Detection and Clearance of Power System Faults Using Soft Computing Techniques

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ABSTRACT

Electrical power systems is growing in size and complexity in all sectors such as generation, transmission, distribution, and load systems. Electrical fault is an abnormal condition, caused by equipment failures such as transformers and environmental conditions. Types of faults like short circuit conditions in power system networks results in severe economic losses and reduces the reliability of the electrical system. These faults cause interruptions to electric flows, equipment damage and even cause death of humans, birds, and animals. The consequences caused by electrical faults strongly depend on the magnitude of the fault current, which in turn depends on the type of fault, the location of the fault, the system earthling, the source impedance, and the impedance of the fault. This project deals with the fault analysis of power system using MATLAB and Simulink. All types of faults in the power system are detected and classified among the 11 types of faults i.e. LG, LL, LLG, LLL and LLLG faults using the Artificial Neural Network (ANN) computation method. ANN with Fuzzy control also generates a signal to the protection relay to disconnect the faultypart from the healthy one making the system error free. Fuzzy with Ann uses the processing of the brain as a basis to develop algorithms that can be used to model complex patterns and prediction problems. The different faults are simulated with different parameters to check the versatility of the method. The proposed method can be extended to the Distribution network of the Power System. The various simulations and analysis of signals is done in the MATLAB® environment.

Key words: Artificial Neural Network, Fuzzy control, fault, tree-phase, Matlab/simulink

I. INTRODUCTION

The electrical power system is made up of several intricate, dynamic, and interacting components that are always vulnerable to electrical faults or disturbances. In order to keep the power system stable, the use of high capacity electrical generating power plants and the grid concept—that is, synchronized electrical power plants and geographically displaced grids—required fault detection and protection equipment operation in the shortest amount of time. On transmission lines used by the electrical power system, defects must first be found, accurately categorized, and removed as quickly as feasible. The additional relays that guard the power system from blackouts can be turned on by the transmission line protection system. Relaying information in an efficient, dependable, quick, and secure manner is made possible by a competent defect detection system. A protective system that is accurate, dependable, and fast is necessary for the complex network that is the modern power system. Power system problems are inevitable, and compared to other key components, overhead transmission line faults are often more common. Recent technological developments have led to the design and development of new and enhanced power system protection devices. The reciprocal interaction between the two circuits makes it challenging to classify faults in double circuit lines using traditional methods (Jain 2013). Zero sequence current is taken into consideration in order to compensate for this reciprocal coupling. (3) fuzzy and neuro-fuzzy approaches (Nguyen and Liao 2010; Mahanty and Gupta 2006) (Koley et al. 2015). While the neural network technique is well-established as a viable methodology for fault classification, it is time-consuming and increases computational complexity due to the laborious training process. In a similar vein, wavelet transform algorithms are difficult to compute. Because they only require a few language principles, fault classification algorithms based on fuzzy logic are relatively easier to use. (Ferrero et al., 1995) determined the kind of fault (LG or LLG), but they were unable to determine which phases were involved and did not take phase fault into account. The enhanced method based on a fuzzy-neural approach was disclosed in (Wang and Keerthipala 1998), which also took into account symmetrical and unsymmetrical faults. However, this approach needed more work to train the ANN. All 10 forms of defect diagnosis using a fuzzy-neural technique were demonstrated in Dash et al. (2000). The pattern recognition algorithm presented by WheiMin Lin et al. (2001) is rather intricate.

The finite impulse response (FIRANN) approach was introduced by Angel L. Orille Fernandez et al. (2002) as a means of defect detection and classification. The author employs voltage and current impulse response, which restricts its applicability. Fuzzy logic approach was suggested in (Das and Reddy 2005; Yadav and Swetapadma 2015b; Saradarzadeh and Sanaye-Pasand 2014) to identify the 10 categories of errors. Wavelet Transform (WT) is a tool that may be utilized in wavelet analysis of faults as a detection and classification approach. This kind of approach might offer a wealth of information and specifics on the fault incidence. The method of classification involves identifying the type of defect by stating its condition. Wavelet can be used to analyze the system's voltage and current in order to confirm the fault type [3]. Transmission lines, which connect generating units and consumers, are an essential component of the distribution system. These systems interact with outside natural forces that mirror the surrounding circumstances, which raise the possibility of a malfunction [4]. Given the high hazards associated with the defect, prompt action is required to resolve it in order to safeguard both people and equipment. By adding a monitoring system, analysis like the Fourier Transform (FT) is utilized to verify the incidence of faults [5]. The artificial neural network and fuzzy system operate independently of one another in cooperative neural fuzzy systems. Through the fuzzy system, the ANN attempts to learn the parameters. While using the fuzzy method, this may be done offline or online. Four types of cooperative fuzzy neural networks are shown in Figure 4. Given training data, the top left fuzzy neural network learns a fuzzy set. Usually, a neural network is fitted to membership functions to do this. After that, the fuzzy sets are identified offline. They are then used, together with fuzzy rules that are also supplied and not learnt, to build the fuzzy system. This research proposes real-time defect detection and categorization using fuzzy logic. Fault categorization considers samples of zero sequence and positive sequence currents as well as post-fault three phase currents. The suggested logic may identify and categorise errors with more precision at a maximum delay of 100 milliseconds or less. Its speed and detection time can also be further enhanced. Real-time data collection guarantees control within the allotted time.

II. PROPOSED SYSTEM

A. Modeling the three phase transmission line

The created approach based on ANNs has been simulated, developed, and implemented on a standard 400 103 V three phase transmission line system with generators at both ends. To mimic and evaluate various problems at different places on the transmission line, the system comprises of two 400 103 V generators that are placed at opposite ends of the transmission line. Distributed type parameters have been used to model the linein order to produce more accurate results when the suggested system is used on a very long transmission line. The Sim Power Systems toolbox in the Simulink in MATLAB® environment is being used to simulate this power system model (Demuth et al. 2014). Figure 1 depicts a sample of the model that is being used toanalyse and acquire the training and testing block daigram data sets. The source impedances of the generators on either side are ZP and ZQ. The corresponding three phase voltages and current samples at terminal A are measured using the three phase V–I measurement block from the Sim Power System tool box. The transmission line spans 200 km, and the model is designed to mimic different kinds of faults at different points throughout its length, with varying fault resistance values. Research activity is conducted at a frequency of 50 Hz.

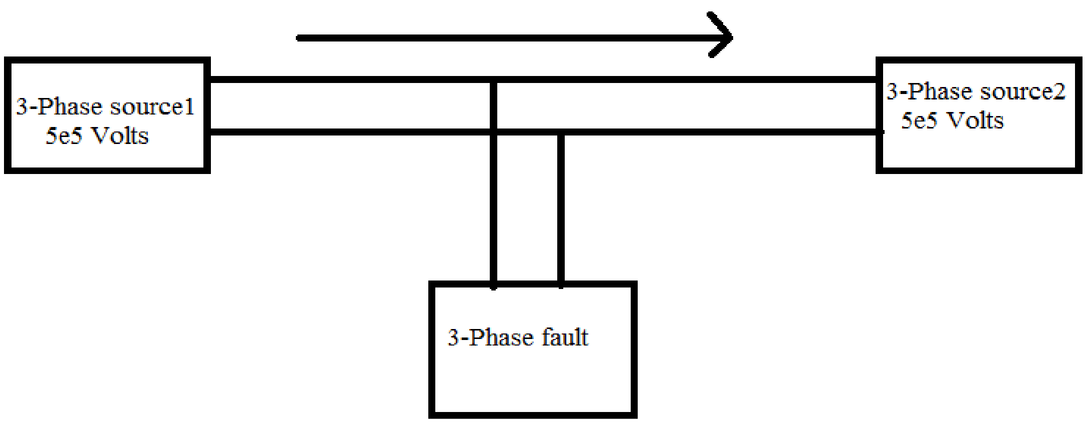


Fig. 1 proposed diagram

B. Measurement voltage and current and pre-processing of data

A frequency of 1,000 Hertz was used to create and sample the three-phase voltage and current waveforms. Each cycle therefore has 20 samples. By optimising the feature extraction, the neural network's total size may be reduced, which enhances the neural network's time performance. This allows for the efficient use of all pertinent and significant data found in the voltage and current signal waveforms. The voltage waveform of a Phase B—ground failure on a 200 km transmission line, 60 km from terminal A, is seen in Figure 6. Plotting the samples acquiredat a frequency of 1,000 Hz is called a waveform. The ratios of the voltages and currents in each phase prior to and following the fault incidence serve as the neural network's inputs. This scaling has the benefit of cutting down on training calculation time.

C. Fault Classification

The sole course of action available when a defect arises is to fix the error that led to the issue in the gearbox line; however, in order to achieve this, the control system must function in several capacities, including fault detection, fault classification, fault localization, and fault clearing. Locating the defect and combining fault detection and fault classification is a crucial step in this control. As was covered in the earlier sections, a defect can arise from a short circuit between one transmission line phase and the other, a phenomenon known as a line-to-line fault. Multiple line faults occur when more than one phase is involved. When anyline, or all of a line, comes into contact with two pieces of earth,as can happen when tall trees come into contact with transmission lines, the same idea can be applied to that line or lines to ground fault. Given the aforementioned information and assuming that the phases are identified as A, B, and C and the earth is recognized as G (a three-phase system), the fault may be categorized as follows:

1. AG: phase “A” is being in short circuit with ground phase;
2. BG: phase B is being in short circuit with ground phase;
3. CG: phase C is being in short circuit with ground phase;

Travelling waves, or voltage and current waves, can be used to monitor transmission lines. The amount of current consumed by a load varies depending on a number of factors, including the environment and the time of consumption. For example, winter and summer load variations occur when winter loads are significantly lower than summer loads in many regional locations.When a failure occurs, the load draws a very huge amount of current, which can exceed mega Amperes. Fault diagnoses will begreatly impacted by the current signal if it is observed in two time windows, i.e., pre fault current and post fault current collecting current signals in all potential failure scenarios and supplying them as digital samples The stage of fault classification is being formed by the classifier over time. Artificial Neural Networks are formed within the classifier. This step involves training the ANN to identify various fault types and provide a control signal or message for the controller stage later on. The job of the controller is to transform the data from the ANN stage into a format that analogue systems, such as circuit breakers, can comprehend. A multiplexer is used in the digital/binary signalling process between the artificial neural network (ANN) stage and the circuit breaker to separate the ANN output array. This process is known as serial to parallel conversion. A logical operator then unties the multiple digit signals into a single message. Ultimately, a digital data converter is developed, which translates binary data into double-digit format that is comprehensible for machinery such as circuit breakers. The control phases as previously mentioned are shown in Figure 3.

TABLE - I

The Targeted Data of Fuzzy Ann's Classifier

Phase 'A'	Phase 'B'	Phase 'C'	Ground
1	0	0	0
0	1	0	0
0	0	1	0
1	0	0	1
0	1	0	1
0	0	1	1
1	1	0	0
1	0	1	0
0	1	1	0
1	1	0	1
1	0	1	1
0	1	1	1
1	1	1	0

III. CASE STUDY

A 200-kilometer transmission line, employed in a three-phase system, is used to provide 230 KV to an inductive load from the generator. In a three-phase system, voltage is given to allow current to flow through each line. Under typical circumstances, the current is drawn based on the simulation's load capacity as well as the losses incurred in the transmission lines. On the other side, the load is drawing current with a big quantity at the fault. A fault is an undesirable occurrence for the system that needs to be fixed right away. The error has to be fixed as soon as possible. If the issue is not quickly fixed, more and more equipment may fall. The short circuiting of one or more phases with ground or with each other frequently results in the detrimental repercussions of a fault. Here is a list of other impacts that can be seen as a result of power system fault rising.

1. The mechanical force generated by the fault as it warms the wires may cause the power generator and/or transformer to collapse;
2. Because of the unsymmetrical fault's negative current effects, the conductor's temperature may rise;
3. Another undesirable consequence of a problem that lowers the voltage profile in the network's portion that is peculiar toit is voltage condensing;
4. Economic problems brought on by significant damage to transmission lines and power equipment, which is extremely expensive from the perspective of the electric service provider;
5. Customer inconvenience as a result of the service being shut down due to a defect that might linger for a long period if it is not resolved quickly.

Relays and circuit breakers are the primary devices used for fault clearance in control equipment that is located on the power system. New methods of fault clearing are intended to swiftly remove the malfunctioning component. Switches and circuit breakers are controlled by digital systems, and smart control is crucial to the power system's quick recovery. A classifier based on artificial neural networks is intended to categorise the defect asshown in Figure 3. The training function and approximation functions are all covered before. Once the classifier input (local database) and classifier target are set up, as mentioned in this part,the system is prepared for training.

In order to shut off the generator and load connection until the problem is fixed, the classifier will create a message containing the fault information and forward it to the controller and relay circuit. When the system is tested with various fault types, if the same mistake is made in the Simulink model, the system will remain shut down until the fault is fixed and will not respond to any other process after the fault is correctly detected by the ANN classifier and controlling signal transmission to the controlling relay.

IV. CONTROL STRATEGY

By connecting the workspace to Simulink, one may enable seamless control message interchange between the two using the 'from workspace' block included in Matlab's Simulink library. The row of binary digits is converted from serial to parallel once the control message enters Simulink.

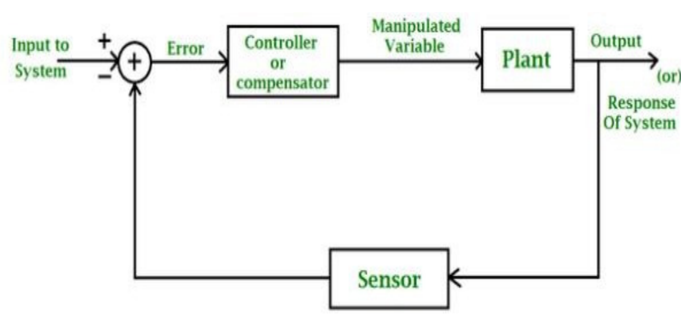


Fig. 2 Fault controlling scheme and decision maker algorithm.

into parallel format, The truth table, or the said logic OR, is supplied in Table 2. An OR gate is required to remove one digit from multiple input in such a manner that, if a fault occurs at any phase, the OR gate will create "one"; if no phase is experiencing a fault, the OR gate will produce "zero". The circuit breaker is then triggered by transferring the final result, or the logic gate, into double format. According to this project, the circuit breaker may automatically return after clearing the fault by delivering another/fresh control message from the classifier workspace into the Simulink. The circuit breaker, which is the last one, is linked on the three phases to trip all the phases in case of fault.

TABLE II
OR GATE TRUTH TABLE

Input X	Input Y	Output Z
0	0	0
0	1	1
1	0	1
1	1	1

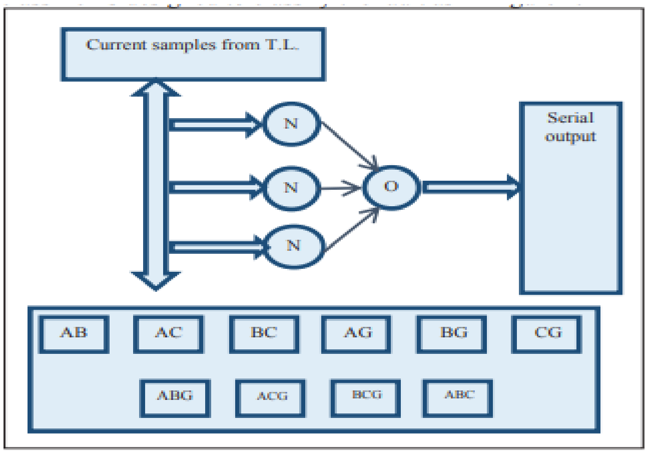


Fig. 3 ANN algorithm

The circuit breaker is then triggered by transferring the final result, or the logic gate, into double format. This project suggests that the circuit breaker might automatically reset itself once the problem is cleared by sending a new control message into Simulink from the classifier workspace. The final circuit breakeris connected to all three phases so that, in the event of a breakdown, all phases will trip. A hybrid system is an intelligent system that integrates at least two intelligent technologies, such asneural networks, fuzzy logic, genetic algorithms, and reinforcement learning, and so on. Because several methodologiesare integrated into a single computational model, these systems have a wider variety of capabilities. These systems are able to learn and reason in an unpredictable

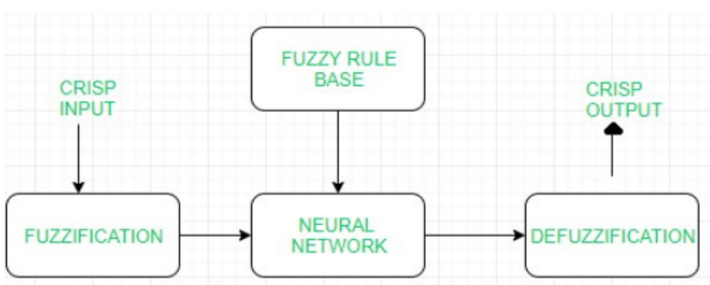


Fig. 4 Fuzzy with ANN controller

and imprecise environment. These systems are capable ofproviding human-like skills such as topic knowledge and noise adaptability. Neural network theory was utilised in the training process of the fuzzy system that forms the basis of the Neuro- fuzzy system. The underlying fuzzy system is only locally and exclusively altered by the learning process in response to the local input. A feed forward neural network with three layers is an example of a neuro-fuzzy system. The first layer represents input variables, the middle (hidden) layer represents fuzzy rules, and the third layer represents output variables. Fuzzy sets are represented as connection weights in the network's layers, which help in processing and model training.

V. RESULTS AND DISCUSSION

The fault classifier's performance analysis is shown in this section. It is evident by closely examining the waveforms that various faults have varying effects on the functionality of the system. From this, it can be inferred that in order to categorise the faults in a large transmission system and enable the substation to conduct an appropriate preventative action, an algorithm based on supervised learning is needed. The protection strategies for this transmission network may also be designed with the help of these simulation findings. A summary is provided of the highest value of the detailed coefficients that were derived by using wavelet analysis for several faults (only one L-G, one L-L, one L-L-G, and Three Phase Fault are displayed) at various locations (transmission lines) from the test system. Table 1 displays several fault occurrences together with the binary representation that corresponds to them. The five cycle transition period is used to mimic these three problems. A fault resistance of 0.001 ohms has been considered. Various faults are simulated and the results are displayed in terms of voltage in order to assess the effects of various failures on the system voltages.

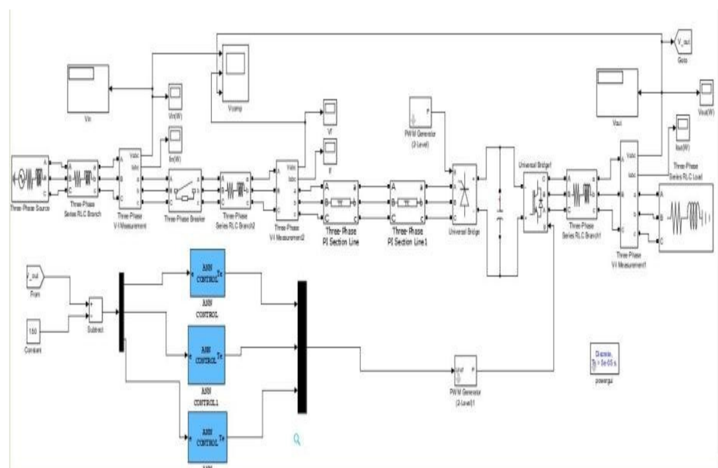
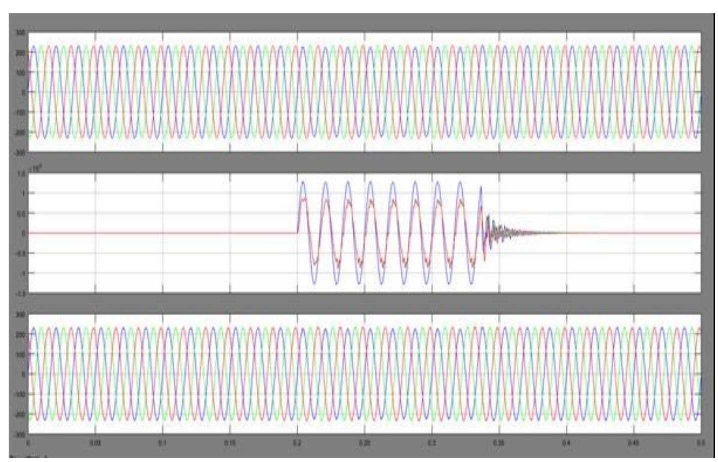
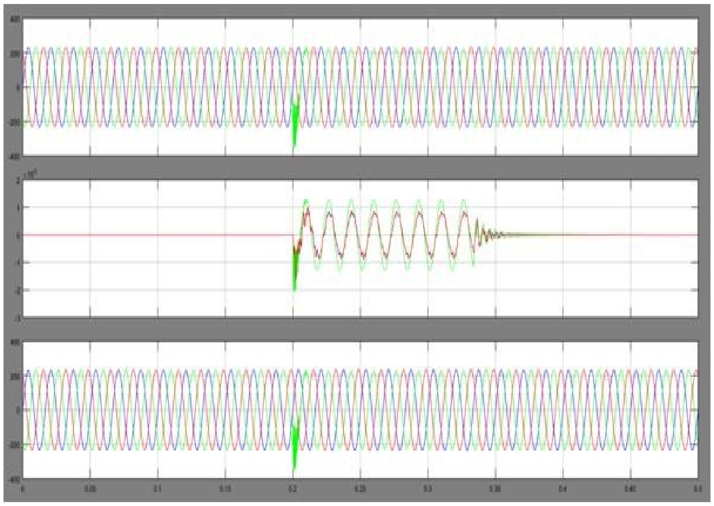


Fig. 5 Simulation model with ANN

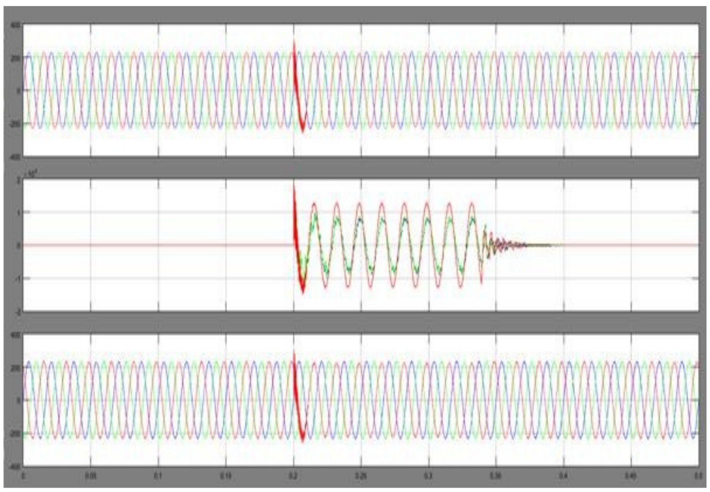
ANN- RESULTS (Single phase)



(a) AG [Vin- -0.009, Vout=0.902]



(b)BG [Vin- -0.009, Vout=0.902]



(c) CG [Vin- -0.0001, Vout=0.902]

Fig. 6 Results with ANN controller

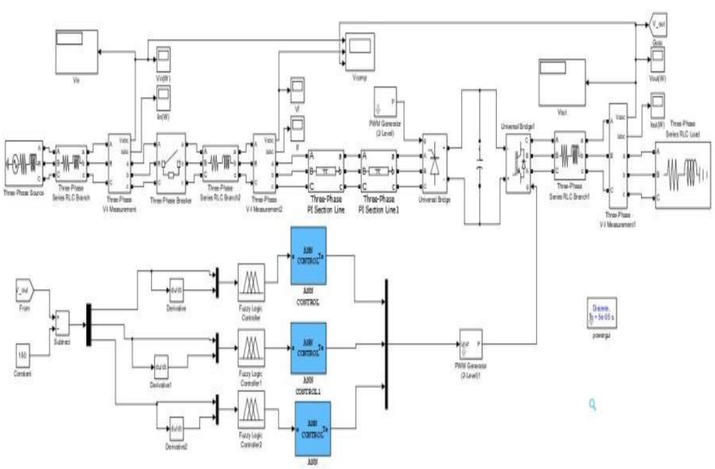
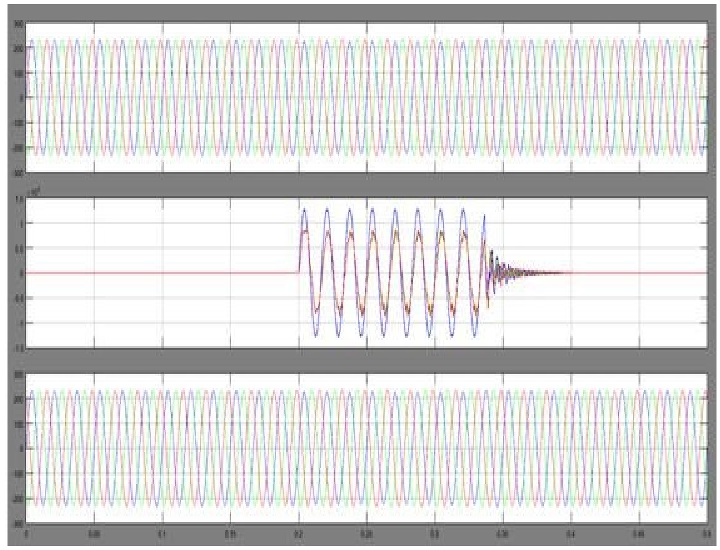
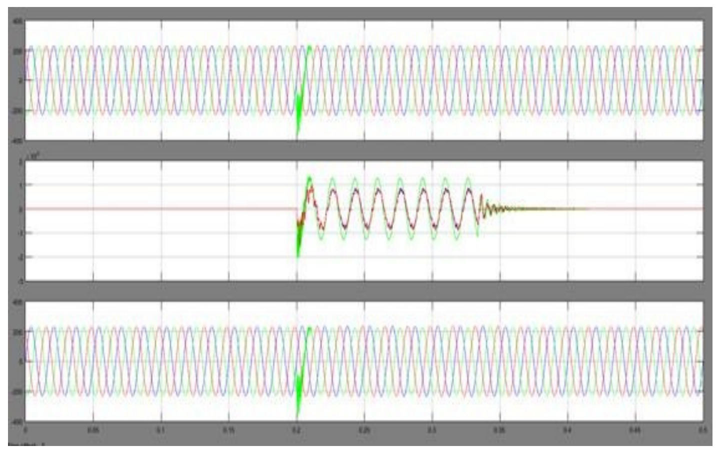


Fig. 7 Simulation model with fuzzy-ANN

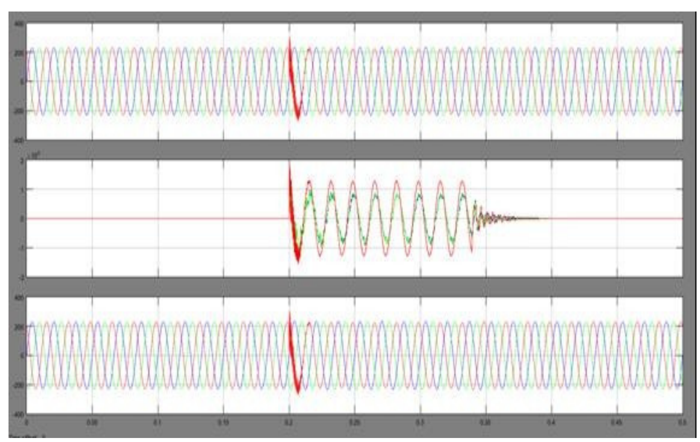
ANN + FUZZY –RESULTS



(a) AG [Vin=-0.0095=Vout]



(b) BG [Vin=-0.0095=Vout]



(c) CG [Vin=-0.0001=Vout]

Fig. 8 Results with Fuzzy-ANN controller

ABC fault-THD (ANN)

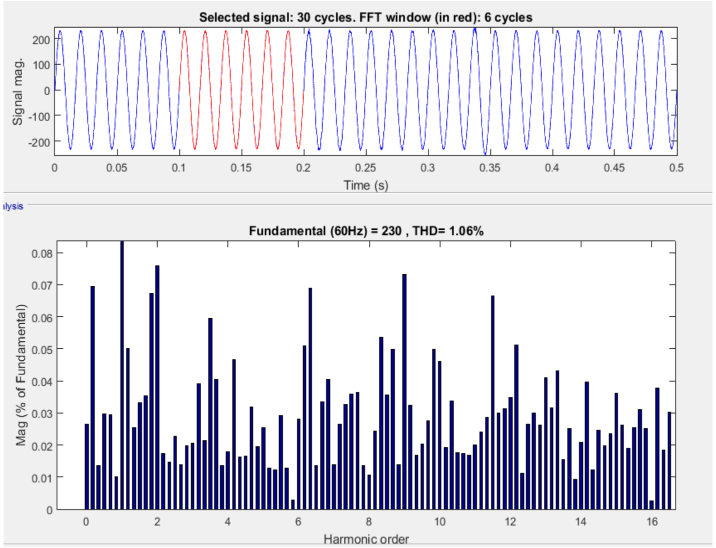


Fig. 9 THD value with ANN

ABC fault-THD (ANN+FUZZY)

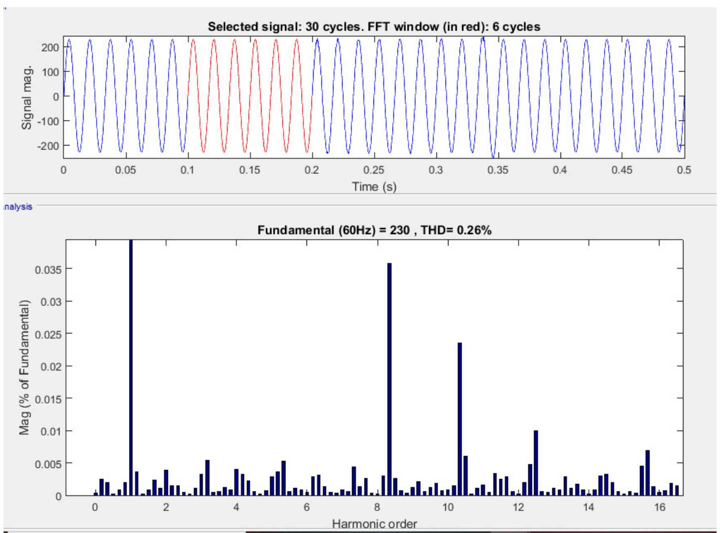


Fig. 10 THD value with Fuzzy-ANN

The suggested technique, fuzzy artificial neural network-based defect detection (Fuzzy-ANN). Fuzzy-neural network approach has been used to explore transmission line failure detection. Single phase to ground faults, double phase faults, and double phase to ground faults are all addressed by the data that is produced. The transmission line fault detection results were superior to those of ANN.

VI. CONCLUSION

The techniques used use the phase voltages and phase currents as inputs to the neural networks, scaled according to their pre-fault values. This work has considered a variety of potential fault types, including single line-ground, line-line, double line-ground, and three phase faults. Unique Fuzzy-ANNs have been proposed for each of these fault types. This thesis examines many fuzzy neural networks, all of which are part of the back-propagation neural network design. The resulting simulation results demonstrate that all of the suggested fuzzy neural networks have, on average, performed satisfactorily. As further evidenced, the size of the Fuzzy ANN (the number of hidden layers and number of neurons per hidden layer) varies with the neural network's application and the size of the training data collection. This research has shown how crucial it is to select the ideal Fuzzy-ANN configuration in order to maximise network performance.

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