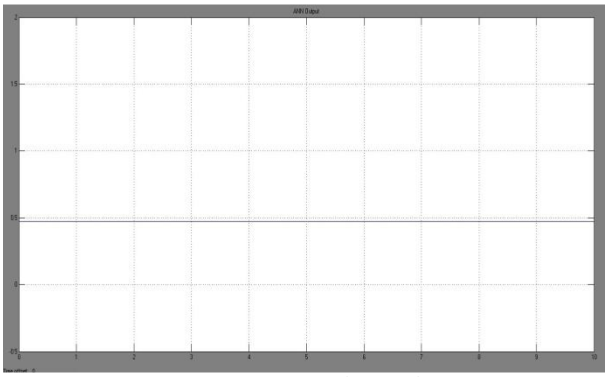


Fig. 11 ANN module output for no fault condition

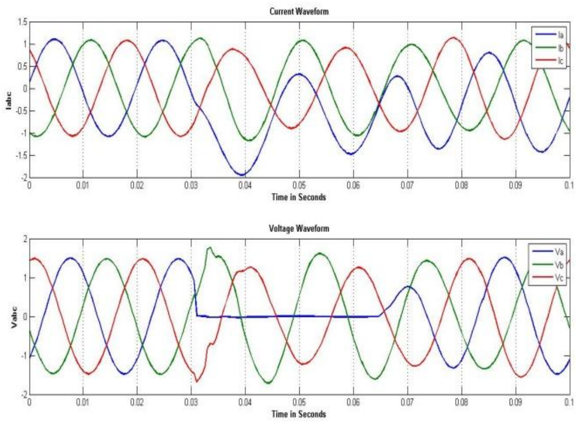


Fig. 12 Voltage & current waveforms LG fault

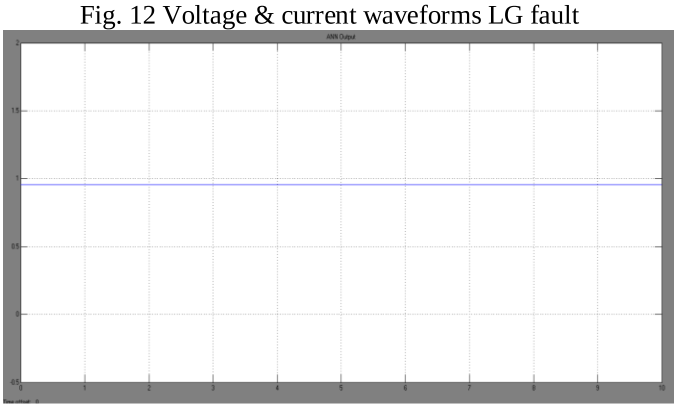


Fig. 13 ANN module output for LG fault

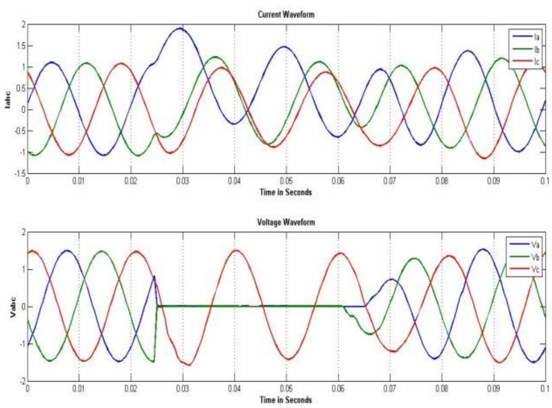


Fig. 14 Voltage & current waveforms for LLG fault

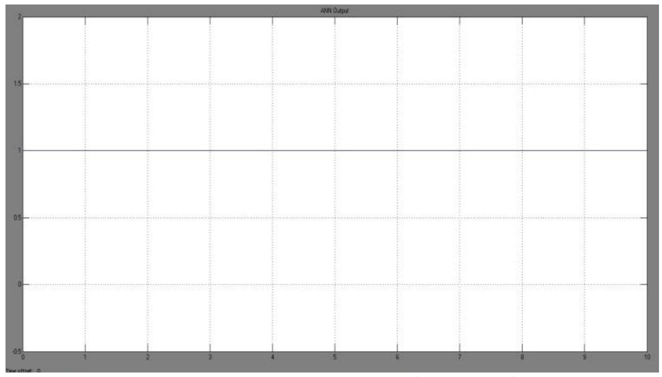


Fig. 15 ANN module output for LLG fault

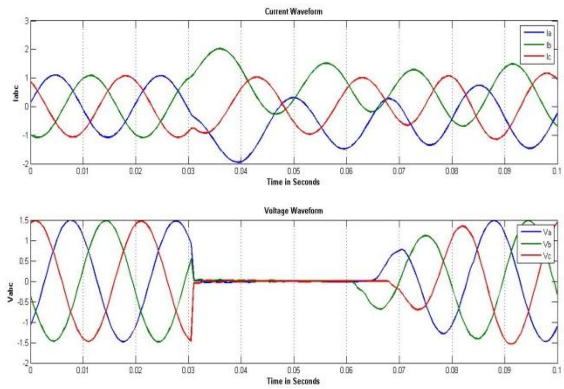


Fig. 16 Voltage & current waveforms for LLLG Fault

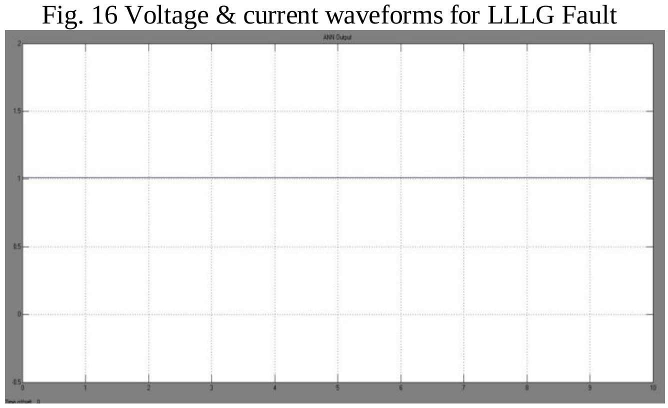


Fig. 17 ANN module output LLLG fault

IV. CONCLUSION

From the simulation results, it is observed that the ANN module for fault detection has identified any fault condition. It has been seen that the ANN module gives output 1 for some fault conditions and near to 1 for some fault conditions. The ANN module is not able to identify the No Fault condition accurately. During No Fault the ANN output should be 0. But from the simulation results it has been seen that the output given by ANN module is not zero but, it is between 0 to 0.5.

REFERENCES

PAPERS

[1] Hasan Rastegar, Amir P. Khansaryan, ''A New Method for Adaptive Distance Relay Setting in the Presence of SSSC Using Neural Networks'', IEEE

transactions, ICIEA 2006.

[2] A. Y. Abdelaziz, A. M. Ibrahim, M. M. Mansour, H. E. Talaat, "Modern approaches for protection of series compensated transmission lines", Electrical Power Systems Research 75 (2005).

[3] D. V. Coury and D.C. Jorge, "Artificial Neural Network Approach to Distance Protection of Transmission Lines", IEEE Transactions on Power Delivery, Vol. 13, No.1, January 1998

[4] Mario Oleskovicz1, Denis V. Coury1, Andre C.P.L.F. de Carvalho2, "Artificial Neural Network Applied to Power System Protection"

[5] M Oleskovicz1, D V Coury1, R K Aggarwal2, "A complete scheme for fault detection, classification and location in transmission line using Neural Networks", IEEE conference publication 2001.

[6] Eisa Bashier M. Tayeb Orner AI Aziz AlRhirn, "Transmission Line Faults Detection, Classification and Location using Artificial Neural Network", IEEE conference publications 2011

[7] S. Websper, R. W. Dunn, R. K. Aggarwal, A. T. Johns and A Bennett, "Feature extraction methods for neural network-based transmission line fault discrimination" *IEE Proc.-Gener. lrntmn. Diwi6., Vol. 146, No. 3, Moy 1999*

[8] A. P. Vaidya, Prasad A. Venikar, "ANN Based Distance Protection of Long Transmission Lines by Considering the Effect of Fault Resistance", ISBN, IEEE conference publications 2012

[9] Anamika Jain and A. S. Thoke & R. N. Patel, "Double Circuit Transmission Line Fault Distance Location using Artificial Neural Network", IEEE conference Publications 2009.

[10] Suman Kumar Saha, Priyanath Das & Ajoy Kr Chakrabothy, "An ANN based Relay Design for Identification Faults of 400kv High Voltage AC Transmission Line", International Journal of Computer Applications, 2012.

[11] Murari M. Saha, Bogdan Kasztenny, Eugeniusz Rosolowski & Jan Izykowski, "First Zone Algorithm for Protection of Series Compensated Lines", IEEE Transactions, April 2001.

[12] Tarlochan S. Sidhu & Mojtaba Khederzadeh, "Series Compensated Line Protection Enhancement by Modified Pilot Relaying Schemes", IEEE Transactions, July 2006.

BOOKS

[13] N. P. PADHY, "Artificial Intelligence and Intelligent Systems", Oxford, 2006.

[14] Abhisek Ukil, "Intelligent Systems and Signal Processing in Power Engineering", Springer Berlin Heidelberg, 2010.

[15] S. Rajeshkaran, G. A. Vijayalakshmi, "Neural Networks, Fuzzy Logic, and Genetic Algorithms Synthesis and Applications".

[16] Bhavesh Bhalja, R. P. Maheshwari & Nilesh G. Chothani, "Protection & Switchgear", Oxford, 2011.

[17] Badri Ram & D N Vishwakarma, "Power Syatem Protection & Switchgear", Tata McGraw-Hill Company Ltd., 2005.

[18] B. A. Oza, N. C. Nair, R. P. Mehta & V. H. Makwana, "Power System Protection & Switchgear", Tata McGraw-Hill Company Ltd., 2011.

[19] R. Mohan Mathur & Rajiv K. Varma, "Thyristor Based FACTS Controllers for Electrical Transmission Systems", Wiley India Pvt. Ltd. 2012.

[20] Narain G. Hingorani & Laszlo Gyugyi, "Understanding FACTS", Wiley, 2000.

