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High Impedance Fault Detection and Location in the Nigerian 330 kV Transmission Network Using Adaptive Neuro-Fuzzy Inference System

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ABSTRACT: Fundamentally, the occurrence of high impedance fault (HIF) can be established when an energy filled conductor contacts a semiconductor. The occurrence of HIF can be described to be subtle and disastrous as it results to low current signal and a signal voltage arc if undetected and without implementation of protective measures, leads to the damage of the power system equipment and in many cases fire outbreak. In this study, the occurrence of HIF on the south-south region of Nigerian 330kV transmission line was studied with the data utilized obtained from the Nigerian control center (NCC) Osogbo. The data obtained was modeled in simulink and the outcome at normal condition was obtained. The transmission line distance was 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 was split to train, test and validate at 70%, 15% and 15% respectively. The data analysis performed was sent to Adaptive Neuro-fuzzy inference system (ANFIS) with the current signal at normal condition and at 3-phase HIF was used as input data while the split distance was implemented as the target data to the model. The effectiveness of the model in detecting and locating HIF was obtained and analyzed in a comparative plot of the location distance. From the results presented, the highest error deviation for fault location with ANFIS was 10%. Hence, it was concluded that ANFIS model had a satisfactory outcome in HIF detection and as such should be utilized for the HIF detection and location.

KEYWORDS: ANFIS, HIF, Detection of HIF, Location of HIF, MatLab, Simulink

I. INTRODUCTION

In the installation and operation of power system equipment and generation, transmission and distribution of electricity, the major concern has always been the occurrence of Fault and the economic growth and development of any nation are intrinsically tied to the availability of energy [1] and access to a reliable electricity supply as conduvted in the performance evaluation of asynchronous motor plays a pivotal role in empowering individuals and facilitating personal and economic development [2]. In the Nigerian power system network, the use and implementation of relays has ensured the detection, classification and location of the occurrence of low impedance fault on its transmission and distribution network but the same cannot be said on high impedance fault [3]. The occurrence of HIF which is the energized contact of transmission lines (between voltage rating of 33kV to 330kV) and distribution lines (11kV below) with a semiconductor (which can be birds, wet trees on line fall to the wet and tarred floor) in several occasions, has been recorded in the Nigerian power network [4,5,6]. However, no system or appropriate measure has been developed for the detection and location of HIF in the Nigerian power system network especially south-south region. This paper delved into the detection and point location of the occurrence of HIF using ANFIS model. Point location in this context according to [7], implies the division of the line distance into specific points and determination of the current signals at each points. The power system network data of the south-south 330kV transmission line is obtained from the national control center (NCC) Oshogbo and modeled in MatLab/SIMULINK. In the model, the HIF fault block is introduced and activated to depict the occurrence of HIF on the transmission line. The distance for each line is divided into specific points with the normal and HIF current signals obtained at each point. The normal conditioned and the HIF current signal was utilized as the input to the adaptive-neuro fuzzy inference system (ANFIS) while the split distance is the target data to the model. inference rules which are of the relationships between the input and the target are developed and the model outcome is generated in simulink block and sent to the power system model in simulink. The performance of the ANFIS model is carried out in the power system model at 3-phase HIF to determine the level of effectiveness of the model in detecting and locating HIF.

II. REVIEW OF RELATED LITERATURE

Several literature are reviewed in the detection and location of High impedance fault. The authors in [3] carried out the detection of HIF by utilizing the following; 3-phase current signal at the feeder, carried out design of HIF detector to monitor the third and sixth harmonics in the feeder, leading to HIF identification of 80% but at current signal of 20A (the model was termed unreliable when the current signal was more than 20A). [7] generated zero sequence current signal for the detection of HIF in a faulty line and healthy line and had 70% and 48% HIF detection and location accuracy on carrying out the simulation in PSCAD. In [8], the authors determined the HIF detection and classification by juxtaposing the voltage signal half cycle with moving window technique on the transmission line and had 45% accuracy. The authors in [9] utilized smart meters in the detection and location of HIF on distributed generators, power electronic loads and electric furnaces and the effect of utilizing broadband impedance spectroscopy in the detection of voltage arcing in single core cables without determining the possibility of location HIF in the cables with the same method obtaining an accuracy of 76%. [10] Utilized least square estimation method in the detection and location of HIF on a 5-bus distribution network in MatLab/SIMULINK and obtained an accuracy of 39%. Utilization of zero sequence current signals and complex sequence current for the detection and location of HIF on transmission lines and obtained was carried out in [11] with 39% accuracy while the authors in [12] examined the effect of HIF location and detection on injected frequency signals on transmission lines but the outcome encountered issues of detecting the occurrence of HIF at voltage of 150kV upwards. [13] Installed smart meters for the sole purpose of detecting the occurrence of HIF on the distribution line and had an accuracy of 43%. The authors in [14] utilized relay scheme of third and fifth harmonic excursion patterns and phase portraits for the detection of HIF occurrence at low frequency distribution network but had an issue in the location of the occurrence of HIF. In [15], the authors utilized UPFC with synchronized power measurement inserted at both ends of the device for the detection and location of HIF on the transmission line and obtained an accuracy of 69% while in [16], the authors utilized the absolute sum of the coefficient of the multiple resolution signal decomposition under discrete wavelet transform for the detection of HIF but the model could not be used for the location of the HIF. [17] proposed the use of phase current increment ratio with symmetrical components determination for the detection of HIF and tested the model on PSCAD/EMTDC and the outcome proved to be effective. Generally, the major gap from the literature reviewed are implementation for the point to point location.

III. MATERIALS AND METHOD

The flow diagram employed in this paper is displayed in Fig. 1.

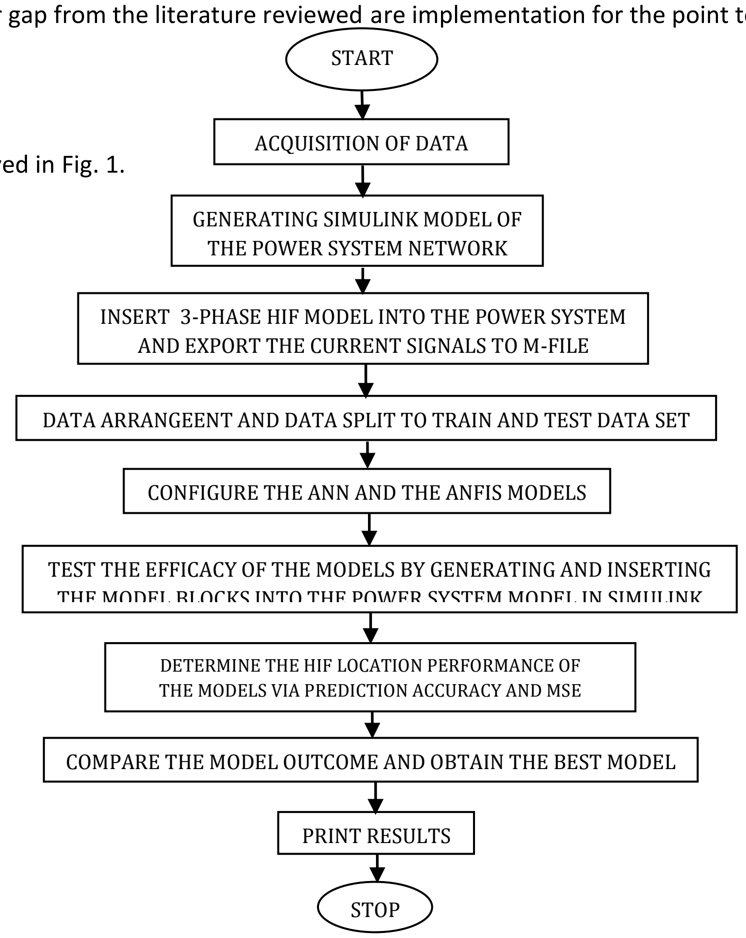

Fig. 1. Methods of HIF detection and location model

The data utilized was obtained from the national control center (NCC) oshogbo. it comprises of the information for the transmission network for the generation stations, transmission stations and transmission lines for the entire Nigerian network. For this study, the 330kV for the south south part of the Nigeria was used and modeled in SIMULINK.

A. *Modelling of the Power System Network*

The line snapshot of the line diagram of the power system network obtained for the model as extracted from [18,19] is shown in Fig. 2.

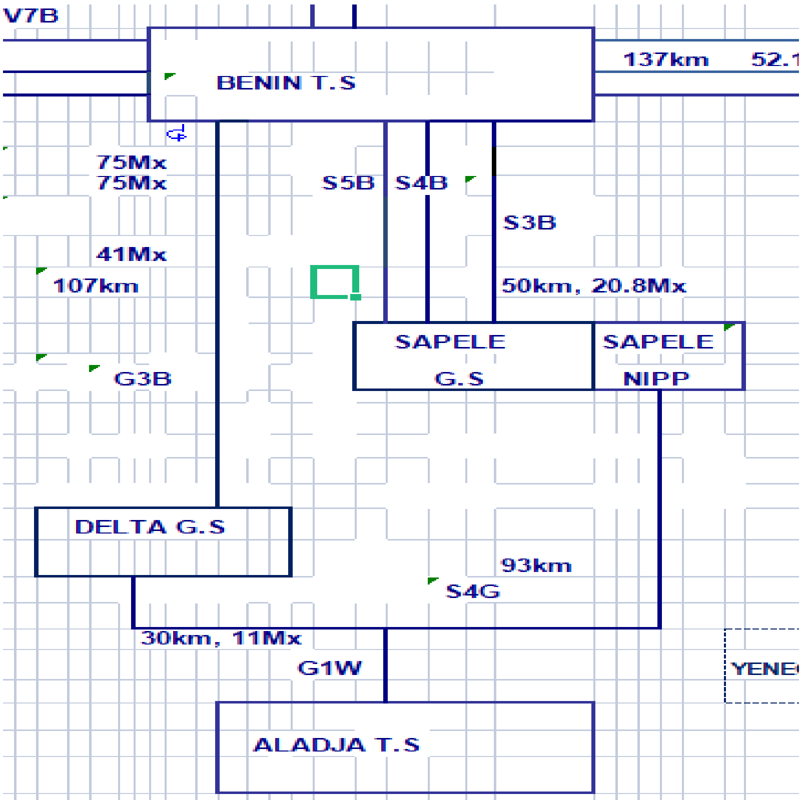

Fig. 2. Line diagram of the power system network model [16,17]

The line diagram in Fig. 2 shows that Delta and Sapele stations are generation stations while Aladja and Benin stations are transmission stations (load stations) at voltage rating of 330kV. The model representation of Fig. 2 is achieved in SIMULINK and presented in Fig. 3.

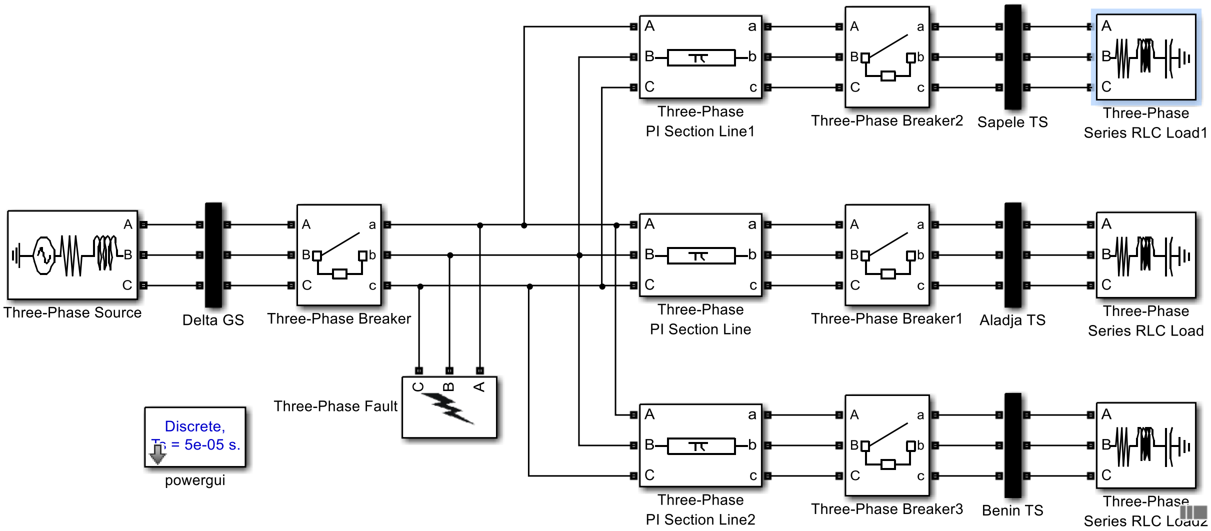

Fig. 3. Simulink model of the power system

The HIF in the model of Fig. 3 is represented by the three phase fault block since the emphasis is on 3-phase HIF class. Other simulink models blocks and functions of the block utilized includes; there phase source blocks for the generation stations, the bar blocks are the current and voltage measurement blocks for each bus location, the circuit breaker block and the transmission line blocks.

B. Development of the ANFIS Model for Fault Detection and Location

The flow diagram generated for the development of the ANFIS model for three phase HIF detection and location is shown in Fig. 4.

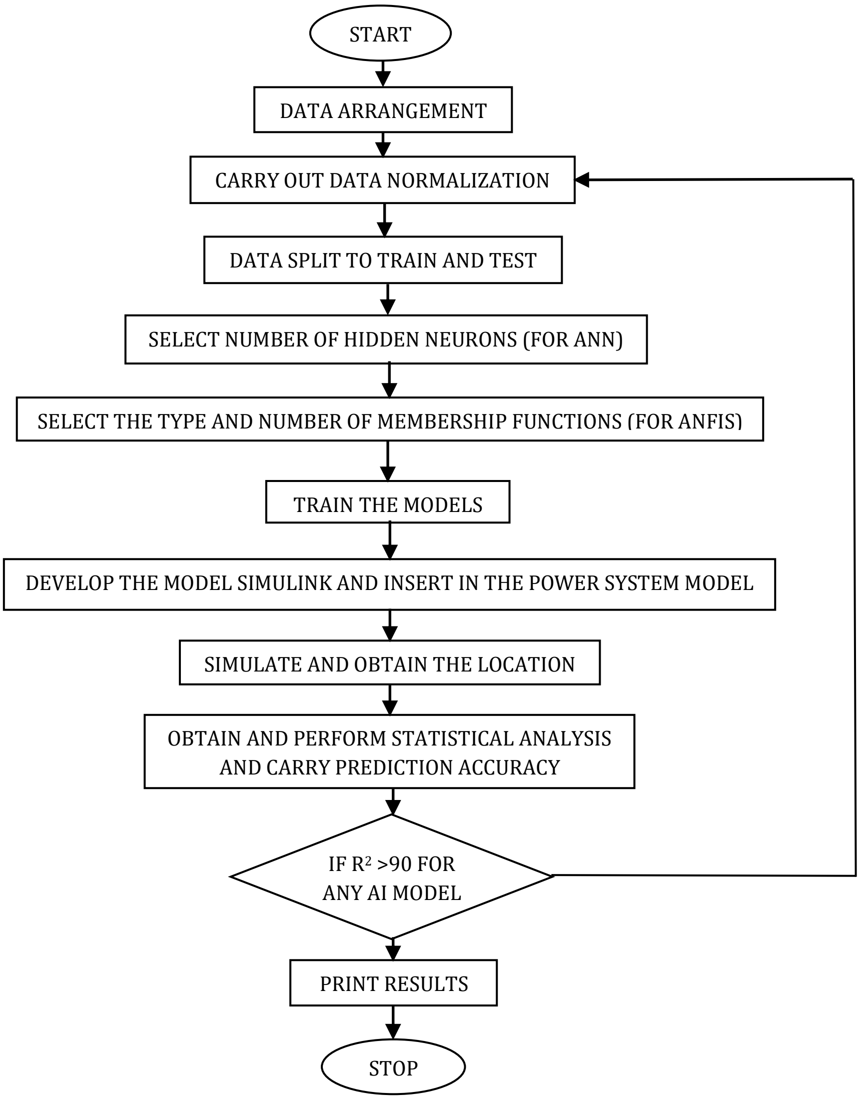

Fig. 4. Proposed procedure of developing ANFIS model

The first step in the generation of the artificial intelligent model is to extract the current signal values from the power system model for each load station. The extracted current signal values with the distance for a three phase HIF is shown in Table 1.

Table 1. Current signal from Simulink model for three phase HIF

Location	Distance (km)	Current signal		
		Phase A	Phase B	Phase C
Aladja	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	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	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 line distance for each of the stations are split into four equal point distances with the current signal for each of the distance obtained at three phase HIF and tabulated for the three phase signals as shown in Table 1. The current signal of the three phase HIF is the input to the ANFIS model and the point location is the target to the model with the model structure of ANFIS shown in Fig. 5.

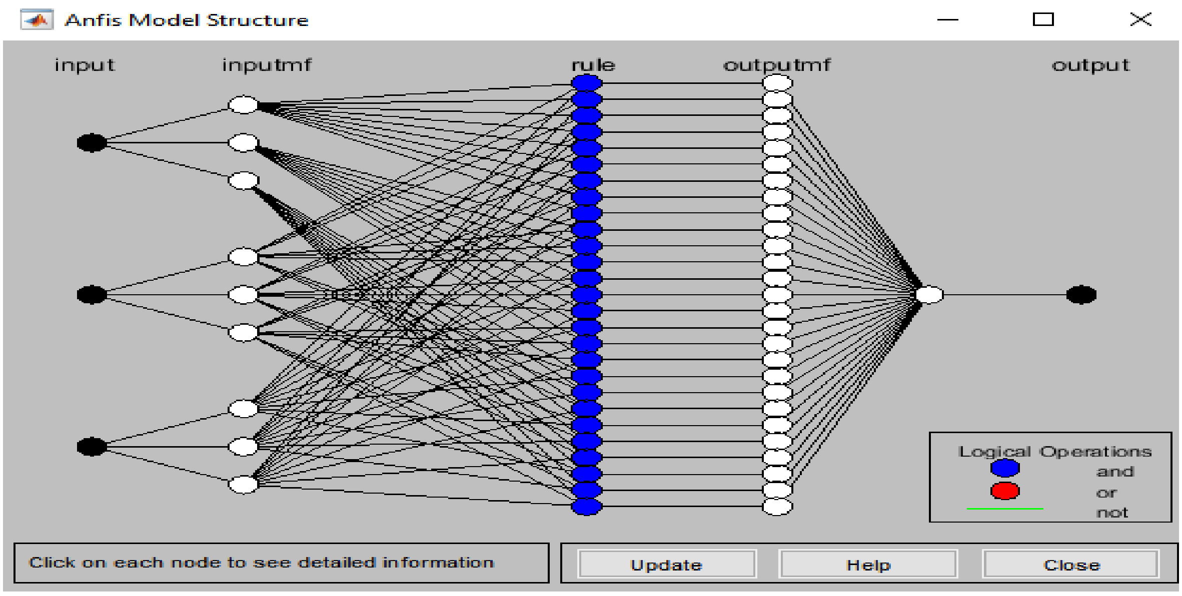

Fig. 5. ANFIS structure for the model

From the ANFIS model structure of Fig. 5, there are three inputs which are the three phases of the current signal. Each of the input has three triangular membership function model with each membership function generating nine inference rules making a total of eighty one (81) rules which formed the number of hidden neurons (81) making the output neurons to be 81 and leading to the formation of one output which is the point distance. The SIMULINK model of the power system network with the ANFIS model is shown in Fig. 6.

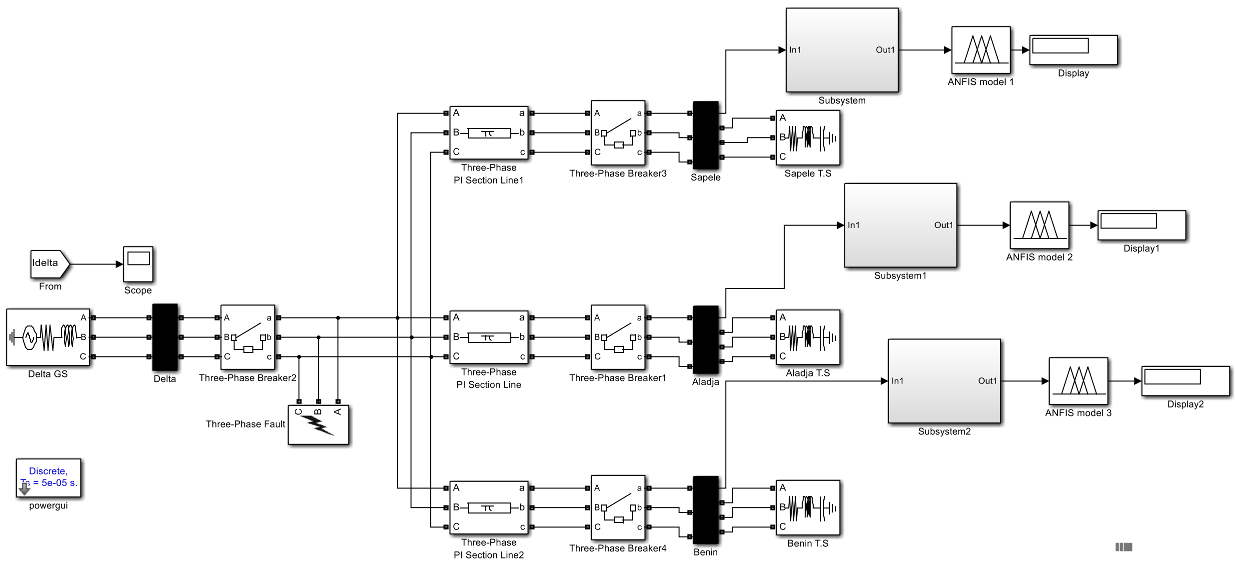

Fig. 6. ANFIS model embedded in the power system network

The developed ANFIS model is embedded in the SIMULINK model of the power system to test the effectiveness of the model in detecting and carrying out point location of HIF in the power system at the occurrence of 3-phase HIF.

IV. RESULTS AND DISCUSSION

The current signals at normal conditions and for the occurrence of three-phase HIF at various locations are shown in Figs. 6-8 and Figs. 9-11 respectively. The current signals of the three phases at Aladja, Sapele, and Benin at normal conditions are well above 100 A, indicating absence of HIF as its presence is always characterized by low current signals.

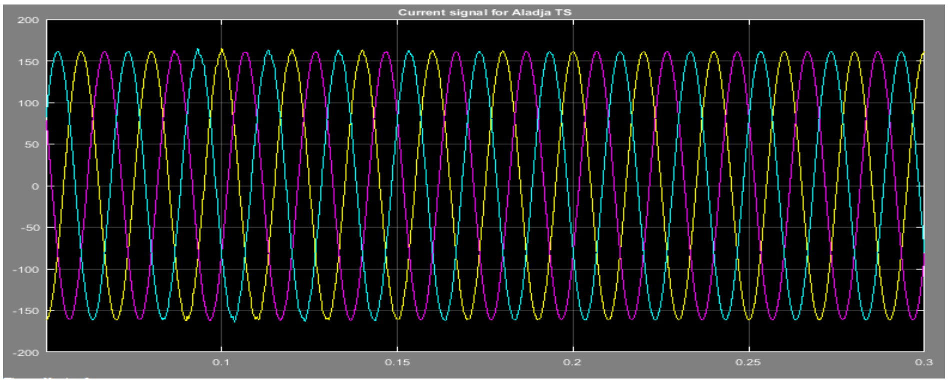

Fig. 6. Current signal at Aladja during normal condition

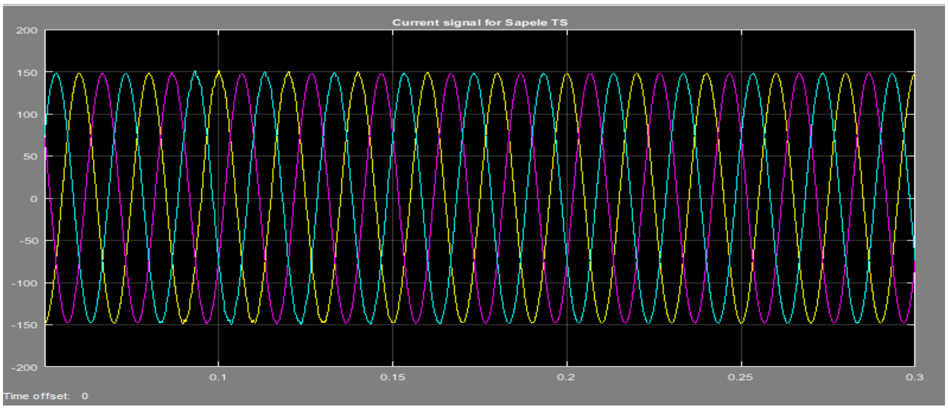

Fig. 7. Current signal at Sapele during normal condition

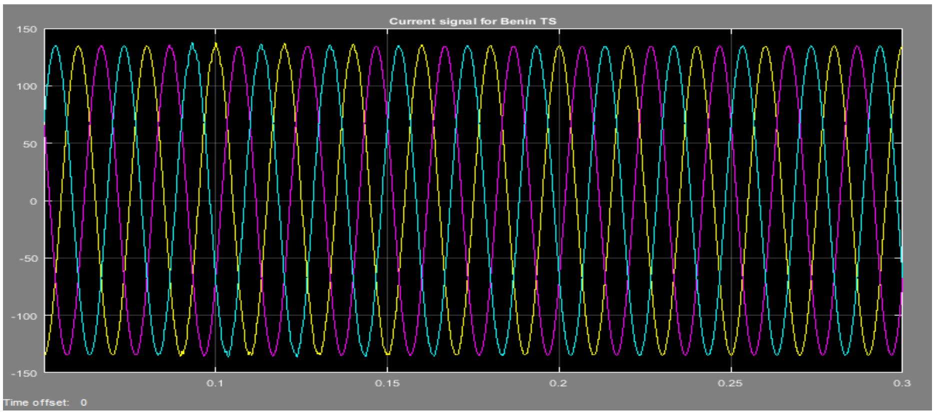

Fig. 8. Current signal at Benin during normal condition

The current signals in Figs. 9-11 for Aladja, sapele and Benin bus stations indicated that the occurrence of three-phase HIF is characterized by current signal of less than 20 A. The comparative analysis of the point locations indicating the effectiveness of the ANFIS model for the detection and location of HIF are shown in Tables 2-4 for each location.

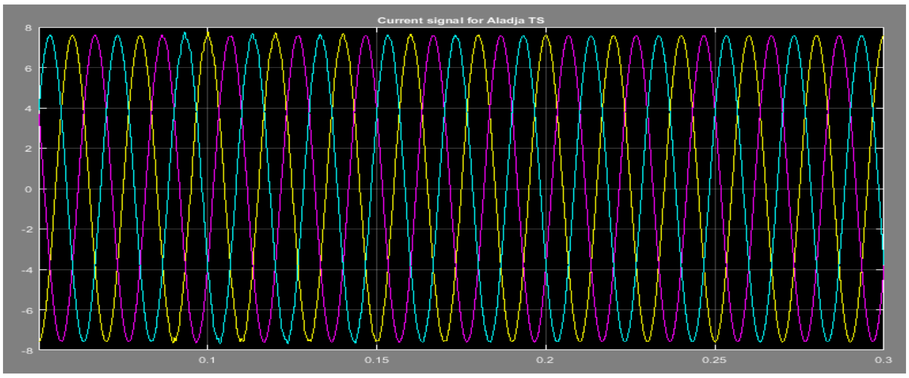

Fig. 9. Current signal at Aladja during the occurrence of 3-phase HIF

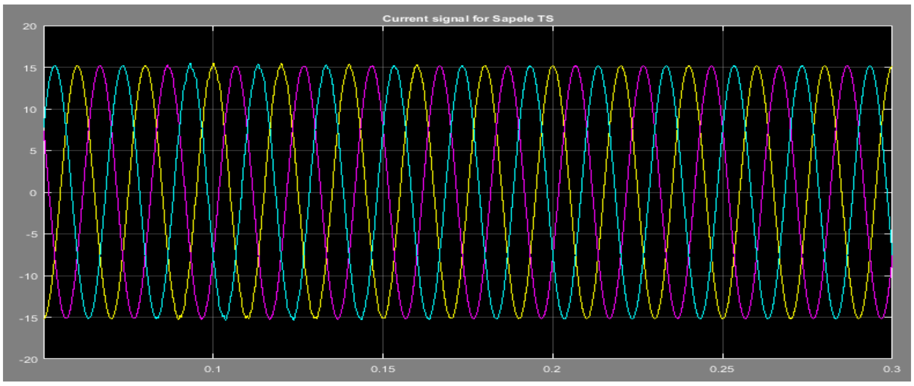

Fig. 10. Current signal at Sapele during the occurrence of 3-phase HIF

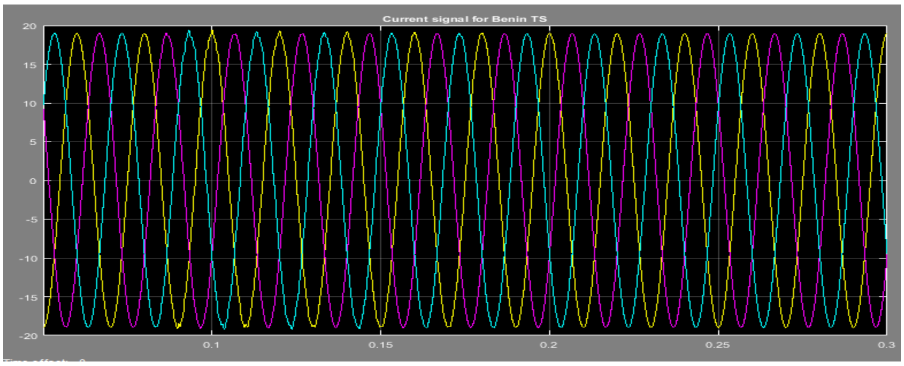

Fig. 11. Current signal at Benin during the occurrence of 3-phase HIF

Table 2. HIF location prediction and error deviation with ANFIS for transmission line to Aladja

Actual HIF location (km)	ANFIS location prediction (km)	error deviation
7.50	7.50	0.00(0%)
15.00	14.98	0.02(2%)
22.50	22.51	0.01 (1%)
30.00	30.00	0.00(0%)

Table 3. HIF location prediction and error deviation with ANFIS for transmission line to Benin

Actual HIF location (km)	ANFIS location prediction (km)	error deviation
23.25	23.35	0.10(10%)
46.50	46.48	0.02(2%)
69.75	69.73	0.02 (2%)
93.00	93.01	0.01(1%)

Table 4. HIF location prediction and error deviation with ANFIS for transmission line to Sapele

Actual HIF location (km)	ANFIS location prediction (km)	error deviation
26.75	26.72	0.03(3%)
53.50	53.47	0.03(3%)

80.25	80.20	0.05 (5%)
107.00	107.01	0.01(1%)

From the three tables (Tables 2-4) of the ANFIS model HIF point location presented above, results show that the percentage maximum error deviation value obtained is 10% which is the first point location in Table 3. This implies that the ANFIS model developed was effective in the detection and location of HIF at minimal deviation errors.

V. CONCLUSIONS

The detection and location of HIF in the south-south region of Nigerian 330kV transmission power system has been carried out. The data for the system was obtained from NCC Oshogbo and modeled in SIMULINK. The line distances were split into 4 equal points for each location with the current signal at each point generated and sent to the Matlab file for the configuration and development of ANFIS model with the current signal used as input and the point locations as the target to the model. the model was inserted into the power system model in SIMULINK with the effectiveness in HIF detection and location tested. It was found out that the percentage maximum error deviation in point location was 10% which occurred at the first point location in table 3. This results show the effectiveness of the ANFIS model developed in the detection and location of HIF at minimal deviation errors.

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