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Power System Fault Detection using Artificial Neural Network

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***Abstract*: The project is centered on the utilization of Artificial Neural Networks (ANNs) to detect faults in power systems. Feed-forward neural networks have been employed and trained with back-propagation algorithms. To validate the proposed fault detection system, a single test system has been modelled in MATLAB/Simulink. The normal state of the model was initially observed; then, different types of faults were simulated on all lines of the model. The voltage and current magnitudes acquired from the fault simulation were used as inputs for the ANN. The output of the ANN should be able to provide information regarding the fault type if a fault occurs.**

***Keywords*: Artificial Neural Networks, fault detection, hidden layers, MATLAB Simulink, power systems.**

1. Introduction

Power systems all over the world are experiencing huge and rapid expansion. An uninterrupted, reliable and stable supply of electric power is required by the end users sensitive to surges and outages. On the other side, the appearances of large generations and highly interconnected systems are making early fault detection and rapid equipment isolation the most important functions to maintain system stability. One of the factors that hinder the continuous supply of electricity and power is a fault in the power system.

It is a necessity to have a protection system which can easily and quickly detect any abnormalities in the flow of power and identify the type of fault as soon as possible. Conventional algorithms based on deterministic computations and well-defined models of power lines, are resulting in the late detection and inaccurate results. Such malfunctioning could lead to serious disturbance of power system stability.

Artificial intelligence-based methods are being used in the process of fault detection and classification to accelerate fault detection and to improve performance of protection systems.

Artificial Neural Networks (ANN) are computing systems inspired by the biological neural networks that constitute animal brains. An ANN is based on a collection of connected units or nodes called artificial neurons, which loosely model the neurons in a biological brain.

Artificial neural networks can be used in Power Systems for fault detection and classification effectively as neural networks can easily learn to solve nonlinear problems.

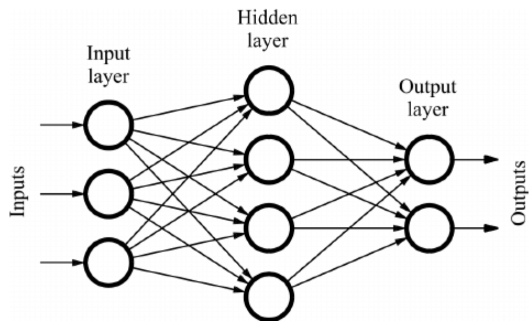

Fig. 1. Feed forward neural network

2. Literature Survey

There are many works presented by various researchers for the fault classification and detection of power transmission. They have employed various different methods for this work.

"A FIRANN as a differential relay for three phase power transformer protection." in IEEE Transactions on Power Delivery, April 2001, by A. L. Orille-Fernandez, N. K. I. Ghonaim and J. A. Valencia: In this paper the authors have presented the finite impulse response (FIRANN) method to detect and classify the faults and they have used the impulse response of voltages and currents for detection and classification of faults, which limits its applications [1].

"Transmission line fault distance and direction estimation using artificial neural network", IJERT 2011, by A. Yadav and A. S. Thoke: In this paper, the authors have presented an accurate fault distance and direction estimation based on application of artificial neural networks for protection of doubly fed transmission lines. This proposed method is used by the voltage and current available at the only local end of line. This method is very adaptive and relearns itself according to the variation of fault location, fault inception angle and fault resistance [5].

"Fault detection and classification in electrical power transmission systems using artificial neural networks.", Springer Plus 4, 2015, by Jamil, M., Sharma, S.K. & Singh, R.: In this paper, the three phase voltages and currents of one end are taken as inputs in the proposed system. The back propagation algorithm of the feed forward neural network is employed for detection and classification of the fault for analysis of each of the three phases involved in the process [6].

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3. Proposed System

A. Planning of the Project

The aim of this project is to model a Three phase power system using MATLAB Simulink and develop a Neural Network which can detect and classify the faults in the system.

To train the Neural Network model all types of faults are simulated on the Power system Model and certain values of the system are recorded. These values are then used as the input values for the training of the Neural Network Model.

B. Working Principle

A three-phase transmission system with one generator, one transformer and one load is modelled using Simulink. The required data for training of a Neural Network is obtained from the same three phase transmission system model. All types of faults are simulated on the model and the values of all line voltages and line currents i.e., V_a, V_b, V_c and I_a, I_b, I_c are stored as the inputs to the Neural Network. For Fault detection, the output of the neural network is a simple 0 or 1 or a Yes or No corresponding to a fault detected or not detected. For fault Classification, the output of the neural network has to be an array containing 0 and 1 which differentiates between different types of faults. The output array contains 4 values either 0 or 1 each corresponding to the absence or presence of fault on line A, B, C or G where A, B, C are the three lines on the system and G is the ground.

Table 1
ANN output for fault classification

Type of Faults	Phase A	Phase B	Phase C	Ground
No Fault	0	0	0	0
AG	1	0	0	1
BG	0	1	0	1
CG	0	0	1	1
AB	1	1	0	0
AC	1	0	1	0
BC	0	1	1	0
ABG	1	1	0	1
ACG	1	0	1	1
BCG	0	1	1	1
ABC	1	1	1	0
ABCG	1	1	1	1

4. Modelling and Simulation

A. Modelling of the Three Phase System

A simple 3 phase Power system model is designed in Simulink having a single Generator of 11kV, a transformer of ratio 11kV/415V, and a load of nominal phase to phase voltage as 415V and Nominal power 20KW.

All the blocks used are available in the Simulink Library and are listed below:

1. Three Phase Source
2. Three Phase Transformer (Two Winding)
3. Three Phase V-I Measurement
4. Three Phase Series RLC Load
5. Powergui
6. Scopes
7. Three Phase Fault Generator

A fault generator is used to simulate all types of faults on the system to obtain the required data for training of the Neural Network.

The values of all line voltages V_a, V_b, V_c and all line currents I_a, I_b, I_c are noted for every type of fault.

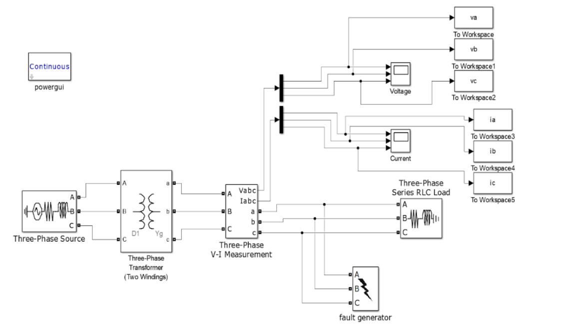

Fig. 2. Three phase power system model with fault generator

B. Simulation of Faults onto the Model

All types of faults are implemented on the model one by one by using the Three phase Fault generator. First, the line values of the model without any fault are noted and then the line values with each fault individually.

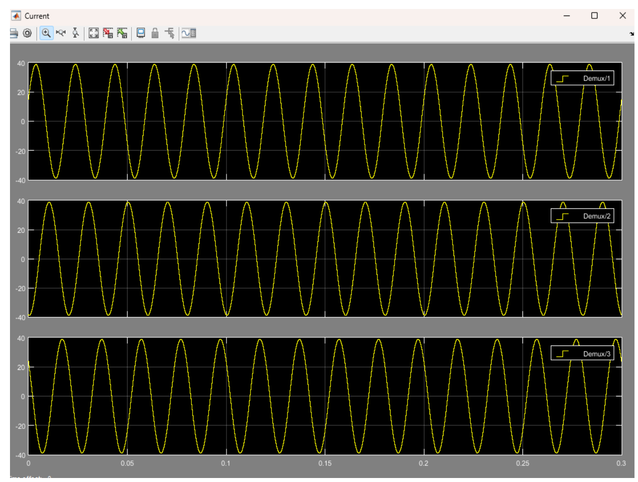

Fig. 3. Three phase current without any faults

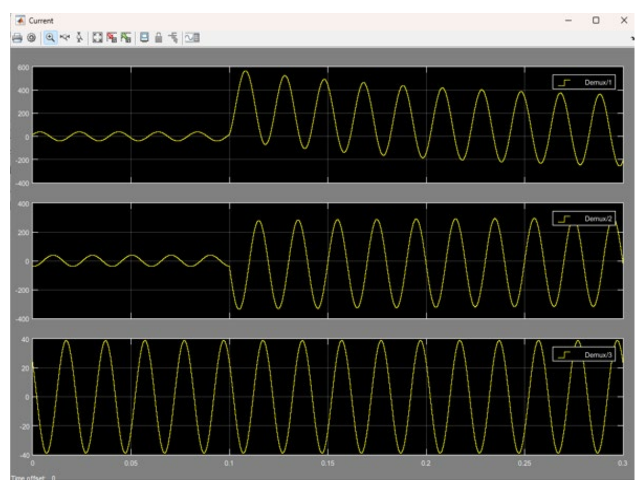

Fig. 4. Three phase current at Line-Line fault at 0.1sec

C. Measurement of Voltage and Current for Neural Network Training

The Line voltages and line currents are recorded at the time when the fault is introduced. Two values for each fault are recorded at a sampling rate of $T_s = 1x10^{-4}$

The obtained Data set is given below:

	1	2	3	4	5	6
1	425.7456	-553.7756	128.0300	11.3382	-37.8740	26.5350
2	461.3488	-534.8592	73.5103	14.8334	-38.5380	23.7043
3	418.1875	-556.9134	138.7260	10.6298	-37.6998	27.0675
4	461.3031	-534.8609	73.5578	14.8290	-38.5370	23.7055
5	390.8412	-566.2674	175.4262	8.1506	-36.9879	28.8441
6	461.2611	-534.8126	73.5515	14.8306	-38.5305	23.7065
7	433.7801	-550.0392	116.2591	12.1023	-38.0468	25.9348
8	461.3343	-534.7919	73.4575	14.8318	-38.5378	23.6967
9	441.8787	-556.3285	114.4498	11.5058	-39.7189	28.0149
10	494.5032	-549.7656	55.2623	15.4008	-41.8140	26.0263
11	402.1450	-563.2515	161.1065	9.3173	-37.4705	28.2453
12	462.3063	-549.7767	87.4704	15.2051	-39.2939	24.9937
13	457.0767	-539.8329	82.7562	14.3158	-38.5623	24.2625
14	462.1901	-536.2648	74.0748	14.8547	-38.6337	23.7931
15	-20.9173	-625.0117	645.9291	25.8835	-35.3739	106.9080
16	157.4230	-2.1227e+03	1.9653e+03	143.4159	-54.3124	355.3565
17	396.3756	-564.5858	168.2102	8.6377	-37.1461	28.4948
18	461.2756	-534.8041	73.5285	14.8252	-38.5369	23.6984
19	330.7129	-577.5863	246.8734	3.0512	-35.0745	32.0276
20	461.1885	-534.7356	73.5471	14.8322	-38.5195	23.7088
21	-5.1016e+08	3.6945e+08	1.4071e+08	-1.4239e+09	3.6591e+09	4.3740e+03
22	-5.1236e+08	3.7104e+08	1.4131e+08	-1.4301e+09	3.6748e+09	4.3805e+03
23	-1.4069e+08	-183.0875	1.4069e+08	-1.3881e+09	-2.6858e+03	-2.6650e+03
24	-1.4148e+08	-534.9571	1.4148e+08	-1.3959e+09	-2.7463e+03	-2.6840e+03
25	425.7456	-553.7756	128.0300	11.3382	-37.8740	26.5350
26	461.3488	-534.8592	73.5103	14.8334	-38.5380	23.7043
27	418.9032	-556.6269	137.7237	10.6965	-37.7167	27.0179
28	461.3066	-534.8605	73.5539	14.8293	-38.5371	23.7054
29	385.1487	-567.8859	182.7373	7.6476	-36.8268	29.1888
30	461.2518	-534.8308	73.5791	14.8298	-38.5302	23.7089
31	391.8906	-566.0019	174.1112	8.2383	-37.0224	28.7795
32	461.3172	-534.8355	73.5182	14.8305	-38.5372	23.7026
33	445.5899	-546.0668	100.4769	13.2411	-38.3732	25.1615
34	460.5265	-535.7007	75.1742	14.9114	-38.6496	23.7187
35	462.4076	-538.2332	75.8255	14.7819	-38.7213	23.9279

D. Developing Neural Network for Detection

Using the Neural Network Toolbox in MATLAB, a required ANN model can be developed. The obtained data is divided into three parts - training data, validating data and testing data.

The following is the snapshot of the developed ANN model.

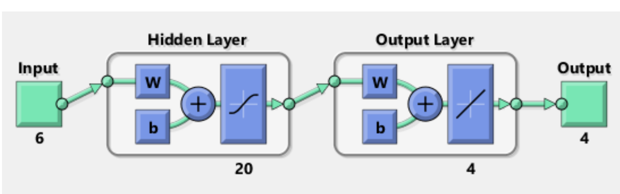

Fig. 6. ANN model

5. Results

After the training of the neural network, the performance is checked by plotting the linear regression graph. This graph correlates the target to the output. R is the measure of how well the NN's targets can track the variation in the outputs. 1 means there is complete correlation.

Here we have achieved R = 0.98269 which shows a very good training.

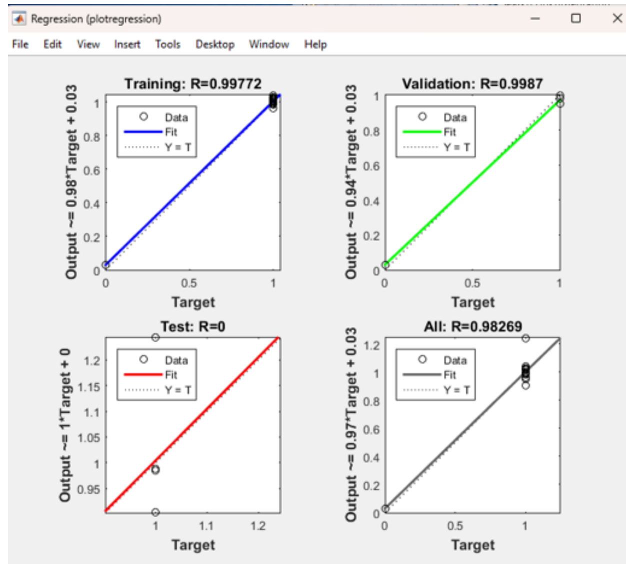

Fig. 7. Regression graph of output vs. target

From the training performance plot, it is clear that the mean squared error is very less which denotes a good performance of the neural network. A lower mean squared error denotes a better Network.

$$MSE = 2.198 \times 10^{-5}$$

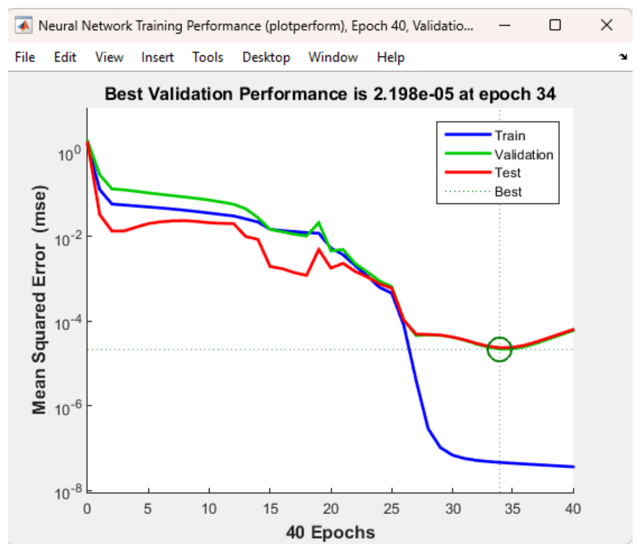

Fig. 8. Mean Squared Error performance

The developed neural network is then implemented in the Three phase power system model as follows.

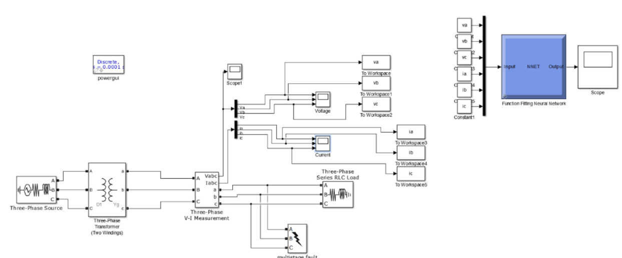

Fig. 9. Three phase power system model with Neural Network implemented

Here, a Line - ground fault on phase B is simulated to check the Neural Network Output.

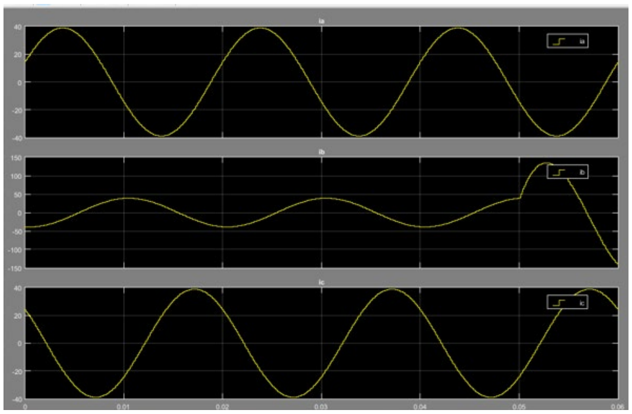

Fig. 10. Line-Ground fault simulated on the model

The expected result here is that the neural network detects that there has been a fault in the system.

That is shown by the neural network giving output as 1.

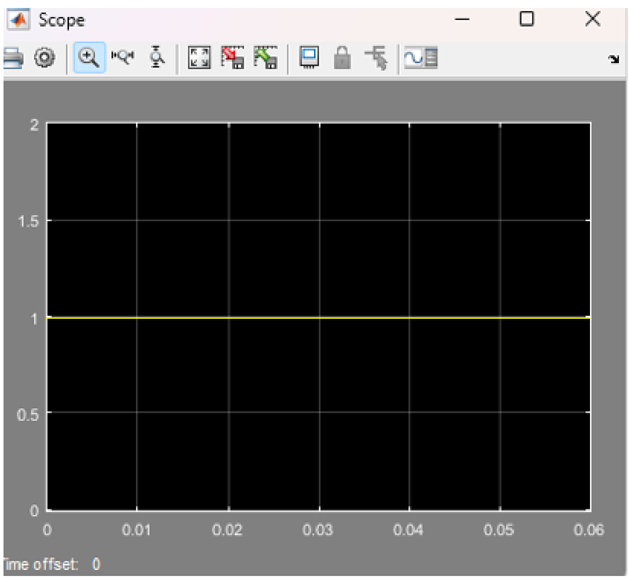

Fig. 11. Neural Network output during fault

6. Conclusion

From this project, we studied the application of Artificial Neural Network for the detection and Classification of faults on a Three phase Power system model. This is done by using the line Voltages and currents of the System model as the input to the neural network for training.

This project has implemented the Neural network only on a single transmission system. Further, we can implement this on a larger scale with a larger data set. Artificial neural networks are a reliable and effective method for an electrical power system transmission line fault classification and detection especially in view of the increasing dynamic connectivity of the modern electrical power transmission systems.

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