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Comparative Analysis of High Impedance Fault Detection and Point Location of the Nigerian 330 Kv Transmission System Using Artificial Intelligent Models

Imo Edwin Nkan[1], Archibong Archibong Etim[2]

[1]Department of Electrical and Electronic Engineering, Akwa Ibom State University, Ikot Akpaden, Nigeria
[2] Department of Electrical and Electronic Engineering, University of Cross River State, Calabar, Nigeria

ABSTRACT: The occurrence of high impedance fault (HIF) in the power system network causes low current signal and sudden voltage surge which is disastrous to power system network. Currently, there has been no available means of detecting and locating HIF which involves low current and voltage arcing but there has been ways for detecting, identifying and locating the occurrences of high current. The occurrence of HIF is based on the contact of transmission and distribution lines with semi conductors which has caused several damages ranging from fire outbreaks to the distruction of power equipment causing increased blackout timeline. In this study, the occurrence of HIF on the Nigerian 330 kV transmission line is studied with the data utilized obtained from the Nigerian control center Osogbo. The data obtained is modeled in simulink and the outcome which is the current signal at normal condition and faulted condition are obtained. The transmission line distance is split into 4 points with the current signal at each point generated in simulink and exported to the matlab file. The data in MATLAB file is split to train, test and validate at 70%, 15% and 15% respectively. The data analysis performed is sent to the ANN (Artificial Neural Network) and ANFIS (Adaptive Neuro Fuzzy Inference System) with the current signal at normal condition. A 3-phase HIF is used as input data while the split distance is implemented as the target data to the models. The effectiveness of the the models in detecting and locating HIF obtained are analyzed. From the results of the comparative analysis presented, it is seen that the error deviation of the predicted HIF location with ANN for line 1 is 62 % whereas ANFIS is 2 %. Also, for line 2, ANN has a maximum error deviation of 50 % compared to 10 % of ANFIS. Lastly, ANN has an error deviation of 90 % while ANFIS has 3 % for line 3. This shows that ANFIS is a better model for detection and point location of HIF in the Nigerian 330 kV transmission network.

KEYWORDS: ANFIS, ANN, detection and point location, HIF, Transmission network

I. INTRODUCTION

One of the key concerns with electricity transmission and distribution networks is safety [1,2,3]. The electrical network's lack of security could cause harm to people and property. The best way to stop negative events from happening is through prevention. One of the problems that causes fatalities and financial harm in the Nigerian power system network is the occurrence of high impedance faults (HIF). When a conductor makes contact with the ground or another high impedance object, the HIF happens. During the occurrence of HIF, the current value is low and typically ranges from 0 A to 30 A (for transmission systems [4,5,6] since the impedance of the current path is high [7]. As a result, this type of fault cannot be detected by the typical over current relay; it is instead viewed as a regular load current rise. There are two variations of the HIF. A conductor breaks and hits the ground in the first form. The second version calls for only connecting an electrical conductor to a high impedance object (such as tree branches and leaves), not disconnecting the conductor altogether. The HIFs frequently involve an electric arc, which could ignite a fire [8,9]. The HIF current contains both low and high frequency harmonic components since the fault is nonlinear and has these harmonic components. Other network elements should be acknowledged as having broad frequency harmonics as well. The HIF should be carefully investigated as a result [10,11]. Artificial neural networks (ANN) and adaptive neuro fuzzy inference systems (ANFIS), are utilized in this paper for the detection and the point location of the incidence of HIF on the south-south 330kV transmission network in Nigerian power system network. Prior to the modeling, the transmission line distance are split into four equal points to ease the identification of the point location. The outcome of the performance of the artificial intelligent models are compared and analyzed.

II. REVIEW OF RELATED LITERATURE

The authors in [12], carried out HIF detection and classification of a transmission line network with alienation coefficients juxtaposed with voltage signals half cycle with moving window techniques. The outcome of the alienation coefficients were compared to the corresponding threshold values to aid in detection and classification of HIF. The research gap to this study was the absent of HIF location and the low accuracy of HIF detection of 45%. Also, in [13], the authors carried out HIF detection and location on power generation feeders by calculating the symmetrical components of current signal harmonics after detecting and classifying HIF with ANN. The current signal symmetrical calculation tends to solve the HIF location at various feeders but were majorly applied to two MatLab simulated feeders. The HIF location accuracy showed 49% outcome. The proposed HIF location outcome was low and can be said to be unreliable. HIF detection and location using distributed voltage monitoring devices that enables access to a fast sampled and expansive voltage measurement on distribution network was investigated in [14]. The measured voltages were modeled and simulated with comparison carried out at various feeder locations with the location selected with golden section search method. The accuracy based on the results presented by the author was 65%. The low accuracy of HIF location causes the proposed model not to be reliable. In [15], the authors carried out HIF detection and location using smart meters (SM) on distribution line networks that has distributed generators (DGs), power electronic loads (PEL) and Electric furnaces (EAFs). the SMs were installed in all the load points of the distribution system and are believed to be in closed proximity to the HIF fault. SMs was used in computing the index of captured second harmonics content in the load voltage measurement believed to be the occurrence of HIF. The procedure was used as a commercial smart energy meter to prove its feasibility. The outcome showed 76% HIF location accuracy in the absence of other forms of harmonics. The method proposed by the author only applies when the system does not have other harmonic distortion which is practically not possible making the proposed SM system not reliable. The authors in [16,17] studied the utilization of broadband impedance spectroscopy for the detection of high voltage (or voltage arcing which is the effect of HIF) in a high voltage single core cables. Distributed parameter model was utilized to study the effect of the wave impedance and the distributed parameters of the transmission lines on the broadband impedance spectroscopy of the lines measured with linear resonance technique to obtain the broadband impedance. The authors detected a 220 kV fault on a 145 kV line which implied that the broad impedance spectroscopy was effective in the detection of the cable insulation effects and occurrence of voltage arcing. However, the proposed method was unable to locate the occurrence of the voltage arcing. Similarly, the authors in [18,19] employed the least square estimation technique with HIF resistance and location estimated with the same model for the detection of high impedance fault in a 5-bus distribution network modeled in MatLab/Simulink. The outcome showed that it indeed required communication link to detect HIF having a location accuracy of 39%. In as much as the proposed model does require communication link to detect HIF, the model had HIF location prediction accuracy of 39% which makes the model unreliable for the location of HIF. HIF detection and location using a comparative analysis of zero sequence current and complex sequence current signals was investigated in [20,21]. Both current signals were measured with waveforms, RMS and spectrum electrical quantities applied on the obtained and determined current signals. The HIF detection and location simulation with these models was done in MatLab. The outcome showed that the use of complex current sequence was more effective in the detection and location of high impedance with the best model (waveform) having an accuracy of 61%. However, the models used for the HIF detection and location had a low prediction accuracy and absence of artificial intelligent model. In the examination of the effect of HIF location and detection on an injected high frequency signals on transmission lines [22,23], the signals at high frequency were transmitted with power line communication (PLC) structure. ATP draw was used for the simulation of the network with the aim of determining the HIF performance in detection and location method under various conditions. The outcome showed that the suggested procedure was effective in HIF detection and location process and hence should be applied on transmission lines but the proposed procedure lacks the ability to detect and locate HIF in a high voltage transmission network (from 150 kV upwards). In [24,25], the authors carried out HIF detection and location using smart meters on distribution networks on smart grids. The system was modeled in Simulink using voltage unbalanced based approach model. The prediction outcome of 43% after simulation was achieved but the low HIF detection and location predictability makes the proposed model to be unreliable. Relaying scheme of third and fifth harmonic excursion patterns and phase portraits on the detection of High impedance fault on low frequency was embarked upon by the authors in [26,27]. The outcome indicated that the proposed scheme was effective in identifying HIF at lower frequency and lower noise harmonics. Also when the harmonics is high (as in the case of the transmission voltages of Nigerian power system), the proposed scheme would not be able to detect HIF occurrence. In [28,29], the authors embarked on detection and classification of HIF in a transmission line compensated by UPFC with the aid of synchronized power measurement inserted at both ends of the transmission line which activates the magnitude of the apparent power difference at the end buses of the network for the detection and classification of HIF. The proposed scheme had a 69% accuracy in the detection and classification of faults.

III. MATERIALS AND METHOD

Modeling of the network in SIMULINK comprising of two generating stations and two transmission stations is shown in Figure 1.

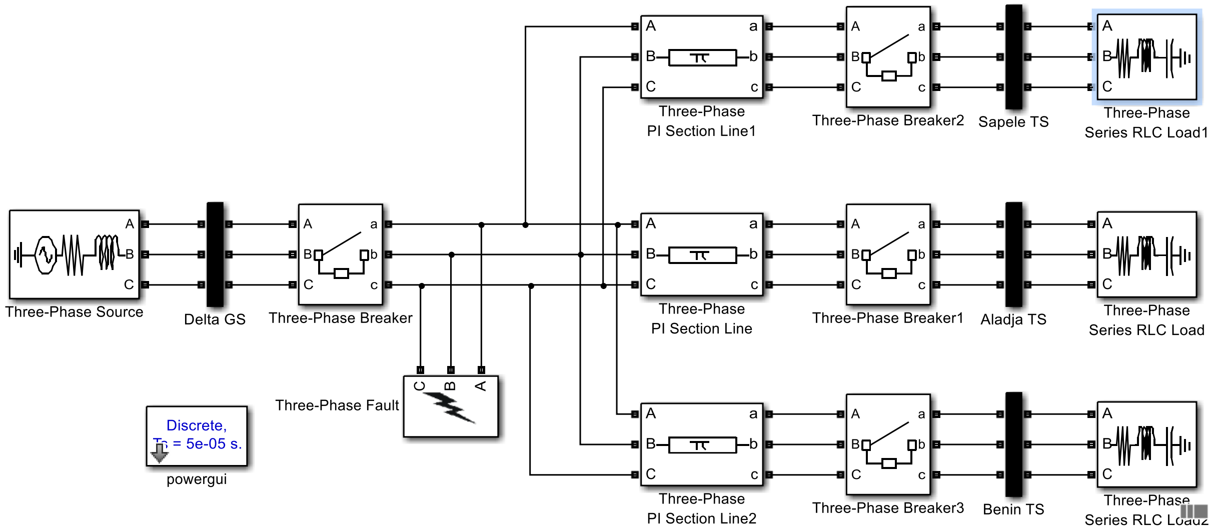


Figure 1. Network model in MatLab/SIMULINK.

Figure 1 is simulated to obtain the current signal from the split distance of the transmission lines as shown in Table 1.

Table 1: Transmission line split distance with the corresponding current signal during the occurrence of HIF

location	Distance (km)	Current signal		
		Phase A	Phase B	Phase C
Aladja (line1)	7.50	2.33	4.82	3.22
	15.00	4.21	8.33	8.99
	22.50	5.87	5.44	11.44
	30.00	6.33	7.97	15.33
Sapele (line2)	23.25	19.77	3.19	4.19
	46.50	5.31	5.42	13.22
	69.75	8.79	6.77	4.89
	93.00	19.11	8.31	10.31
Benin (line 3)	26.75	4.89	8.19	7.33
	53.50	3.11	4.11	4.32
	80.25	6.18	5.32	5.42
	107.00	5.67	6.71	1.41

The contents of Table 1 show that the distances of the transmission line are split into four points and the current signal obtained for each of the point location. The flow diagram for the modeling of the artificial intelligent in the detection and location of HIF is shown in Figure 2.

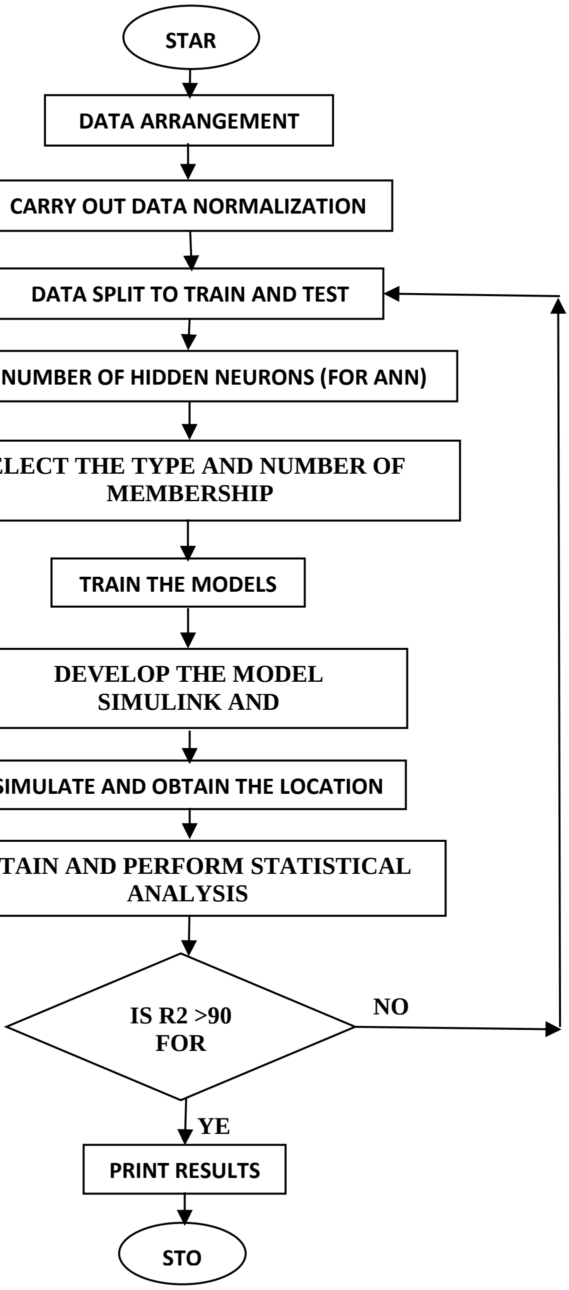


Figure 2. Proposed procedure of developing AI model

The power system network with ANN model is shown in Figure 3.

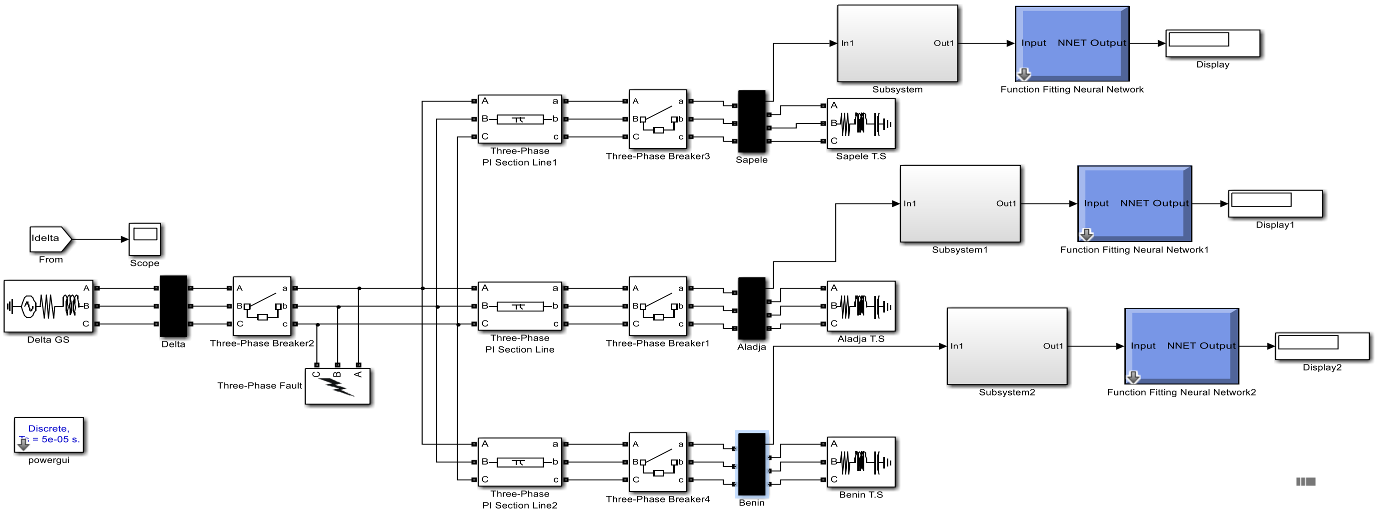
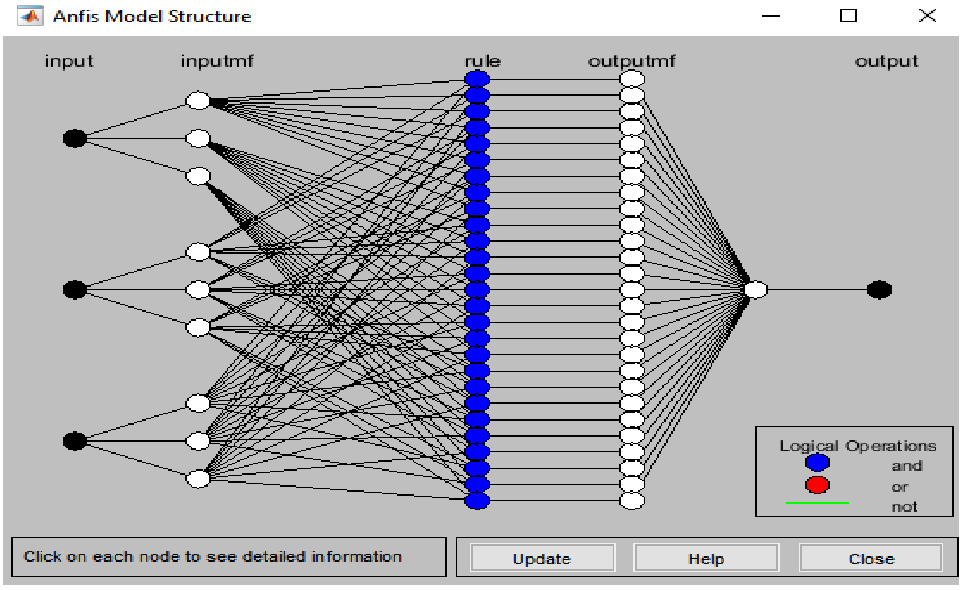


Figure 3. Power system network with ANN model

The ANFIS model structure is shown in Figure 4.



Click on each node to see detailed information

Figure 4. ANFIS model structure

The ANFIS model structure in Figure 4 comprises of three input neurons (which represents the HIF current phases) with each input data having three neurons which are the membership functions (which means each input data has three membership functions) making a total of nine membership functions. It also has 27 rule neurons with each rule having one output membership function leading to one output neuron which is the point distance location of the transmission line. The table for the inference rules is shown in Table 2.

Table 2. Inference Rules

Rule	Input 1	Input 2	Input 3	Output
1	In1mf1	In2mf1	In3mf1	Out1mf1
2	In1mf1	In2mf1	In3mf2	Out1mf2
3	In1mf1	In2mf1	In3mf3	Out1mf3

4	In1mf1	In2mf2	In3mf1	Out1mf4
5	In1mf1	In2mf2	In3mf2	Out1mf5
6	In1mf1	In2mf2	In3mf3	Out1mf6
7	In1mf1	In2mf3	In3mf1	Out1mf7
8	In1mf1	In2mf3	In3mf2	Out1mf8
9	In1mf1	In2mf3	In3mf3	Out1mf9
10	In1mf2	In2mf1	In3mf1	Out1mf10
11	In1mf2	In2mf1	In3mf2	Out1mf11
12	In1mf2	In2mf1	In3mf3	Out1mf12
13	In1mf2	In2mf2	In3mf1	Out1mf13
14	In1mf2	In2mf2	In3mf2	Out1mf14
15	In1mf2	In2mf2	In3mf3	Out1mf15
16	In1mf2	In2mf3	In3mf1	Out1mf16
17	In1mf2	In2mf3	In3mf2	Out1mf17
18	In1mf2	In2mf3	In3mf3	Out1mf18
19	In1mf3	In2mf1	In3mf1	Out1mf19
20	In1mf3	In2mf1	In3mf2	Out1mf20
21	In1mf3	In2mf1	In3mf3	Out1mf21
22	In1mf3	In2mf2	In3mf1	Out1mf22
23	In1mf3	In2mf2	In3mf2	Out1mf23
24	In1mf3	In2mf2	In3mf3	Out1mf24
25	In1mf3	In2mf3	In3mf1	Out1mf25
26	In1mf3	In2mf3	In3mf2	Out1mf26
27	In1mf3	In2mf3	In3mf3	Out1mf27

From Table 2, the inference rules is formulated. For the first rule, if the first input variable (phase A current signal) is in1mf1 and second variable (phase B current signal) is in2mf1 and the third input variable (phase C current signal) is in3mf1, then the location distance (output variable) would be out1mf1. The same procedure is used for all the rules in table 2. The power system network with ANFIS model is shown in Figure 5.

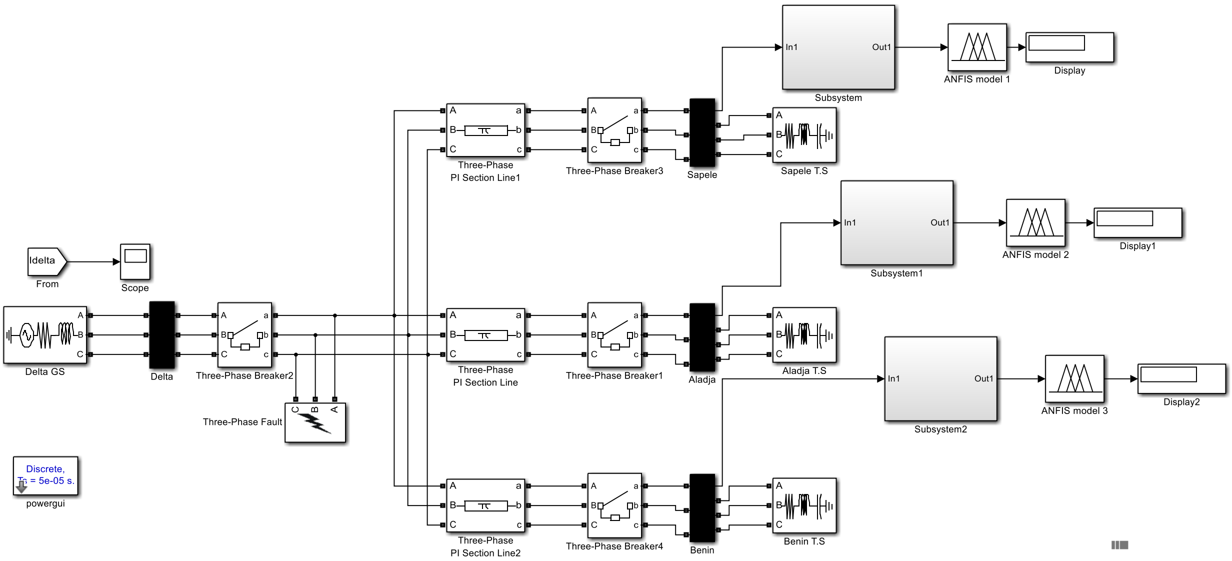


Figure 5. Power system network with ANFIS model

IV. RESULTS AND DISCUSSION

The error difference of the point location with ANN and ANFIS are depicted in Figures 6-8 for lines 1-3 respectively.

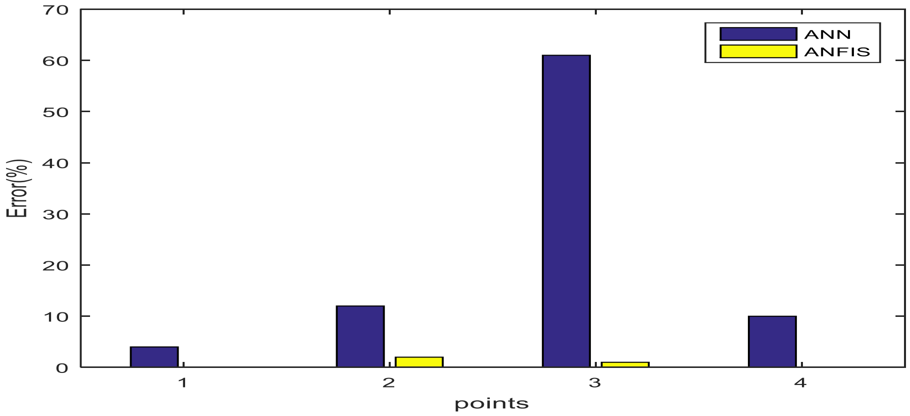


Figure 6. Error deviation in percentage for line 1

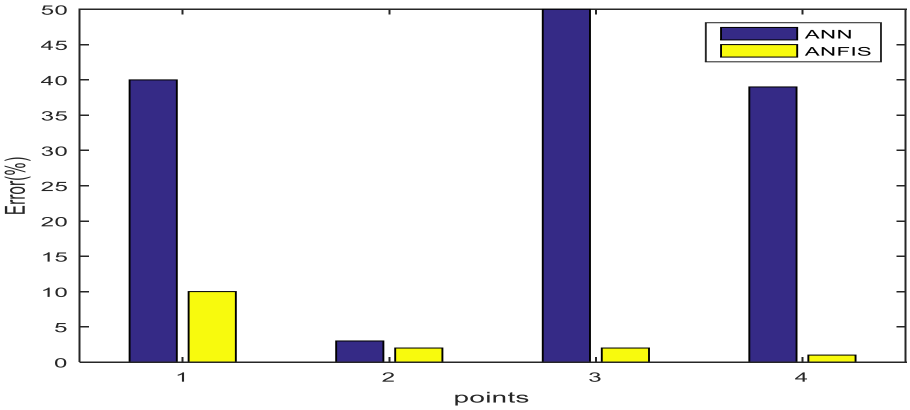


Figure 7. Error deviation in percentage for line 2

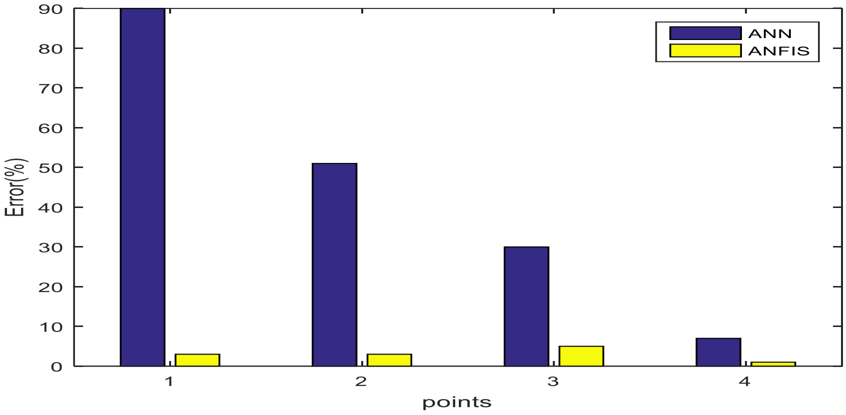


Figure 8. Error deviation in percentage for line 3

From the comparative analysis presented in Figures 6-8, it can be seen that the error deviation of the predicted HIF location with ANN for line 1 is 62 % whereas ANFIS is 2 %. Also, for line 2, ANN has a maximum error deviation of 50 % compared to 10 % of ANFIS. Lastly, ANN has an error deviation of 90 % while ANFIS has 3 % for line 3. This shows that ANFIS is a better model for detection and point location of HIF in the Nigerian 330 kV transmission network under review.

V. CONCLUSION

The major emphasis in this study was to carry out ANN and ANFIS for the location of HIF and apply the models in the power system network of the south south Nigerian 330 kV transmission network for the location of three phase HIF occurrence. The generation (source) station was Delta GS where the 330 kV line was linked to Sapele, Aladja and Benin at various distance of 93 km, 30 km and 107 km respectively. Each of the distances were split into 4 equal points where the faulted current signal were obtained and used as inputs to the ANN and ANFIS models. The target to the AI models was the actual distance. the simulink blocks of ANN and ANFIS models were inserted in the developed power system network model in simulink and the HIF location point distances were predicted and presented for the three locations with error deviation from the actual distance obtained and plotted. The result showed that ANFIS model had the better point location of HIF occurrence than the ANN model and as much should be utilized in the location of HIF.

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