A Proposal Technique of High Impedance Fault Detection Using Adaptive Neuro- Fuzzy Logic Control

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ABSTRACT

High impedance fault HIF produced when an energized conductor falls and contact with an objects have high impedance like: tree limb, concrete walls, or falls down to the ground. The importance of these undetectable faults is represent a safety hazard, also a risk of arcing that causes ignition of fires. This type of fault is cannot be detected by overcurrent protections . The techniques of detecting HIFs are depending on harmonic analysis of the line current. In this paper, a proposed technique used depending on the measure of the 3^{rd} harmonic. Takagi-Sugeno fuzzy controller is proposed and the rules are trained off-line. The practical results show the ability of the controller to detect and distinguish the HIF with high accuracy. The magnitude and angle of 3rd harmonic were 1% of fundamental and 80^0 respectively. The experiment results obtained using the NI 6250 data acquisition board and Matlab real time toolbox.
Keywords: High Impedance Fault (HIF), Takagi-Sugeno fuzzy (TS Fuzzy), Adaptive Neuro Fuzzy Logic System (ANFIS),overcurrent relay, Fast Fourier Transform(FFT).

INTRODUCTION

The conductors of distribution networks are always facing in the risk of occurring unexpected contacts with the surrounding objects like walls of building, trees limb, and ground surfaces. These objects are always close to the conductors of distribution networks, this will increase the possibility of happening these contacts all the time. High impedance fault is an unwanted electrical contact of an energized conductor and an objects have high impedance [1]. These objects are resist against carrying current on the distribution conductor and produce insufficient fault current that cannot be detected by conventional protection such as overcurrent relay and fuses [2].The sign of this type of fault is a function of the contacted object surfaces such as concrete, dry, and wet surfaces in general the contact will result an “arcing fault” with increase in RMS fault current. Typically, an HIF exhibits arcing and flashing at the point of contact [3]. Figure (1) shows the HIF due to earth contact. Many proposed techniques have been used for improving the detection of high impedance faults in distribution networks:

1. Sustain increasing in the phase angle between 3^{rd}harmonic of the line current with respect to the distribution phase voltage. [4].
2. incremental variance of even order harmonic power [5]
3. wavelet coefficients of the line currents [6]
4. energy variations in a concerned frequency band [7]

In this paper the capabilities of Adaptive Neuro Fuzzy Logic System Control is used to detect high impedance faults in electrical distribution feeders. Design of a Fuzzy unit based approach for an accurate HIF detection algorithm was presented. The protection scheme based on microcomputer combined with digital signal processing analysis to discriminate and identify

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HIFs on feeder by measure magnitude and phase angle of 3rd harmonic with duration of time more than 0.5 second.

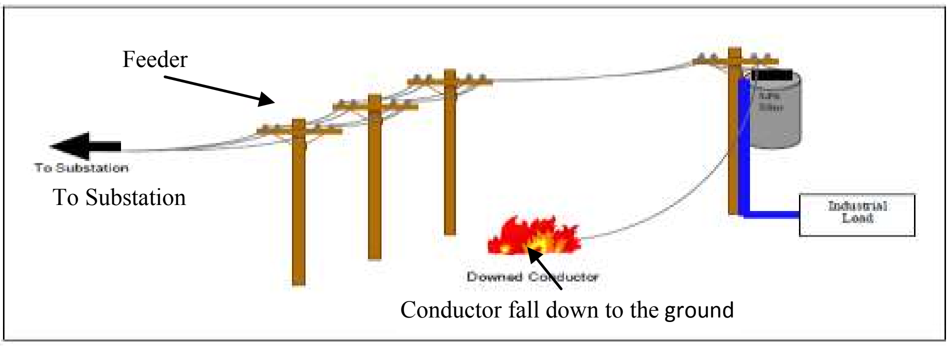


Figure (1) Feeder Downed Coductor [3]

Feature Extraction for Detecting HIF

Tracking harmonics is usually used for the fault detection. However, power systems have time-varying harmonics due to applications of power electronic devices, switching and fault events [8]. After many experiments tests the threshold values for magnitude and phase angle of 3rd harmonic have been specified. For 3rd harmonic magnitude a 1% of the magnitude of fundamental line current was set, and for the phase angle of 3rd harmonic, the threshold between50^0 and 150^0 with respect to line voltage was set [9]. Before the fault happens, the line current is in normal value without harmonics content or the harmonics are less than the threshold values. After the HIF occur, the rms of the load current is increased but not sufficient value for the overcurrent relay to act. High impedance fault detection requires inputs from the three phase and ground currents. In order to get an approximation of the current components, the mathematical models are used. The fundamental waveform of the current and its harmonic components, can be written [10]:

$$i(t) = \left\{ I_0 + \sum_{i=1}^{m} I_{fi} \cos(\omega_{fi} + \theta_{fi}) \right\} \cos(\omega_0 t + \theta_0) \quad \ldots (1)$$

Where:

I_o is the amplitude of the fundamental component,

ω_o is the radian frequency,

I_{fi} is the amplitude of the harmonic current the flicker component,

ω_{fi} is the radian frequency of the flicker current component,

m is the number of flicker component ,

θ_{fi} is the angle of flicker component.

θ_0 is the phase angle of the load current depends on the load

The outputs real-time of FFT are the amplitude of the harmonic component, the harmonic frequency, and harmonic phase angle of spectral content in the input signal. The harmonic analysis using FFT is the key in study of high impedance fault. In this paper the FFT block in Matlab/Simulink version R2013was used as a signal processing to find the main component of the signal (3rd harmonics and phase angle of 3rd harmonic with respect to the line voltage) .

Adaptive Neuro Fuzzy Inference System Control

Fuzzy systems are suitable for uncertain or approximate reasoning especially for the system with mathematical model that is difficult to derive. Fuzzy logic controllers play an important role in many practical applications. There are many fuzzy inference mechanisms in fuzzy logic control system from which Takagi-Sugeno is chosen in this study instead of mamdani type where mamdani type needs big computation time and large data memory and [11]. It maps inputs through input membership function and related parameters, then through output membership function to outputs. ANFIS uses back-propagation or a combination of back-propagation and least square estimation for estimation the membership function parameters[12].

The most important point in classification of data by ANFIS is to design the rules of fuzzy logic [13]. The inputs to the controller are the magnitude and phase angle of the 3rd harmonic, for single phase detecting shown in figure (2). The decision to declare HIF occur in any current phase depends on the existence of the 3rdharmonic.

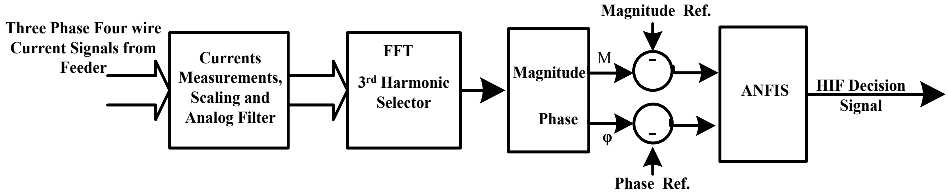


Figure (2) Structure of Control system for one phase

Modeling System and Design Control

The system model selected consists of an 11-kV feeder of ~25KM in length, the loads are consists of resistive load of 40KW as shown in figure (3).

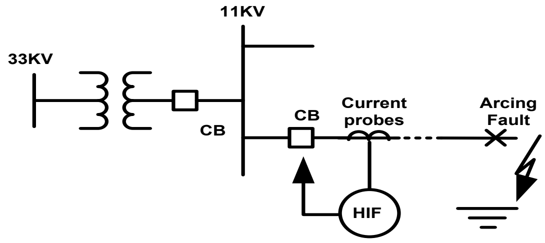


Figure (3) Power System model study

The three phase and ground wires as four inputs to currents measurement through currents probes, scaling to match the values of electronic circuits and analogue high pass filter to eliminate the high frequency components and the noise. The signals inter the microcomputer through input/output ports and storage in the memory, the FFT is used to select the 3rd harmonic for detecting the HIF. The inputs data to the controller are two vectors of 3rd harmonic parameters magnitude and angle. The input universe of discourse Fuzzy Logic is split into 3 triangular membership function MFs with 50% overlapping. Therefore, for two inputs, 4 control rules consequent linear functions need to be determined. The rules of the ANFIS designed shown in table (1). The procedure is performed using the ANFIS included in the Matlab/Fuzzy Logic Toolbox. The harmonic selector, fast Fourier transform and ANFIS control system designed using MATLAB\Simulink is shown in figure 4. The ANFIS control design structure and surface structure are shown in figure (5a) and (5b) respectively. The resultant of controller design information is shown in Table (2).

Table (1) The rules of TS Fuzzy Control Design for HIF

The output of the TSFuzzy Controller	Magnitude of 3rd harmonic (M>1% of fundamental)	Phase angle of 3rd harmonic (50<angle<150)
0	0	0
0	0	1
0	1	0
1	1	1

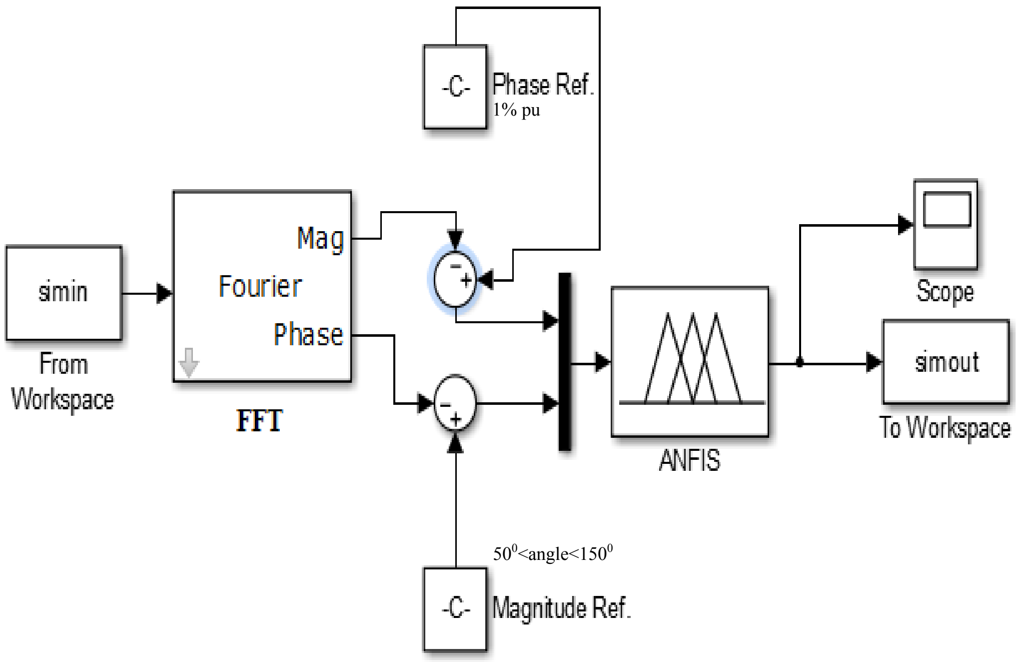
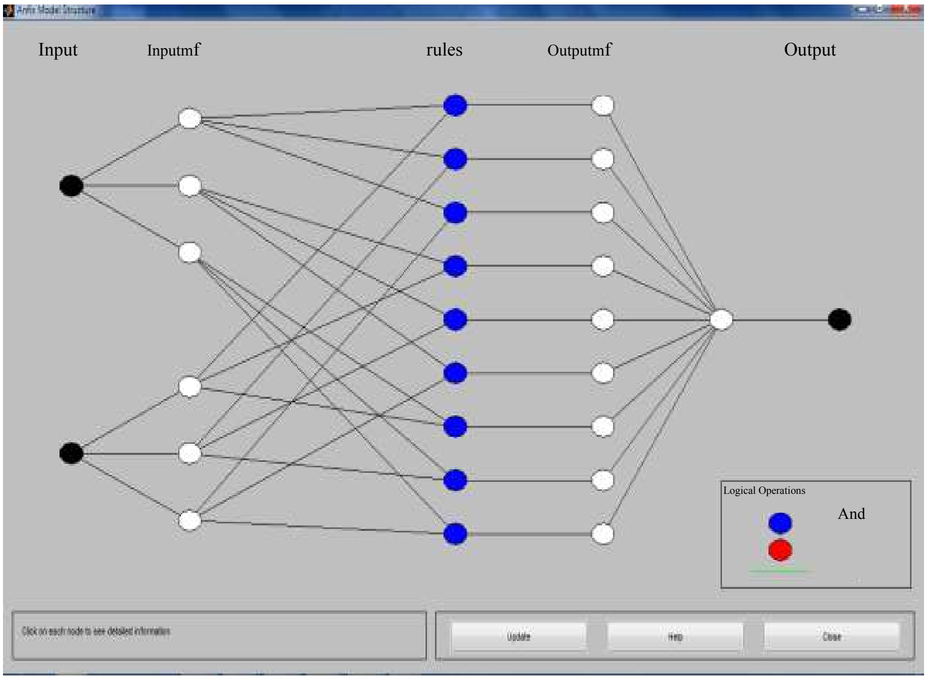
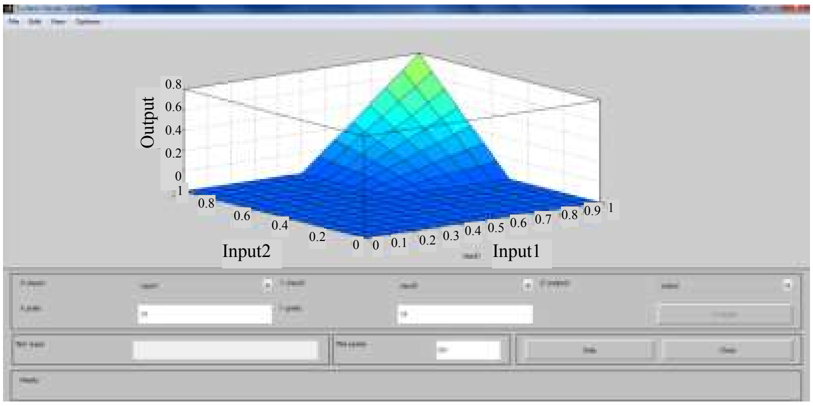


Figure (4) Control design using Matlab



(a)



(b)

Figure 5 (a) ANFIS design structure (b) The surface of ANFIS

Table (2) ANFIS information

Number of nodes	35
Number of linear parameters	9
Number of nonlinear parameters	18
Total number of parameters	27
Number of training data pairs	441
Number of fuzzy rules	4
Testing error	5.004e-05

Algorithm Criteria

Figure (6) shows HIF-declare algorithm. Firstly the memory should be build up and store the steady state conditions of voltages and currents on the feeder as Ms. It does this process by taking four samples at least, from i=0 to 4, where the ith sample measurement of Mi is stored at every-time. After taken four samples this mean i>4, the fifth sample measurement M_5 will be compared with the previous measurement of four samples taken. If the difference of load step with the range of (Ms-Mi)>0.1pu (the limits can be adjusted), the first flag will set to one. Following this flag, the algorithm checks the similar condition in other two phases to confirm HIF occur in single phase. In this work, the HIF assumed is single phase; two phase or three phase faults are not considered. If the angles of 3rd harmonic settle to within the ranges specified then the second flag will set to one. When these two parameters (magnitude and phase angle) in specified range of HIF, the output of control system will be =1. If the fault conditions still exists for more than 0.5 seconds, this will be compared with total increment in the line-current which must be more than the normal value of maximum load then the HIF will be declared.

Practical Test of HIF

The study model is assumed the feeder in steady state condition without transient condition. The lab model used in this study includes, the host computer that was interfaced with the HIF and feeder system hardware through the input/ output interface software and NI 6250 data acquisition board. The details of the practical prototype in appendix. The controller algorithm is developed in the Matlab. The power circuit consists of three phase supply of 380V and 5KW load. The signal taken from line current and sampled at sample frequency Fs=5KHz or t_s=0.2 msec more accurate for measured 3rd harmonic and the phase angle, the measured values of HIF fault taken and stored in M-file of Matlab. Figure 7a and b show the phase current without and with existing HIF respectively. Before occurs of the fault, the current is in normal operation value without harmonics as shown in figure8a, the current was 23A and the angle of

3rd harmonic was 0.70. After the HIF has been applied by downing one of the three phase conductor to the sand soil. The arcing at touch point will appeared results is an increase in the load current; the current is 28A the angle is 80.70 as shown in figure8b. The result of the experiment shown in table (3). Figure (9) shows the experimental model.

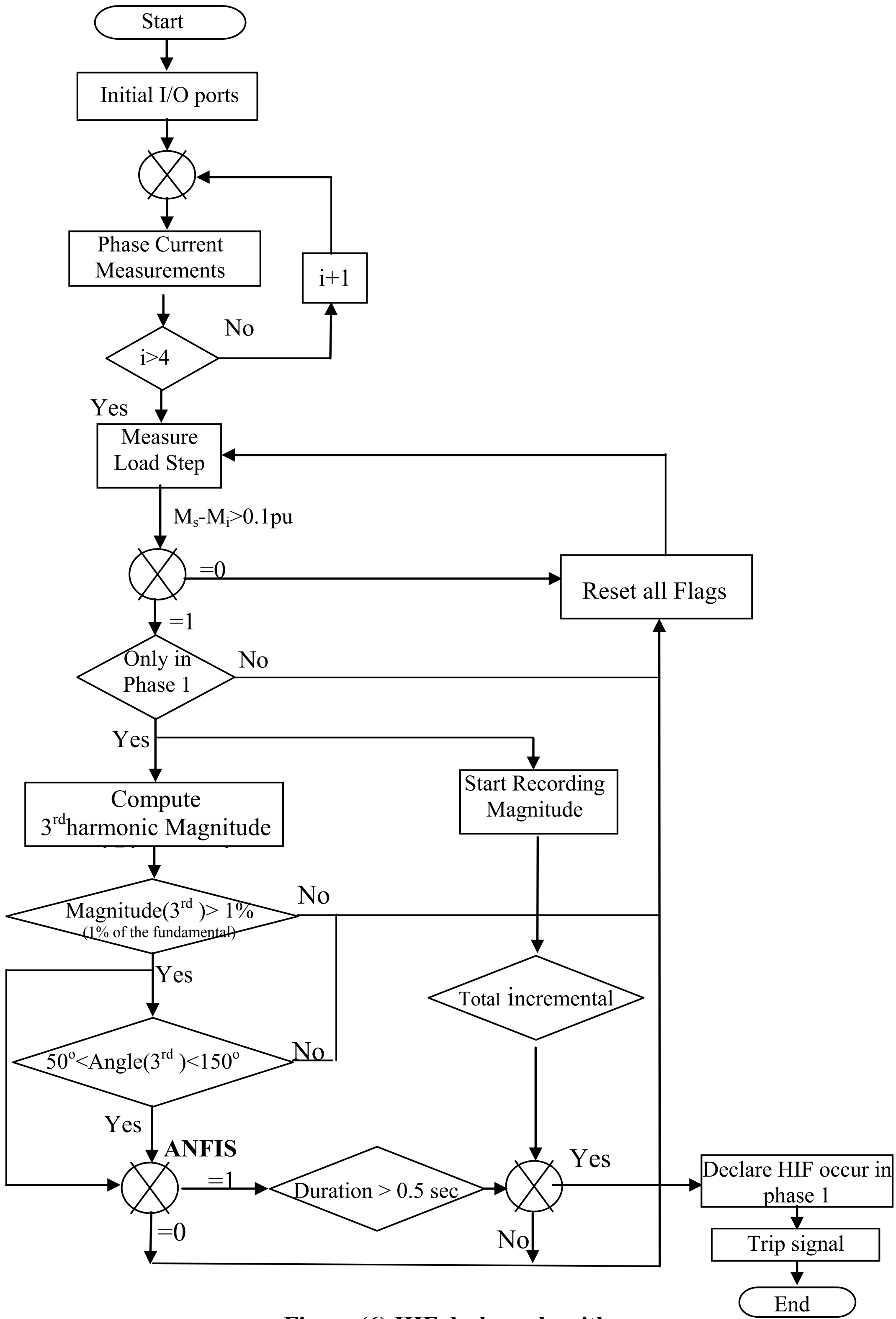
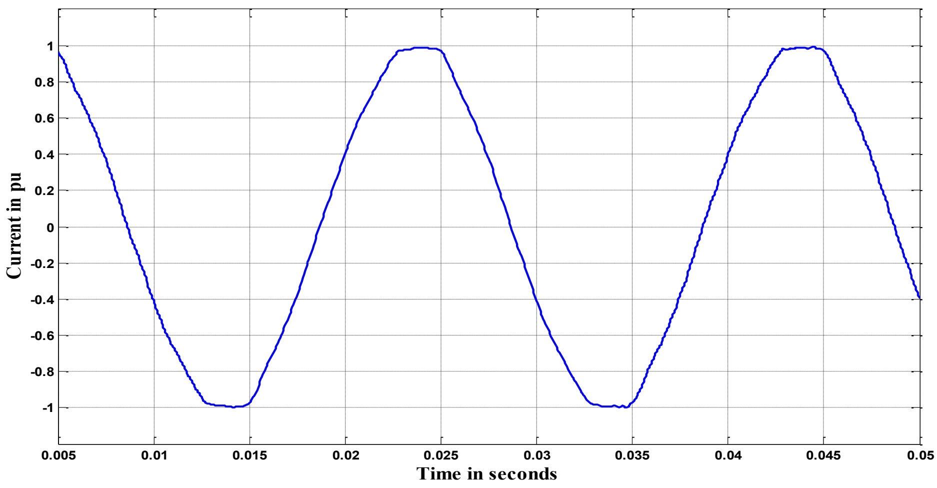
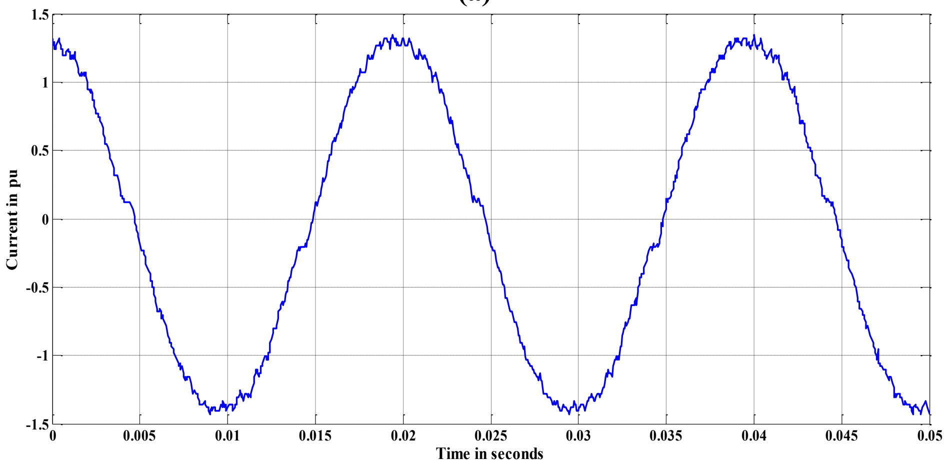


Figure (6) HIF declare algorithm



(a)



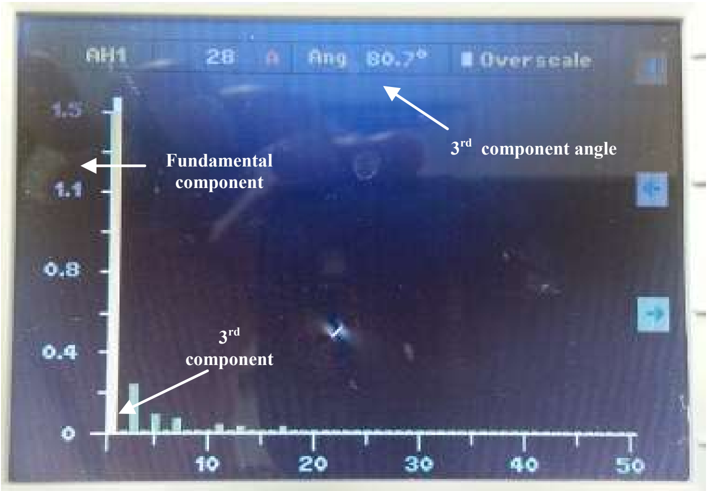
(b)

Figure (7) Phase current a-without HIF b-with HIF

Table (3) The phase current and 3rd harmonic before and after HIF

Phase Current and 3rd Harmonic	Before HIF	After HIF
Phase Current	23A	28A
3rd Harmonic Magnitude	0.001	2A
3rd Harmonic Phase angle	0.7	80.7

(a)



(b)

Figure (8) Phase current and harmonics content(a) Before HIF(b)After HIF

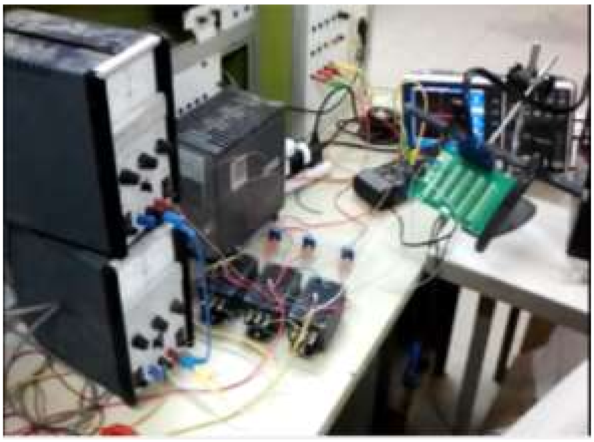


Figure (9) shows the experimental model.

CONCLUSIONS

In this paper, Takagi-Sugeno fuzzy control system algorithm was used to detect High Impedance Fault. The tuning algorithm is performed off-line employing the concept of Adaptive Neuro-Fuzzy Inference System (ANFIS). In this study magnitude and phase angle of 3rdharmonicswas used to detect the HIF. The controller algorithm is developed in the Matlab. The experimental results show that the proposed controller can provide an adequate performance for detecting HIF. The existence of the 3rd harmonic magnitude, phase shift and slight increase of load current for duration of more than 0.5 seconds these parameters confirm the existence of the HIF. The practical results that obtained show the proposed technique used was reliable for detecting HIFs.

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APPENDIX

The practical prototype of high impedance fault detection