Fault detection in Electrical Power Transmission System using Artificial Neural Network

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***Abstract*— Since the number of transmission line is increasing day by day to meet the increasing load demand; occurrence of faults is also increasing. For clearance of faults their detection has to be spontaneous and accurate so that it will cause less damage to the power system. One of the best methods for detection of fault in transmission lines is Artificial Neural Network (ANN). After creation of the Simulink model the phase currents of different faults are generated and it has been given as input to the Neural Network Model. For the input data a target data is generated which consist values for no fault and fault conditions. Programming is used through which all the variables and target data are passed for creation of ANN model. After creation of the model, it is trained and tested for the same input & label data. The testing results show the good performance of the Artificial Neural Network for all types of faults**

Keywords— Artificial Neural Network (ANN), Fault detection, Transmission line, Distributed generation (DG), Mean Square Error (MSE).

I. INTRODUCTION (*HEADING 1*)

technique of electrical power application & innovation which opened the door for human society to a new age of electricity [1]. Using non-renewable sources to produce electricity was not a big assignment in old days as electricity use was less. But now-a-days the need of electricity as the world is growing [2]. Due to industrial expansion and increased consumption of power the energy demand is rising progressively at its full perspective. This led the way to explore new and sustainable technologies such as wind, thermal, solar, hydro etc. to produce power. The main focus is to convert these renewable resources into electrical energy in order to fulfil the increased demands [3]. More power generation leads to setting up of more generating units and henceforth more transmission.

In the electrical industry, distributed generation (DG) is a notable event that has occurred over the past few years. With the DG units in distributed networks, the behavior of the system is changed and these units have different effects on the system which each of them can investigate, separately [4]. DG unit is the electrical energy source that is connected to the distribution networks [5]. Since the DGs are having advantages over conventional power systems, their use is attaining recognition. DG is having a crucial part in the power system network. The increase in use of distributed power is because of its unique advantages over the conventional power system.

Fault incidents are regular occurrences in power systems and timely detection and location of the fault are essential for the restoration of the power system to acceptable working conditions [6]. Transmission lines can have faults. To find the correct phases and protect the fault phases, there are different proposals related to modern relays [7]. There has been huge development since last past 20 years in various fields towards the classification and detection of faults in power systems [8]. Since continuous power interruptions, especially in industries can lead to huge economic loss, the primary task must be detecting faults in the power system [9]. Since in the past, power utilities have been practicing with techniques of conventional methods like visual inspection and trial-and-error switching for fault identification [10].

Many techniques for detection and classification of faults have been reported in contemporary years. With 4th Industrial Revolution occurring in recent years new technologies have been introduced to us which made our work more quality efficient and time efficient. Since the past 15-20 years Deep learning techniques are under consideration, as they can adjust actively to the system operating conditions at a very high speed. As the fault which occurs in the transmission lines if persists for a long time it causes the more damage to the power system. In order to overcome these problem ANN techniques has been used lately to detect the fault so that it will save more time and power restoration would take place. ANN show qualities, for example, design affiliation or mapping capacities, adaptation to internal failure, strength, speculation and fast data preparing [11].

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II. Artificial Neural Network(ANN)

A neuron is the basic unit of biological brain. All the parts of body sense the environment and send inputs to the brain through neurons. The brain accepts the inputs, processes them and gives accurate output to respond at a given instance. Development of Artificial Neural Network (ANN) was inspired by this process.

Usually the ANN consists of 3 layers named as Input layer, Hidden layer & Output layer. The Input layer is where we basically provide data in the form of commands or datasets etc. The input data has to be normalized before feeding to the input layer and this can be done by applying feature scaling so that all values range from 0 to 1

$$\text{i.e. } \boldsymbol{X'} = \frac{\boldsymbol{x}-\min(\boldsymbol{x})}{\max(\boldsymbol{x})-\min(\boldsymbol{x})} \quad (1)$$

The fault data are then passed to the hidden layer along with an assigned weight to transform them into higher features

$$\text{i.e. } \boldsymbol{h} = \boldsymbol{\sigma}\big((\boldsymbol{w} \times \boldsymbol{x})\big) + \boldsymbol{b} \quad (2)$$

where $x \in R^{n_x}$ These data are then multiplied with their assigned weight and summed up with their respective bias and sent to the activation function.

$$\text{i.e. } \boldsymbol{h_i} = \boldsymbol{\sigma}((\boldsymbol{w_i} \times \boldsymbol{h_i}) + \boldsymbol{b_i}\,, \boldsymbol{i} = \{\boldsymbol{2}, \dots, \boldsymbol{d}\} \quad (3)$$

where $\boldsymbol{h_i} \in \boldsymbol{R}^{n_{h_i}}$ are the vectors of hidden input representations, $\boldsymbol{w_i} \in \boldsymbol{R}^{n_{h_i} \times n_{h_{i-1}}}$ are weight matrices, $\boldsymbol{b_i} \in \boldsymbol{R}^{n_{h_i}}$ are bias vectors , $\boldsymbol{n_{h_i}}$ are no. of neurons in each hidden layer, '*d*' is the no. of hidden layers which must be determined before training the ANN model and σ is a linear function and is defined as :

$$\boldsymbol{\sigma}(\boldsymbol{x}) = \max(\boldsymbol{0}, \boldsymbol{x}) \quad (4)$$

Equation-3 is then applied to the last hidden layer without activation function

$$\text{i.e. } \boldsymbol{h_s} = (\boldsymbol{w_s} \times \boldsymbol{h_s}) + \boldsymbol{b_s} \quad (5)$$

and the output layer calculates value of each output using the following SoftMax function :

$$\boldsymbol{Y_j} = \frac{\exp(\boldsymbol{h_{s,l}})}{\sum_{l=1}^{n_{h_l}} \exp(\boldsymbol{h_{s,l}})} \quad (6)$$

The network then selects a label with optimized output value. The training given to the model basically focusses on the result's accuracy which is given by

$$\boldsymbol{Accuracy} = \frac{\boldsymbol{no.of\ correct\ samples\ detected}}{\boldsymbol{total\ no.of\ samples}} \times \boldsymbol{100}$$

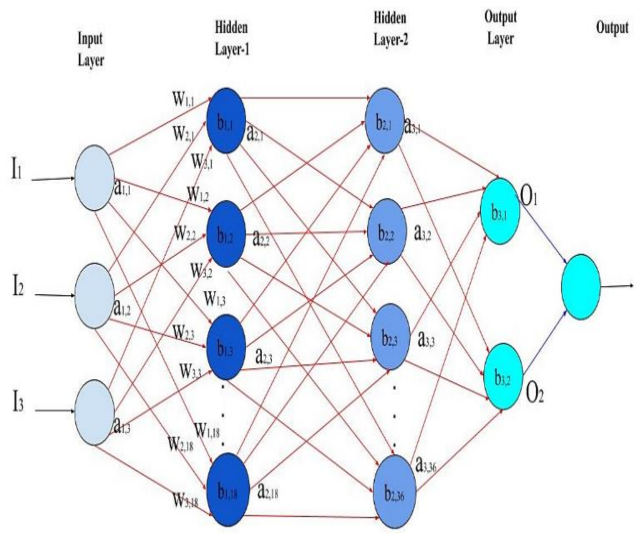

Fig. 1. Configuration of ANN Classifier

Our model has 4 layers, 1st layer has 3 inputs, 2nd and 3rd layers are hidden layers and have 18 and 36 neurons, 4th layer is the output layer having 2 outputs having SoftMax activation function

III. System Model

A 500×10^3 V 3-phase transmission line having 2 voltage sources at the two ends has been used for modelling, which is used to implement the developed algorithm based upon ANNs. Fig 2 shows the single line diagram of the proposed model.

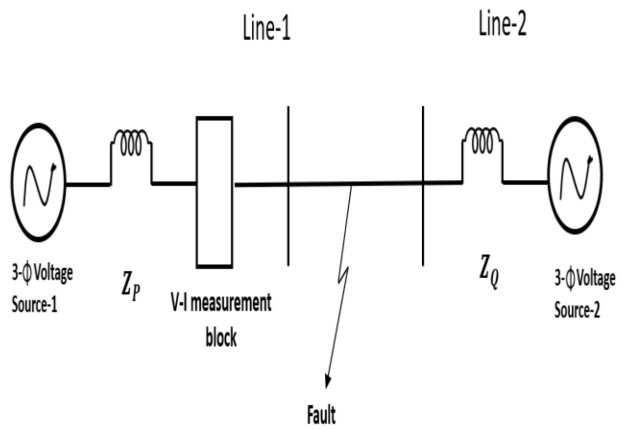

Fig 3 Structure of Artificial Neural Network Classifier

Distributed type parameters have been used to model the line to get more accurate results while implementing the model on long transmission lines. The source impedances of the voltage sources are Zp and ZQ. The 3-phase V-I measurement block has been taken to measure the 3-phase currents and voltages of the 300 km transmission line. The model is simulated for 11 types of faults. Frequency of 50 Hz has been used to carry out the simulation.

IV. RESULT ANALYSIS

In the way to apply the given method for transmission line fault detection phase current samples of no fault and fault conditions have been obtained by simulation of the faults using MATLAB Simulink. Number of tests was conducted with many types of faults. In this way we have collected the data of phase currents i.e.-Ia, Ib, Ic of different kinds of faults. After storing the data, we have done the data cleaning process, we have looked whether there is duplicate data and missing data present in the datasets then we moved to our algorithm part. In the algorithm part the Back Propagation technique also has been used. In Back Propagation, the output is feedback into the input to calculate the change in the weights.

For the fault detection we have obtained that whenever the magnitude is exceeding ±250 the fault is occurring. With this value we have generated the training sample dataset with the help of Python programming language. After both the datasets have been generated we have created the ANN model using 'Sequential' Module of 'Keras' library of Python. The ANN model developed has 4 layers with a 3-18-36-2 neural network architecture i.e.- it has 3 inputs with 2 hidden layers having 18 & 36 neurons and having activation function of 'ReLU' for both the hidden layers respectively. After creation of the model, the model has been compiled with 'Adam' optimizer with learning rate of 0.001 which gives the best result.

The model has been trained up to 50 epochs which gives accuracy more than 97% for every types of faults. After finishing of the training pattern the model was tested and the fault was detected for more than 97% of the original fault.

After the fault obtained, we have recorded the accuracy and the mean square error produced from the model. We can view all the 11 fault's accuracy and MSE from the table-1 below

Table-1: Correct percentage of fault detection and MSE

Types of Faults	Accuracy	Mean Square Error(MSE)
A-G	98.86	0.0000119493979576284
B-G	99.41	0.000340897309334162
C-G	99.26	0.0000076521486276827
A-B	98.56	0.0000032116750812553
B-C	97.26	0.0002588914655781144
C-A	97.14	0.0001236529868189701
A-B-G	98.10	0.0002438683745332984
B-C-G	99.36	0.0000273478556073739
C-A-G	99.28	0.0000368120295627978
A-B-C	98.97	0.0000503786484092786
A-B-C-G	99.92	0.0000006369390239164

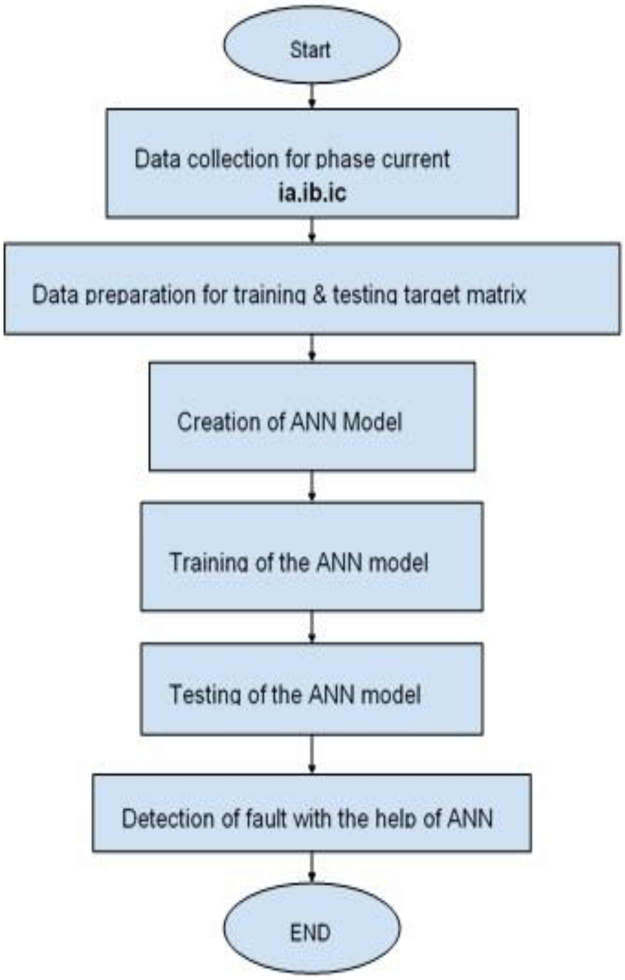

Fig. 3. Flow chart for ANN based fault detection

For both training and testing we have taken a certain number of datasets which have generated by taking a complete cycle of pre fault and post fault. For example in A-G fault we have taken 2025 of sample data of input and output from which the model predicted 1722 of actual fault condition and 280 of actual no fault condition which sums 2002 of correct samples. This gives us the accuracy of 98.86%. We can view the results of all the 11 faults from the table-2 given below.

Table-2: Detection of fault using ANN

Types of Faults	Total number of samples	Samples detected	Samples undetected	Accuracy
A-G	2025	2002	23	98.86
B-G	1884	1873	11	99.41
C-G	2169	2153	16	99.26
A-B	1116	1100	16	98.56
B-C	1243	1209	34	97.26
C-A	1259	1223	36	97.14
A-B-G	1793	1759	34	98.10
B-C-G	1721	1710	11	99.36
C-A-G	1813	1800	13	99.28
A-B-C	1268	1255	13	98.97
A-B-C-G	1253	1252	1	99.92

V. CONCLUSION

This paper suggests a deep learning based model to detect both symmetrical and unsymmetrical faults in transmission lines. The ANN technique has been employed using the phase currents of system model which was built using Simulink/MATLAB. The data generated from the model it has been given as input to ANN for both training and testing using Python programming language. The results obtained shows that the performance of ANN is quite impressive. We can also achieve better results by implementing more deep learning methods like CNN (Convolutional Neural Network). These methods will ensure cost effectiveness and easier maintenance of the transmission lines

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