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Detection and Location of High Impedance Fault on the Nigerian 330kV Transmission System Using Artificial Neural Network

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ABSTRACT: The effect of the occurrence of high impedance fault (HIF) in power system networks results to low current signal which cannot be detected by the electrical equipment which results to fire outbreaks. Nigerian power system network has witnessed the occurrence of HIF which has led to fire outbreak in buildings and in minor cases grid collapse. In this paper, the performance of ANN in the detection and location of HIF was studied and determined. The transmission network located in south-south region of the Nigerian 330kV power system network was obtained and modeled in SIMULINK. The line distance was split into six points and implemented in the SIMULINK to obtain the current signals at each point of the lines. The current signals were used as the input data with the split distance utilized as the target to the ANN model. The ANN had three input neurons (each neuron represented the phase current signal), the hidden layer had five neurons with each neuron incorporating log sigmoid curve and the output layer having one neuron which was the split distance. The outcome had the least error deviation value of 0.0118 making the performance of ANN effective in the point location of HIF occurrence on the transmission line.

KEYWORDS: Artificial Neural Network, Fault detection, Fault location, high impedance fault, Transmission system

I. INTRODUCTION

The electrical power system network comprises of generation stations, transmission stations and distribution systems [1, 2, 3]. The generation plants generate electricity at voltage of between 16kV to 25kV with the voltage stepped up to high voltage transmittable power (330kV for the Nigerian power system network and 735kV for the United States power system network) [4, 5, 6, 7]. The essence of voltage rating step up was to minimize losses on the lines. The transmission system has transmission station and substations where the transmission power voltage rating was stepped down on reaching the required load demand location. The occurrence of faults has limited the effectiveness of the operation of power system network. The occurrence of fault can yield high current or low current signal [8, 9, 10]. The type of fault occurrence that results of high current signal is known as low impedance fault which the introduction of relays has aided in the identification, classification and location of the fault in power system network [11, 12, 13]. The same cannot be said to the occurrence of high impedance fault (HIF) which is characterized with low current signal because there is no existing material or power system equipment that can identify, classify nor locate the occurrence of the fault. The occurrence of HIF is known to be the contact between the transmission line and a semiconductor and the case of the transmission line energized when there is a cut and falls on the ground was considered [14, 15, 16, 17]. In this paper, artificial neural network was deployed in the fault detection and location on the Nigerian 330kV transmission line in south-south region was considered. The data utilized was obtained from the transmission center in Osogbo and modeled in SIMULINK. A three phase HIF was introduced into the power system model with current signal obtained and at various transmission line distances for each location and sent to the ANN model. While the current signals at each distance was used as the input data, the transmission line distances were used as the target variable leading to the generation of the output variable by the ANN model. The ANN model was carried out in the neural network toolbox located in MatLab toolboxes. The configured ANN model was inserted into the power system network modeled in SIMULINK model to determine the point location of the HIF 3-phase occurrence and the outcome was compared with the target to determine if the proposed model was effective for the detection and location of 3-phase HIF in the Nigerian power system network.

II. REVIEW OF RELATED LITERATURE

The authors in [18, 19, 20], the author proposed the use of three phase voltage and currents angles of certain specific points on the transmission line and the use of transfer matrix of the current signals of the transmission line. The three-phase current and voltage angles were calculated form the ends of the transmission lines and the finite differences between the outcome of the calculated angles from the transmission line ends were computed at infinitesimal points of the line to obtain the occurrence of the HIF and to identify the location of the faults. The obtained results showed that the proposed method was effective in the determination of the HIF and location of the occurrence of the fault. The author emphasized that despite the efficiency of the model in the determination and location of HIF, the model is complex and can be very difficult in implementation which was the gap of the research. In [21, 22, 23], the author suggested the use of power line communication device for the detection and location of HIF in transmission line power system network. the power communication line was installed at the start point of the transmission line where the occurrence of HIF was monitored. The frequencies at the narrow heads of the transmission line and the power line were determined and the impedance values of the transmission. The current flow on the power line was monitored and the occurrence of HIF was determined to be the difference in metrics between the original frequency, impedance and current signals and the response of these parameters to responses when the transmission line was introduced to HIF. Different case test was carried out and it was found that the proposed method is effective in the detection and location of HIF on the transmission system. The system of connection of high voltage transmission line and power line communication cable could result to constant occurrence of faults due to interference and the fault location accuracy was low. Utilization of a zero sequence current signal values from the transmission line terminals that are connected to earth for HIF detection and location was carried out in [24, 25, 26] where the authors compared the outcome to negative sequence current signal. In each case, the HIF was obtained at the maximum time of several cycles. The use of zero sequence and negative sequence current signals were found to be insensitive to the variations in HIF class, HIF pattern and transmission line parameter variations. The outcome of the result obtained showed that the proposed methods were effective in detection and location of HIF with Negative sequence current signals being more effective than the use of zero sequence signals. The gap in this research was the models were the large of HIF location which was considered too wide of onsite power engineers to track the faults. In [27, 28, 29, 30], the author utilized power line system cable as seen in [31, 32, 33, 34] but this time, the author embarked on several test signals injections and installed HIF occurrence alarm. The identification of HIF occurrence was based on impulses recorded by the power lines on the transmission lines on Greek rural electrification scheme and it was found that the use of power lines was effective in fault detection and location. The use of power lines on the transmission line has been described as dangerous due to fault occurrence as a result of signal and magnetic interference and hence should be avoided. The authors in [35, 36, 37, 38] proposed the use of electromagnetic time reversal (EMTR) voltage method for the determination of the occurrence of HIF and location of the fault on the transmission line. The use of EMTR involves the determination of the frequency of the traveling wave of the different on the current signal from the point of HIF occurrence. Also, the author performed a reduced scale experiment and modeled the system with the method on PSCAD. The outcome showed that the system was effective in detection and location of HIF. The HIF location accuracy of the model was low and the proposed method is complex to implement. In [39, 40, 41, 42], the author utilized analyzed the effects of fault from pole to pole, pole to ground and other types of fault contingencies in the detection and location of HIF on the transmission system with equivalent network of multi-terminal MMC-HVDC systems for HIF identification. Furthermore, the author utilized modal transformation for line-mode and zero mode voltages. The proposed method identified the occurrence of HIF but was not efficient in location of the fault and has been described as complex in implementation. The authors in [43, 44, 45, 46] utilized a developed synchronized waveform for the detection and location of HIF in the power system network. The modeling of the power system network was done and simulated in Matlab. The outcome showed that the developed method detected the occurrence of fault but was not adequate in the point location of the HIF because fault location has no relationship with signal waveform which was the gap in the study. In [47, 48, 49, 50], the author proposed the use of synchronized current information for the detection of HIF in the power system network especially in noisy environment.

III. MATERIALS AND METHOD

The data utilized for the power system network model was obtained from the national transmission center in Osogbo in Osun State and the single line diagram for the model was shown in Fig. 1.

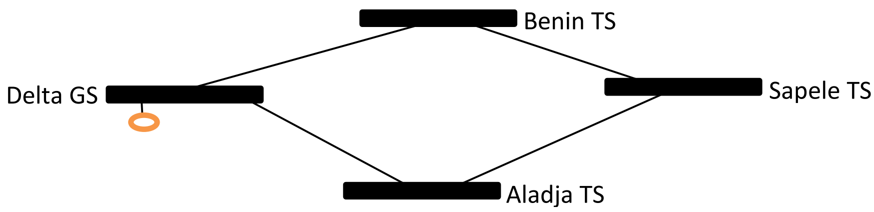

Fig. 1. Power system line diagram of the network

The Line diagram encompasses of two generation stations and two transmission load station. The generation were in Delta GS and the transmission load stations selected were Aladja TS, Benin TS and Sapele TS. The transmission voltage rating utilized in this study was 330kV. The line transmission distances from the data obtained were shown in Table 1.

Table 1. Transmission line distance

Transmission line number	From bus	To bus	Distance (km)
1	Benin TS	Sapele TS	50
2	Benin TS	Delta GS	107
3	Delta GS	Aladja TS	30
4	Sapele GS	Aladja	93

The power system diagram was subjected to SIMULINK and was simulated. The current signal for each line distance was split into 6 equal distance with the maximum current signals at each phase obtained. The Simulink diagram of the model network was shown in Fig. 2.

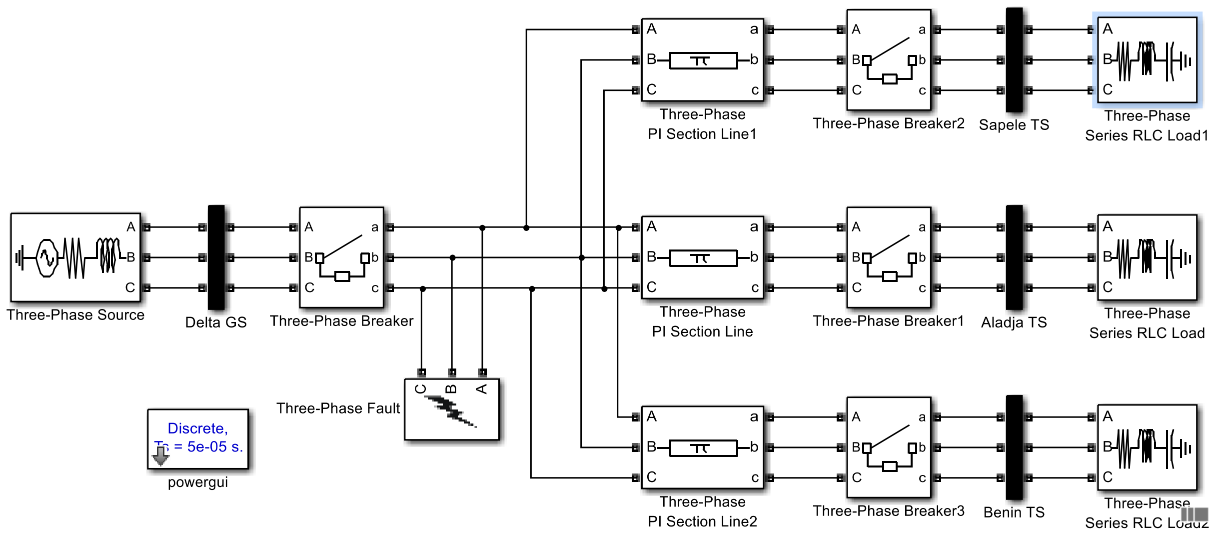

Fig. 2. SIMULINK model of the power system network

The split distance and the current signal for each phase for the transmission line at three phase HIF generated from the SIMULINK model and sent to the MatLab editor for the ANN model was shown in Table 2.

Table 3. Split distance with three phase HIF current signal data

	Split distance (kM)	Phase A	Phase B	Phase C
Line 1	8.3300	3.4882	4.8602	4.4175
	16.6700	4.3114	3.7836	3.5308
	25.0000	5.3126	4.3279	3.5540
	33.3300	3.9686	4.7470	3.7888

	41.6700	4.5000	5.1633	5.0544
	50.0000	3.7157	5.3117	3.7818
Line 2	17.8300	6.9491	6.7029	6.7621
	35.6700	7.3121	6.8743	5.2991
	53.5000	6.6530	6.8426	5.8309
	71.3300	5.3075	6.0811	5.3302
	89.1700	7.0726	6.6524	5.4408
	107.0000	7.2568	5.6015	7.0169
Line 3	5	9.4421	6.6698	10.1786
	10	9.9129	8.0574	7.7394
	15	5.8865	10.1803	9.3675
	20	9.9522	10.2185	5.9636
	25	8.4993	6.0449	7.4105
	30	5.7343	10.2480	9.9644
Line 4	15.5000	6.7378	6.8912	6.7693
	31.0000	5.9181	6.9556	6.8677
	46.5000	7.2920	5.6355	5.8290
	62.0000	5.3047	6.2928	6.7050
	77.5000	6.1821	6.1969	6.6516
	93.0000	6.0580	6.6325	5.5829

ANN model was formulated for each of the transmission line with the current signal at different phases being the input data and the split distance used as the target variable. The ANN structure that was implemented was shown in Fig. 3.

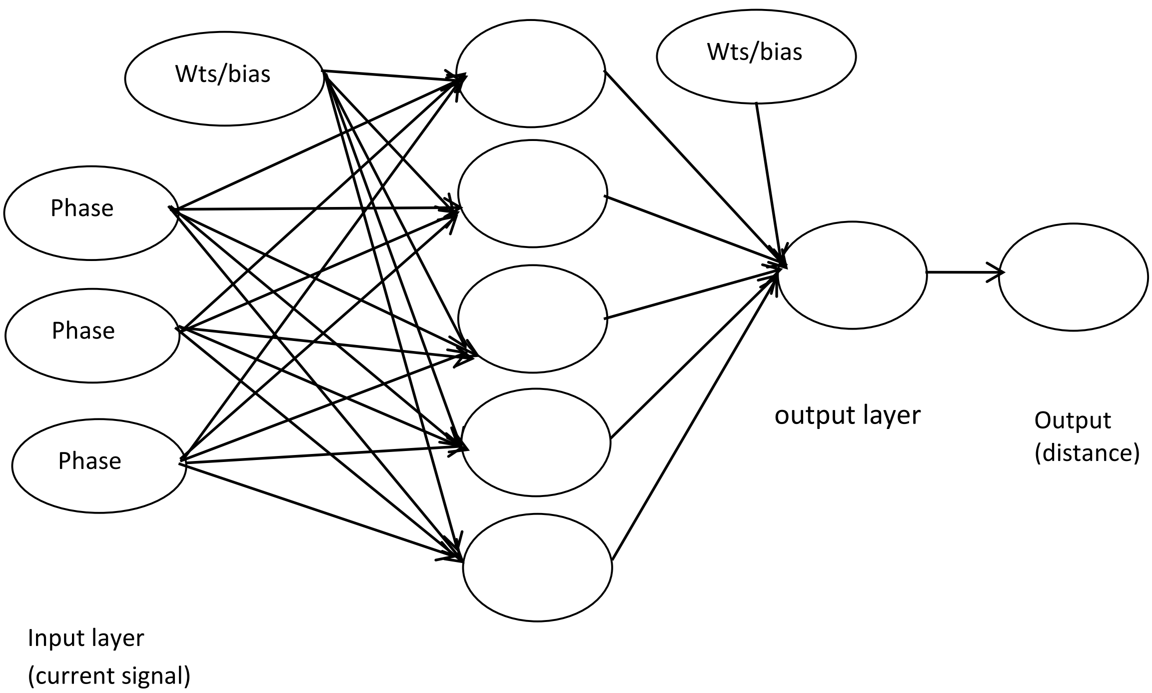

Fig. 3. ANN structure

Form the model structure in Fig. 3, the input has three input neurons which indicated the HIF current phases, the hidden neurons has five hidden neurons with each neuron using log sigmoid curve model shown in quation 1.

$$\log(input) = \frac{1}{1 + e^{input}} \qquad (1)$$

The output layer has one neuron which represents the split distance. The target variable was compared with the predicted distance and outcome presented in the result section. The Simulink model with the ANN HIF locator was shown in Fig. 4. The ANN model was configured for each of the transmission lines as shown in Fig. 4.

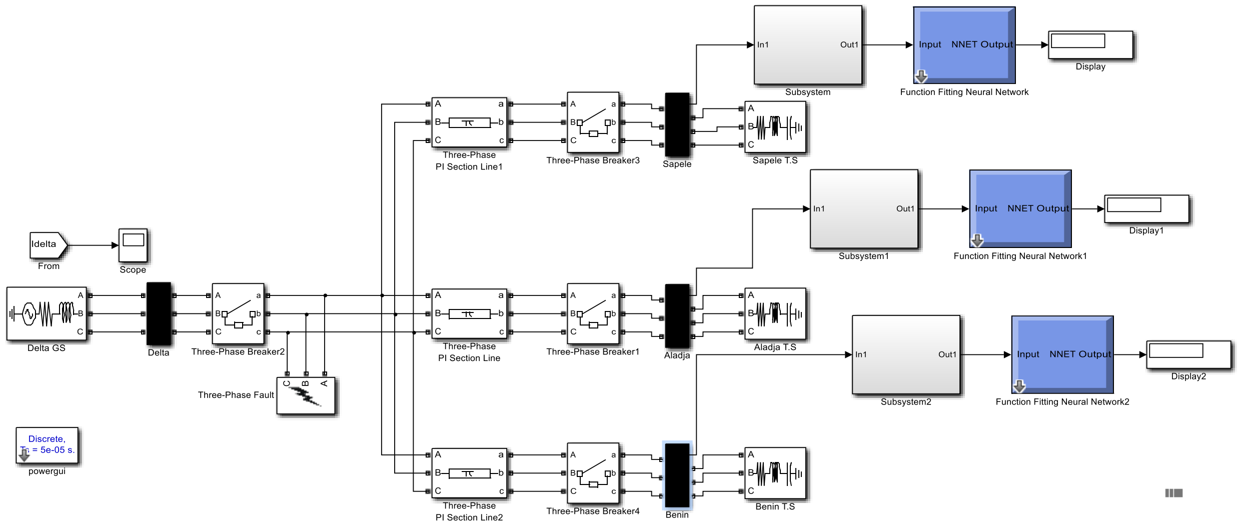

Fig. 1. Methods of HIF detection and location model

IV. RESULTS AND DISCUSSION

The HIF location prediction with ANN model for the three phase HIF occurrence in along Line 1 is shown in Table 3.

Table 3. HIF location with ANN along Line 1

Actual HIF location (km)	ANN location prediction (km)	Error
Line (1)		
8.3300	8.4200	0.09
16.6700	15.3100	1.36
25.0000	24.7000	0.30
33.3300	31.9300	1.10
41.6700	42.1300	0.36
50.0000	48.8800	1.12
Line(2)		
17.8300	17.0100	0.8200
35.6700	35.6000	0.0700
53.5000	52.9000	0.6000
71.3300	70.9920	0.338
89.1700	90.3100	0.1400
107.0000	106.1400	0.8600
Line (3)		
5	5.0200	0.0200
10	10.3312	0.3312
15	14.5331	0.4669
20	21.0121	1.0121
25	24.5220	0.4780
30	29.9299	0.0701

Line(4)		
15.5000	15.1000	0.4000
31.0000	30.1001	0.1001
46.5000	46.1000	0.4000
62.0000	62.2000	0.2000
77.5000	77.5116	0.0116
93.0000	93.2100	0.2100

The barchart representing the location of HIF in line1 to line 4 are shown the Figs. 5-8.

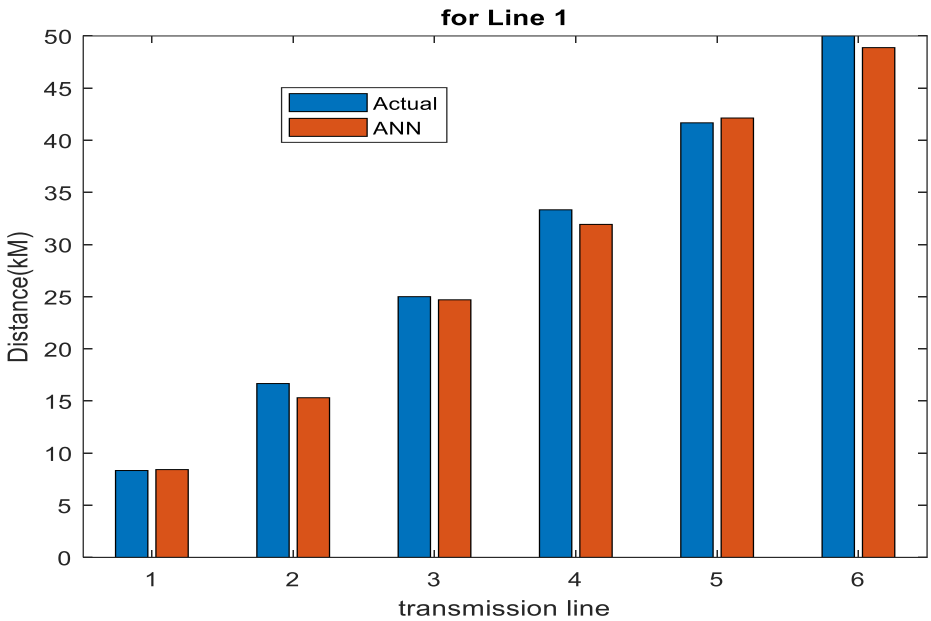

Fig. 5. HIF location with ANN for line 1

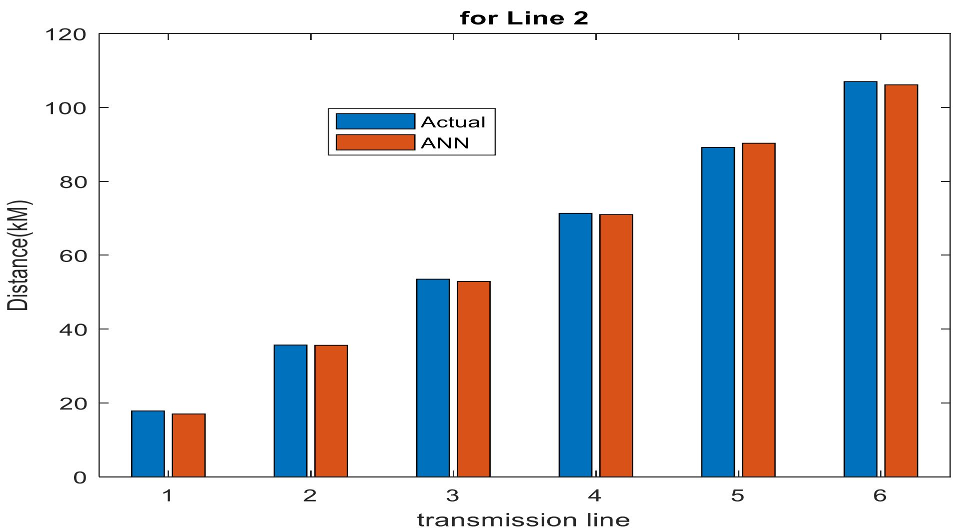

Fig. 6. HIF location with ANN for line 2

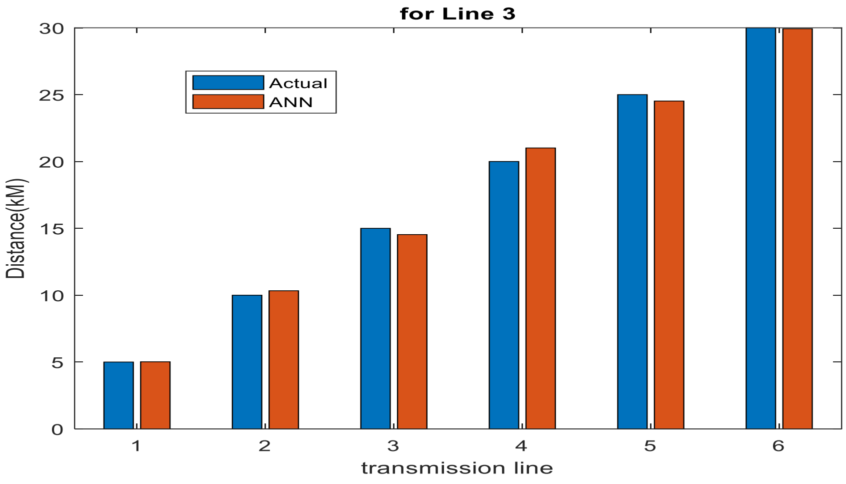

Fig. 7. HIF location with ANN for line 3

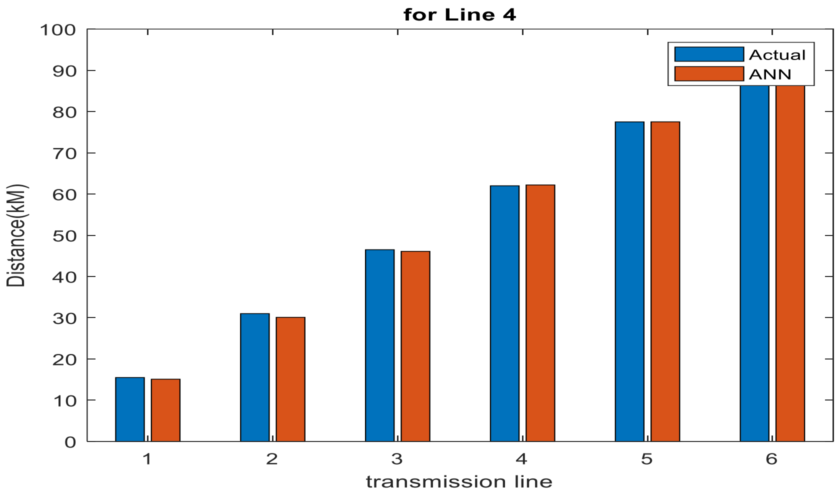

Fig. 8. HIF location with ANN for line 4

It is observed that the location accuracy is high. However, the performance of ANN in detecting and locating the occurrence of HIF on the transmission line is presented in the error barchart of Fig. 9.

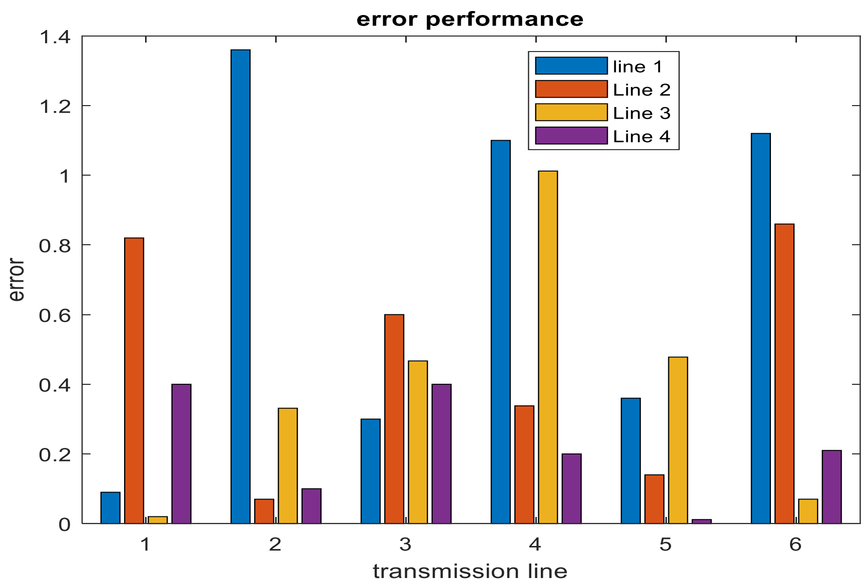

Fig. 9. Error analysis of performance of ANN model in locating HIF on transmission line

It is observed in Fig. 9 that the highest error deviation with ANN prediction occurred in transmission line 1 split 2 with error value of 1.36. This implies that cite engineers would have to obtain the fault location 1.3km from the point of HIF occurrence which was excessive. However, in critical study of figure showed that the use of ANN can be utilized for fault detection and location due to the least error being 0.116.

V. CONCLUSIONS

The paper was centered on the detection and location of the occurrence of HIF on the Nigerian Power system network in South-south region of Nigeria. The network encompasses the transmission line connecting Benin TS, Delta GS, Aladja TS and Sapele TS. The location of HIF was carried out with ANN mode. The line network was modeled in SIMULINK where the line distance was split to six equal points and implemented in the SIMULINK model to obtain the current signals at each point of the four lines. The outcome showed that ANN can be used to determine the HIF occurrence location on the lines except on point 2 of the first transmission.

It is recommended that a comparative analysis of the performance of ANN in point HIF location be compared with other artificial intelligence model such as ANFIS and Fuzzy logic for transmission line HIF point location.

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