DETECTION AND CLASSIFICATION OF HIGH IMPEDANCE FAULT (HIF) IN THE 330kV HIGH VOLTAGE POWER SYSTEM NETWORK IN NIGERIAN WITH ANFIS ADAPTIVE NEURO-FUZZY INFERENCE SYSTEM (ANFIS)

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Abstract

The complexity of the power system network can be said to have resulted in the occurrence of faults of a complex nature. Misinterpretation and misrepresentation of faults have become common as power system blackouts are caused because of this issue. The paper presented the utilization of an adaptive neuro-fuzzy inference system for detecting and classifying high impedance fault (HIF) of the Nigerian 330kV transmission line connecting the Awka-New-heaven transmission system. The modeled network was simulated and the current signals at each fault class were simulated and sent to the Matlab environment for data analytics performance. The current signals and classification code were used as input and output variables to the adaptive neuro-fuzzy inference system (ANFIS) models respectively and the performance of the adaptive neuro-fuzzy inference system (ANFIS) model was determined. From the results presented, the maximum fault class at AB-g error value of 0.023 was very tolerable. Hence, the adaptive neuro-fuzzy inference system (ANFIS) model was sufficient for detecting and classifying high impedance faults (HIF) on high-voltage transmission lines.

Keywords: ANFIS (Adaptive Neuro-Fuzzy Inference System), HIF (High Impedance Fault)

INTRODUCTION

The power system electrical network has been described as a highly complex system. The network comprises generation stations, transmission lines, loads, transformers, distribution lines, breakers, and other numerous components very numerous to mention. The use of these electrical components gives in the transmission of the electrical energy from the power generation source to the respective load destinations [1.2]. It commences from the generation station where power is generated between 15kV to 90kV, then sent to the transformer to be stepped up to a high voltage as high as 750kV (the purpose for the rise in voltage was to allow a high rate of power system transmission to long distance as much as 500kM) [3]. The transmission of high voltage electricity was a system called transmission power system transmission. At the end of the transmission system lies a transmission station or substation where the power system transmission would be stepped down to lower voltage transmission ratings such as 130kV, 45kV, 33kV and as low as 11kV which were all identified and transmission voltages [2]. The outcome of the transmission voltage was reduced to distribution voltages to be sent via a power system grid to load stations then onward distribution to load stations. The power system network has been plagued with a lot of issues ranging from line faults, generator faults, transformer faults, and unbalanced faults on the generation systems [5]. The occurrence of these issues can be also described as complex as each issue requires a particular system of solutions to mitigate the occurrence and cascading of the fault. Hence, it became imperative that one must determine the type of fault that occurred and then classify the fault. These steps lead to appropriate measures to ensure proper power system network device maintenance to discontinue the fault occurrence. However, on several occasions, the reverse has been the case as fault diagnostics has always reported the wrong fault occurrence leading to power system shutdown. Hence, it has become imperative to study the impact of the utilization of artificial intelligence models in the detection and classification of faults especially in a high-voltage network [6,7].

In this paper, the occurrence of high impedance fault (HIF) was detected and classified with ANFIS model controller on the 330kV transmission line connecting Awka (the capital city of Anambra state) and new-heaven in Enugu state with both locations in the eastern region of Nigeria. The model of the line was done in SIMULINK with the fault implementation, detection, and classification carried out in the SIMULINK application. Computations and generation of graphs were done with the utilization of Mat Lab's main environment.

Literature Review

The implementation and utilization of electricity have in many ways improved the degree of livelihood among the power network users. The description carried out by [8] on the importance of electricity reiterated an increase in the industrial operational activity which increases the economic stability of any nation, improvement of livelihood of consumers (majorly citizens of the nation that utilizes electricity), and improvement in commercial activity. The author in [4] described the various types of faults that have marred the functionality of the power system network. some of these faults involved those that impact negatively on the power generation system, transmission system, and distribution systems. [3] pointed out that the transmission power system network was the most important in every aspect of the power system network and it allows the power flow of electricity to locations that do not have resources for a power generation system. hence, a fault occurrence on the transmission power system would automatically result in a power system shut down which would cripple the activities of any functional economy. [1] further described faults in the transmission system to be highly complex, especially in detection, classification, and location.

Several authors have deployed several mechanisms in the detection and identification of faults (especially HIF) in the power system network. The detection of low-impedance faults can be described as quite simple when compared to HIF [9]. The occurrence of low impedance fault can be identified with the utilization of relays (especially in the Nigerian transmission and distribution level for all the voltage ratings of distribution and transmission) however, no system has been implemented for the detection of HIF [11]. [10] carried out characteristics of HIF on the power system network and found that it occurs when the transmission or distribution lines come in contact with semiconductor materials namely; trees, birds peach on the lines, and when the line cuts and falls to the floor. These occurrence results in sudden rises in voltage arcs and falls in current signals which could cause fire-related damage in infrastructures. [12] utilized wavelet transform in the detection and classification of the HIF based on the type of signal noise generated by the current signal, voltage signal and frequency signals but the graphical representation showed had the same signal progression resulting in difficulty in identifying the class of fault that occurred on the transmission system. [13] utilized machine learning system for the classification of HIF on the power system network but the outcome obtained failed to properly analyze the classes of fault and the author pointed out that it was difficult to implement data related systems on fault identification on the power system network. [14]-[16] utilized artificial neural network for the identification and classification of HIF by utilizing the voltage signals as the input and the classification code as the target (output) variables with the outcome showing the signal characteristics of the network at each fault class but absence of ways of measuring the performance of the ANN model utilized. The paper utilized ANFIS for the HIF detection and classification and the case study was a real time 330kV power system transmission line connecting Awka and New heaven in Nigeria.

Methods: The research procedure was summarized in the flow diagram in figure 1. The data collected was majorly the distance of the transmission line and the power transmitted from the source to the destination station. The power system network was modeled in the power system library in SIMULINK with the HIF fault inputted and implemented in the power system model. The three phase current signal at each fault class was obtained and utilized as the input data while a classification code was utilized as the target variable. The data utilized was obtained from the National control center (NCC) in Osogbo. The ANFIS model was configured and implemented in the power system model for the HIF classification and the outcome was compared to the actual HIF classification.

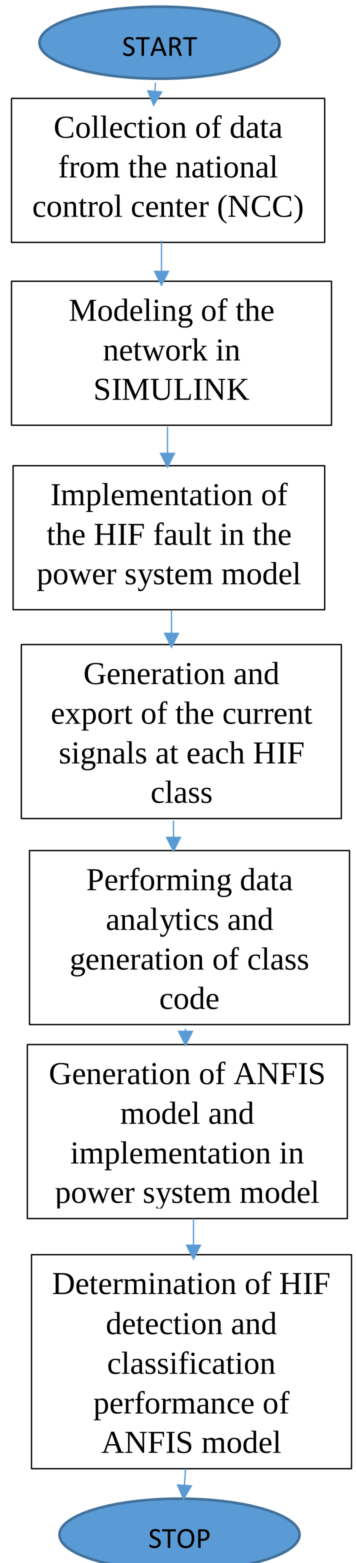

Figure 1: Flow Diagram of the Research Procedure

The line diagram of the power system network was shown in figure 2.

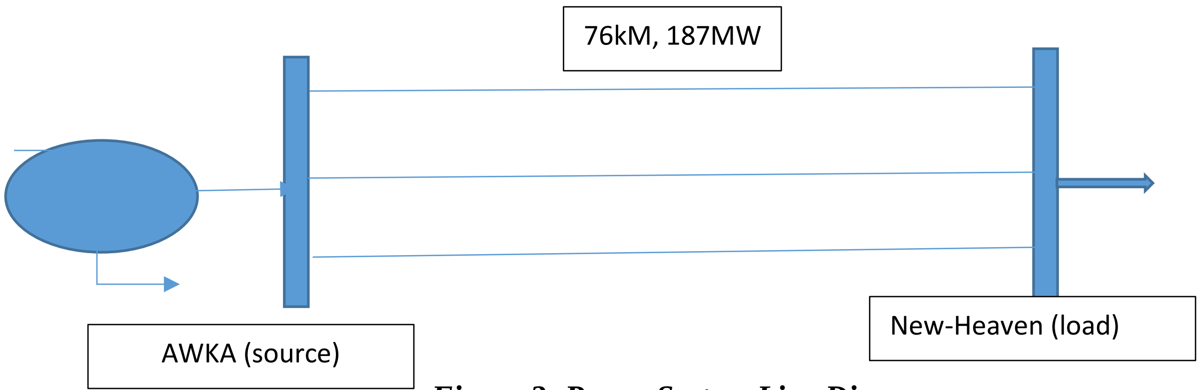

Figure 2: Power System Line Diagram

The SIMULINK model of the power system network was shown in figure 3.

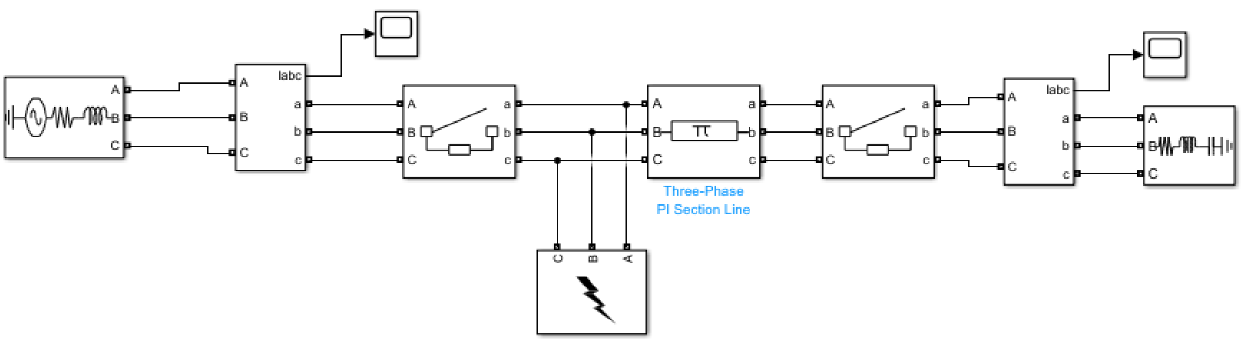

Figure 3: SIMULINK Model of the Power System Network With HIF

Each of the class of HIF were activated and the current signal from the normal condition to the balanced three-phase HIF was exported to the MatLab environment. The current signal data at each fault class are presented in table 1;

Table 1: HIF Class and Classification Code

Fault class	Faulted current signal			Classification code
	Phase A	Phase B	Phase C	
Normal	100.3	160.37	121.2	0
A-g	2.11	129.04	141.31	1
B-g	120.32	1.09	99.17	2
c-g	143.11	103.21	1.33	3
AB-g	1.77	2.07	104.73	4
AC-g	2.03	107.33	1.03	5
BC-g	102.17	3.44	2.11	6
ABC-g	3.11	4.31	3.09	7

From the data of the power system simulation presented in table 1; the current signals at normal and faulted conditions were the input to the ANFIS model while the classification code was the target to the ANFIS. The comparative analysis of the code was presented in the result section.

In the ANFIS model, it had three input variable (each of the current signal) and one output variable (representing the classification code). Each of the input neurons had three triangular membership function and the output had eight liner membership functions (with each membership function representing each HIF class.

Result

The result of the actual classification code utilized as the target to the ANFIS model was shown in figure 4.

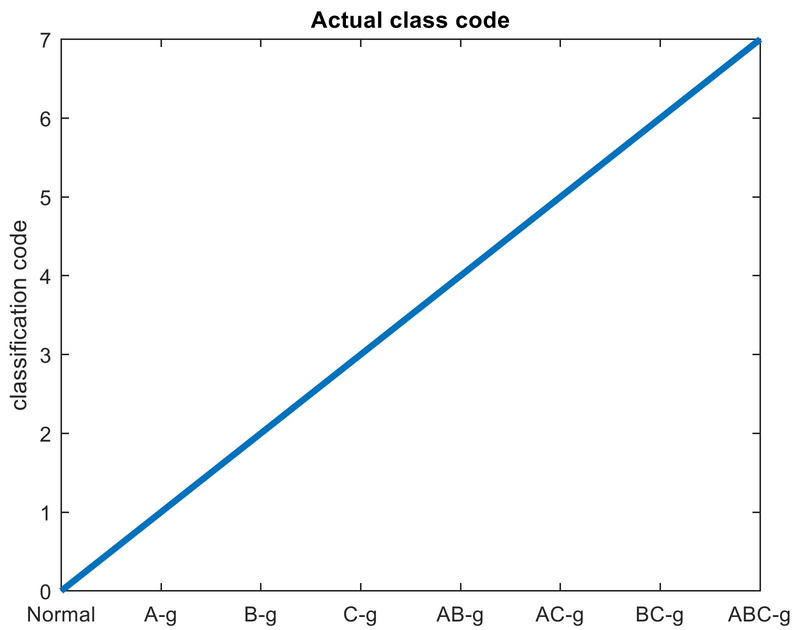

Figure 4: Actual HIF Classification Code

The result of the HIF-predicted classification code with the ANFIS model is shown in figure 5.

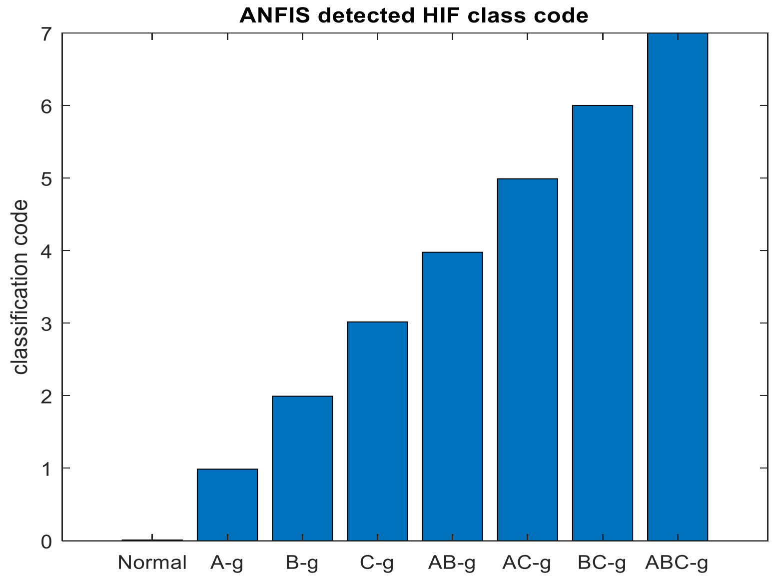

Figure 5: ANFIS Predicted Classification Code

The performance of the ANFIS model in the detection and classification of HIF on the power system transmission network using the comparative analysis of the actual and predicted classification code is shown in Figure 6.

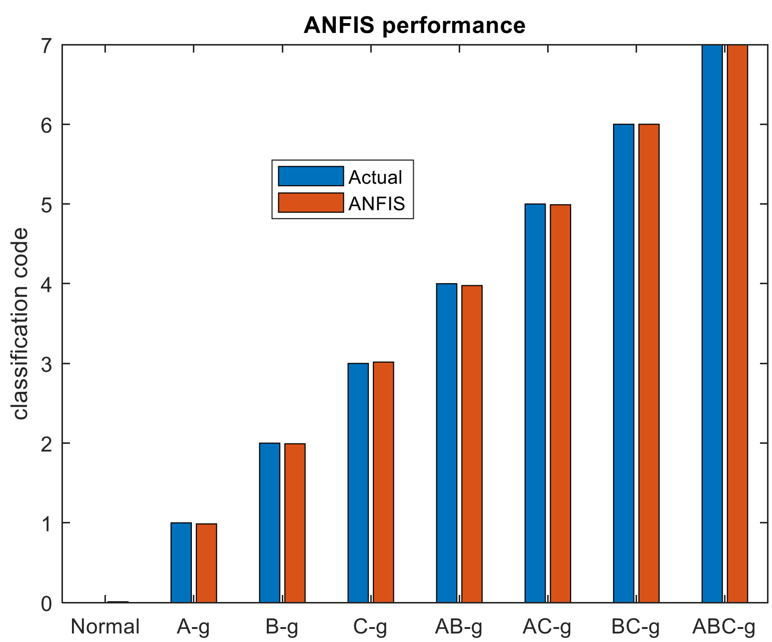

Figure 6: ANFIS HIF Performance

The results are presented in Figure 6. It was observed that the ANFIS model tracked the actual code with minimum error. Hence, it implies that the ANFIS system was able to detect and classify the HIF. The errors generated are shown in the bar chart in Figure 7.

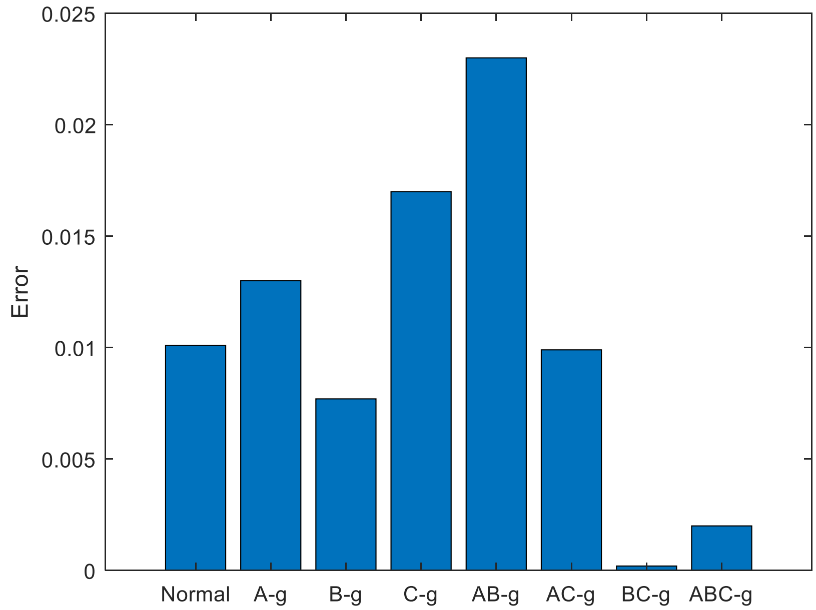

Figure 7: Error of the ANFIS Performance

The error deviation of the ANFIS model from the actual code is shown in Figure 7. It was seen that the maximum performance error was 0.023 at AB-g which was minute. Hence, figure 7 shows that the ANFIS model was effective in the detection and classification of HIF on the transmission line network.

CONCLUSION

The ANFIS model system was utilized for the detection and classification of HIF on the 330kV transmission network on the transmission line connecting Awka and New Heaven in the eastern region Nigerian power system network. The data for the power system was obtained and modeled in SIMULINK with HIF implemented in the power system model. The current signal for each class of fault was exported to MatLab and was used as input to the ANFIS model with the classification code used as the target to the ANFIS model.

From the results presented, it was seen that the ANFIS model was able to detect and classify the HIF on the transmission line with minimal errors.

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