

Fault Location in Sub-Station using Artificial Neural Networks

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Abstract—In a power system the detection of the faults is very important. The faults occurred should be detected and corrected as soon as possible in order to protect further damage to the system. The faults can cause very adverse effects to the system. However the fault detection is not an easy task. In this paper we have considered a sub-station and the detection of the faults within that sub-station is done with the help of Artificial Neural Networks. The purpose of using ANN in this work is very simple, As ANN has various advantages like it can handle huge amount of data without any difficulty and it also takes less execution time. The sub-station considered in this work is the 500kV gas-insulated substation of the Itaipu system. The MATLAB software and the ANN toolbox within it is used here and the network is trained and tested.

Index terms—Faults, Fault location, Neural Networks

I. Introduction

In the power sub-stations various types of faults can occur. These faults can cause adverse effects and extreme conditions which can cause damage to the whole system. In order to protect the system from damage, the faults which have occurred in the system must be located or detected as soon and possible and then the faulty components should be immediately isolated from the normal or the non-faulty part of the system.

The whole process of fault detection is not an easy task, it can be very complex. In the power sub-station whenever the fault occurs then alarms are produced. These alarms are also produced when the mis-operation of the protection system occurs. The alarms correspond to the fault occurrence and these are produced by the remote sensors which are placed in the sub-station.

These alarms are then sent to the control centers. The control centers handle these alarms. The alarm handling at the control centers is done by the operators who are responsible to deal with these alarms and handle them. Earlier the manual operators were used but as the amount of alarms to be handled were very huge so the manual operators were not able to handle all of them and sometimes even the critical alarms were ignored which lead to problems to the system. So now the intelligent systems are used to handle these alarms. The identification of the faulty component becomes a very important task which needs to be addressed.

In the technical literature various methods have been proposed for this problem [1-10]. The expert system is also used to serve this purpose [4-5]. In the expert system a knowledge base is constructed by using the various alarm patterns. Set of rules are formed by an human experts and when any fault or disturbance occurs then these alarm patterns which are received at the control center are evaluated with reference to the set of rules. Constructing the knowledge base is a difficult task in itself. The human expert must be knowledgeable and experienced. The expert system has been widely used and explored but it did not prove to be very efficient as it was only useful for those conditions which were included in the knowledge base. So it did not serve to be fruitful in those conditions which were not included in the knowledge base like the new or corrupted alarm patterns. This was the main demerit of expert system.

So the alternative methods were proposed which could overcome this problem. Various methods of fault detection using the artificial neural networks (ANN) are also proposed in the technical literature and they have been widely used in recent years [1-3] [8-10]. ANNs are fault tolerant and they have an excellent learning ability i.e, they can learn from historical data.

In this work we have performed the fault location process in a sub-station. The tests are done on the 500kV gas-insulated sub-station of the ITAIPU system [3]. This work is done using the MATLAB software and the ANN toolbox within it is used to train and test the network. ANN proves to be very useful in the process of fault detection. The data which is used here are the alarm patterns which are generated by the occurrence of faults.

II. Power system protection

Power system is a crucial branch of power systems which deals with the protection of the system from faults. Protection

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system also limits the duration of the interruption of services after fault occurrence and protects the system from further damage. In the power system faults can occur due to various reasons but the system should be capable enough to handle such situations so the protection system is designed. It is the responsibility of the protection system to provide proper protection to the power system. We need protection system to protect the equipment as well as to provide safety to human personnel working with them. The protection system is so designed to keep the system stable by only isolating the faulty portion whereas leaving the rest of the portion i.e, healthy portion in function.

The protection system for any system must be very well designed and reliable enough. The other desirable features of protection system are fastness of operation, discrimination and selectivity. Selectivity is that property by which the system recognises the faulty elements and isolates it leaving the remaining healthy section intact.

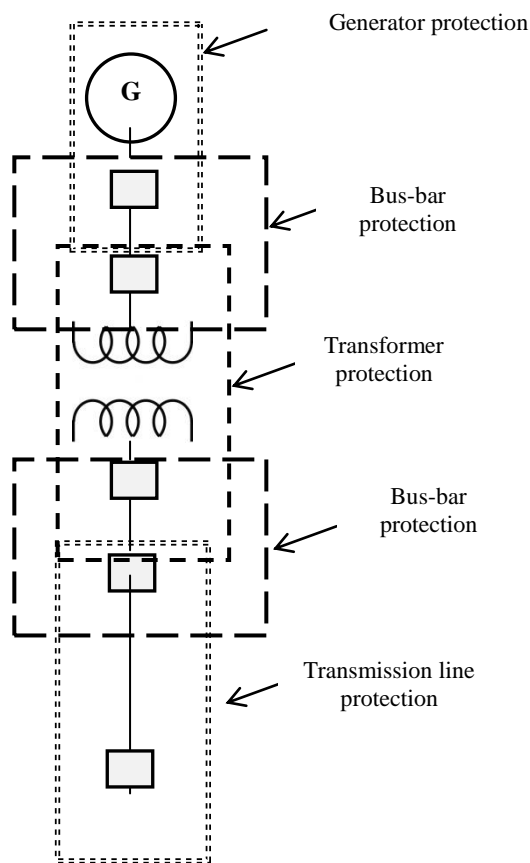


Figure 1. Protection System Zones

The whole system is divided into protective zones and each zone consists of a number of protection devices as depicted in the figure1. The relays determine the existence of faults and send the trip signal to the circuit breaker while the circuit breakers separate the faulty portion from the rest of the

system. If the primary protection fails to clear the fault then the back-up protection performs the action.

As the power system comprises of several equipment and elements. The separate protection is provided for these equipment and elements like transmission lines, generators, distribution lines and bus-bars. The types of protection are:

- Transmission Line Protection
- Transformer Protection
- Generator Protection
- Motor Protection
- Bus-bar protection

The protection system is divided into zones. Each zone consists of several protection devices like relays and circuit breakers and usually contains one or two elements of the power system. The zones are designed in such a way that they cover all the parts of the entire system. So the overlapping of the zones is done so as to ensure that no part of the system remains unprotected. In the power system whenever the faults occurs then the alarms are generated. These alarms are then sent to the control centre. The control centre handles all this alarms the alarms are diagnosed and the decisions are taken. The relays and the circuit breakers operate and in-turn produce alarms which are used here for the purpose of fault detection. The various types of relays and circuit breakers are used.

The relays locate the faults by measuring the electrical quantities like current, voltage and frequency. The relays operate when there is any sort of change in these electrical quantities. Relays protect the system by locating the faults immediately and generating the trip signal. This trip signal is further send to the circuit breaker which in-turn breaks the circuit i.e, it isolates the faulty part of the system from the rest healthy part. It acts as a switch which protects the system from short-circuits and overloads. This way these devices serve as protection devices for the power system and thus minimize the damage.

III. Faults in power system

Fault refers to any abnormal condition in the power system. Faults can damage the system and even disrupt the working of power system. Faults give rise to abnormal conditions like they can give rise to excessive voltages and currents. The excessive currents lead to the overheating and may lead to insulation breakdown. The prolonged heating of the components may result in significant reduction in the life of the equipment. The high-voltage power lines are more prone to faults because of the greater length and exposure to atmosphere. The faults can occur due to various reasons. The natural disturbances like lightning, snow-fall, storms, earthquakes, high-speed winds can cause faults. Over-loading, ageing of insulators and external objects falling on the power lines and some accidental situations like perching of birds, vehicles colliding with supporting structures and airplanes

crashing can also cause faults. Faults can also result in the complete shutdown of the entire system. Faults make the system unstable and severe faults can even lead to fires so they must be disconnected as soon as possible so as to provide the system from failure. Faults are mainly divided into two categories:

- Symmetrical faults
- Unsymmetrical faults

In case of the symmetrical faults the system remains balanced even after the occurrence of fault. In unsymmetrical faults the system becomes un-balanced, this fault involves only one or two phases. Faults can be classified as:

- Single line to ground fault (LG)
- Line to line fault (LL)
- Double line to ground (LLG)
- Three phase short-circuit fault (LLL)
- Three phase to ground fault (LLLG)

LL, LG, LLG are unsymmetrical faults while LLL and LLLG are symmetrical faults.

The table below shows the frequency of fault occurrence in different equipment of the power system. While designing the protection system this information should be kept in mind so as to design an efficient power system. [13]

TABLE I. FREQUENCY OF FAULT OCCURRENCE IN DIFFERENT LINKS OF POWER SYSTEM

<i>Equipment</i>	<i>% of total</i>
Overhead lines	50
Cables	10
Switchgear	15
Transformers	12
CTs and PTs	2
Control equipment	3
Miscellaneous	8

IV. Problem and proposed methodology

Fault detection is very crucial for the efficient working of power system. The methodology for fault detection is presented here. This is done with the help of ANN (artificial neural network). The MATLAB software and the ANN toolboxes are used here for the problem of fault location in sub-station.

- ANN has desirable features like learning from historical data and excellent generalization capabilities.
- ANN is very useful and robust.
- ANN has fast processing speed.

The problems of the neural networks involve seven basic steps as follows:

- Collect data
- Create the network
- Configure the network
- Initialise the weights and biases
- Train the network
- Validate the network
- Use the network

First of all we need to collect the sample data which would be used for training process. Before testing the data it needs to be pre-processed and divided into sub-sets. The three sub-sets in which the sample data is divided are:

- Training sub-set
- Validate sub-set
- Testing sub-set

The training set is used for computing the gradient and for adjusting the weights and biases. During the training the errors on the validation set are monitored. These errors are less during the initial training phase. The default values in which the sample data is divided is 70% for training, 15% for both testing and validation.

V. Artificial neural network

ANN stands for artificial neural networks which are very much similar to the nerve cells of the brain. The neural networks are composed of many artificial neurons. ANN are the parallel computational systems which comprised of a number of simple processing elements which may be connected together. These are connected in order to perform a particular task.

The model of an artificial neuron is shown below.

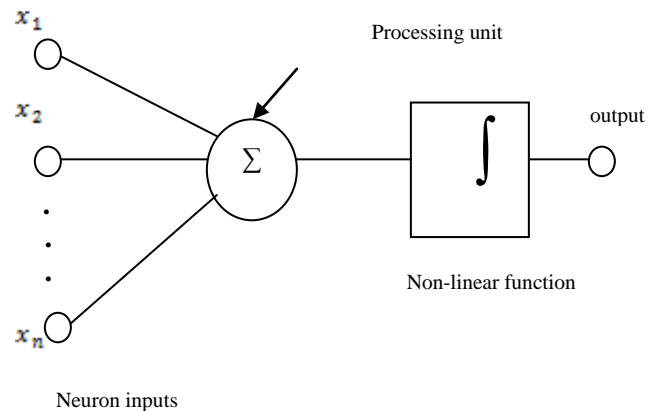


Figure 2. Artificial Neuron

There are various architectures of artificial neural networks. ANN is composed of many layers which are basically divided into three categories namely:

- Input layer
- Hidden layer



- Output layer

The number of hidden layers may vary from one to many. The input layers feed input to the network while the output layer transfers the information and may serve as an input to the next neuron. Thus the ANN forms iterative structure.

VI. Problem statement

In this work we have considered a 500Kv Itaipu indoor gas insulated sub-station. The length of the sub-station is 1000m, the width is 35m and the height is 20m. In this sub-station there are many compartments (approx. 321) which created a problem for the fault detection. In this substation there are 9 generating units, 4 transmission lines, 4 buses, 1 auxiliary transformer, 26 circuit breakers and 66 relays. The relays used are of various types namely differential relays(18), bus differential relays(8), transformer differential relays(2), distance relays(8) and circuit breaker failure relays(30). [3]

VI. Fault location

For this sub-station we will perform fault detection and location by ANN. As we know when a fault occurs the relays and the circuit breakers will operate. The relays will sense the faulty conditions and send a trip signal to the circuit breaker which then operates and isolates the faulty part from the healthy part of the system. If the fault occurs and the relays and circuit breaker operates then we have considered it as a 1 and when they are in-operative then we have considered it a 0. This way the training data will be in the form of 0 and 1. Now we form the training set data by considering only the relay and the circuit breaker status.

Here the 66 alarm patterns are considered. There are two data tables: input data table and output data table. The input table consists of 18 variables. These are the alarms which are generated by the different components of the sub-station. Here the 66 alarm patterns are considered. The initial 26 are circuit breakers and rest 40 are different types of relays. [3]

As previously discussed the status of these protective devices are used to locate faults. These patterns are in the form of 0 and 1. Here 0 represents that the relay/ circuit breaker is in-operative and no alarms are generated while a 1 indicated that the relay/ circuit breaker is operative and alarm is generated. The circuit breakers and the relays operate for the defined areas. These input and output tables are used while training the network and then testing can be done. The levenberg- Marquardt algorithm also known as damped least-squared method is used here. In the process of training the weights and biases are adjusted in-order to optimize the performance of the network.

The NN toolbox is used, the input and output files are fed to the network. These files are in the form of matrix which represents the samples. The number to samples of the input and the output file should be same and orientation is set. The samples are divided into three sub-sets namely training samples, testing samples and validation samples. By default these samples are divided in the ratio of 70:30:30. The network requires several iterations to train itself. Mean square is averaged difference between the outputs and the targets. The mean square should be zero which means that there is no error.

$$F = mse = \frac{1}{N} \sum_{i=1}^N e_i^2 \quad (1)$$

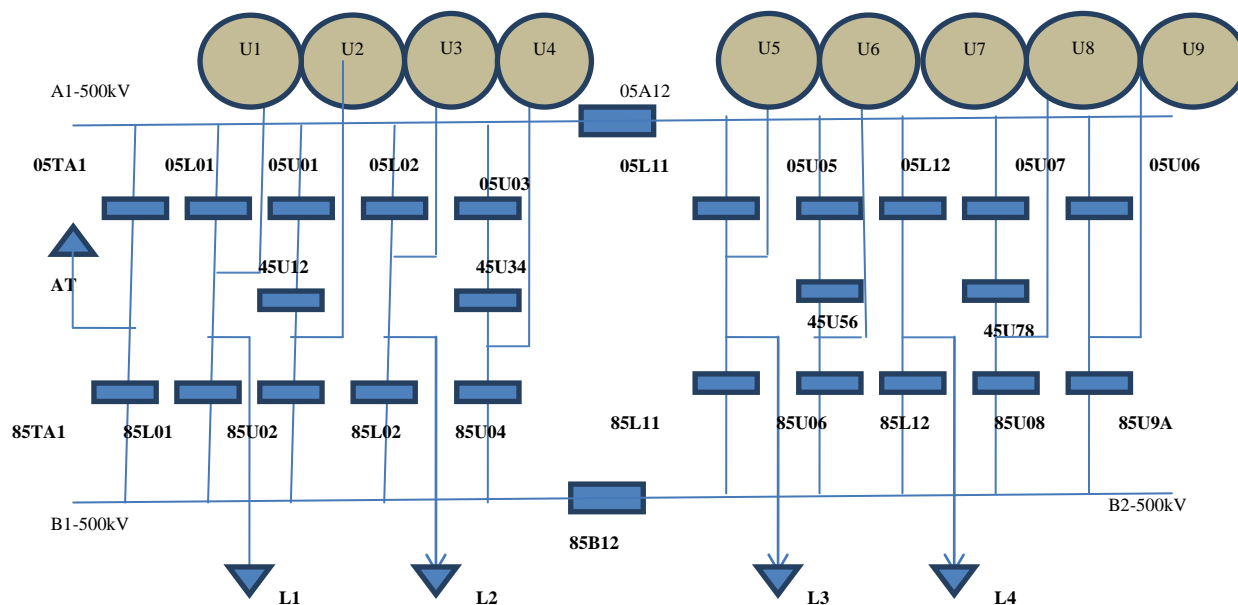


Figure 3. Sub-Station Model Considered

The performance plot denotes the training, testing and validation curves. The regression is used to measure the correlation between the outputs and the targets. Here a 1 denotes a close relationship while 0 denotes a random relationship. We can train the network multiple times or as required. After each training cycle the network weights are adjusted.

We can then test the network and check the performance. The graph shows the performance of test performed. The graph as denoted shows a linear relationship between the targets and the output. This means the problem of the fault location has been done successfully. We can now use this network for unseen alarm patterns as the network has been properly trained. We can train the network multiple times if we are not satisfied with the previous training. In each training cycle the weights and biases of the network are adjusted. Due to different initial conditions and sampling each training cycle generates different results. The training will automatically stop when the generalization stops improving. The trained network can be used to perform the function of fault location in the sub-stations.

VII. Conclusion

In this paper a technique for fault detection in sub-stations is presented. This work is carried out using the ANN as the implementation tool to perform fault analysis. Different alarm patterns have been considered and the network is trained offline using this sample data. The MATLAB software has been used to perform fault detection by training and testing the network. Once trained, the network can be used even for the unseen alarm patterns. The tests show excellent results as there is linear relationship between the output and the targets. Hence we have successfully solved the problem of fault location in sub-station using ANN.

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