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Research Article

Fault Detection of Distribution Feeder Based on Wavelet Transform and Power Spectrum

Mousa K. Wali, A.N. Hussain and Hani. W.F
Department of Electrical Power Engineering Techniques, Electrical Engineering Technical College, Middle Technical University, Baghdad, Iraq

Abstract: The High Impedance Fault (HIF) is abnormal event occurred in distribution system feeder whenever the cable downed on the tree, sod, towers and any objects have high impedance which produced little current passes through the cable. So; the protective devices cannot identifying this lightly current because it allocated only for detecting high faulty current (low impedance fault). This situation caused dangerously cases to the human and environment like shocking and firing. The Capacitor Bank (CB) and Nonlinear Load (NL) have waveform nearby to HIF waveform. So; this study proposed technique has ability to recognize between the HIF, CB, NL and other normal working have same waveform. The MATLAB/Simulink is used to simulate distribution feeder associated with HIF model, CB, NL and Linear Load (LL).The signals extracted by simulation decomposed by Wavelet Transform (WT) in order to extract the HIF signals and other feeder incidents. Power Spectrum (PS) technique has been used to identify HIF and differentiate it from any usual cases on feeder.

Keywords: Distribution system, HIF, MATLAB/Simulink, PS, WT

INTRODUCTION

A HIF is an extraordinary case and difficult to identify on feeder. HIF results via a feeble electrical communication between main conductors and (tree, sod, road surface) or other bodies which restrict the flow of fault current to a level less than other fault current measurable via security devices. The current result in this event is between 10A and 50A of feeder. The problematic of untraceable HIF leads to hazardous situation corresponding to shock and fire. HIF does not to do any risk to feeder, unlike, the protecting devices in feeder predictable.

The HIF first time was found at 1970. Researchers have tried to search about the physical characteristics of HIF since 1970 with positivity toward realize numerous features in the physical current signals which create the detection valuable (Hou, 2007).

HIF has various physical characteristics with important features such as little current and arcing. The latter is due to air gap caused by little contact occurred with the ground. Air gap is found sometimes in (sand, concrete etc.). When the air gap collapses, a little current resulted, therefore, it cannot be identified by protective devices.

The researchers discovered there are too much electrical circumstances which have physiognomies like HIF (CB, NL, air switching). The algorithm which proposed for disclosing HIF should be accomplished to differentiate between HIF and any usual event in feeder. Many of disclose method requests an enormous calculation recycling step for statistics extract of signals. The extracted signals applied to catch reveal parameters (Conrad and Dalasta, 2009; Russell *et al.*, 1988; Benner and Russell, 1997; Yu and Khan, 1994). After 1970, researchers have searched to realize totally consequences for this type of mistake. HIF has harmonics; however, revealing technique desire to distinguish HIF from other event by extracted the signals of feeder. The signals treating examines on current signals, making an allowance for each and every likely feeder circumstances, can be recycled to the progress algorithms, which are constructed upon frequency and time domain and this extremely expands the HIFs detection capability in feeder . Rather than examining time domain and frequency domain facts, the mixture analysis of low frequencies and high frequencies can be realized by the de-arrangement of the measured current signal by using WT (Lai *et al.*, 2005; Akorede and Katende, 2010; Sedighi *et al.*, 2005; Costa *et al.*, 2015).

In this study, WT technique is used for signals extraction; usual current waveform and an arcing fault waveform are studied in both frequency and time domain. The data obtained by WT is applied to PS

Corresponding Author: W.F. Hani, Department of Electrical Power Engineering Techniques, Electrical Engineering Technical College, Middle Technical University, Baghdad, Iraq, Tel.: +964-07700294967

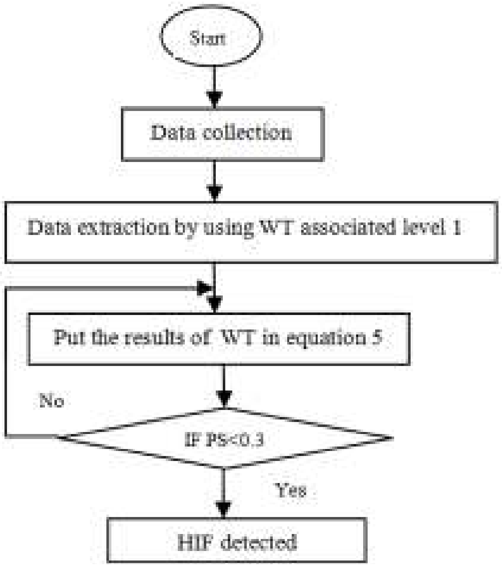


Fig. 1: Flowchart of the HIF detection method

technique which is recognizing HIF from other usual event in feeder.

MATERIALS AND METHODS

Proposed detection algorithm: The submitted algorithm used to reveal HIF and to differentiate it from any usual event in feeder, consist of three stages. The first concludes the current signals of feeder. The second conclude the WT which recycled to extract the data signals of faulty phase with level 1. The third achieves the PS methods to recognize the HIF from any accomplishments in feeder. The flowchart of the proposed detection algorithm is given in Fig. 1.

Discrete wavelet transform: The WT is an influential technique in the examination of transient occurrences for the reason that it has capability to extract time and frequency data from the transient signal. This segment makes available clearity details of wavelet analysis and best part deliberations. The signal can be processes by wavelet analysis therefore, afterward the decays, it signified at changed frequency varieties. This is realized by expansion and version of a mother wavelet concluded the signal. The Discrete Wavelet Transform (DWT) is used to development the statistics is set via:

$$x(c,d) = \frac{1}{\sqrt{c}} \int_{-\infty}^{\infty} f(t) \Psi(\frac{t-d}{c}) \quad (1)$$

where c and d are the continuous variables of dilation (scale) and translation respectively, $f(t)$ is the original data signal in one dimensional domain that is decomposed into two a new signals in two dimensional domain across c and d.

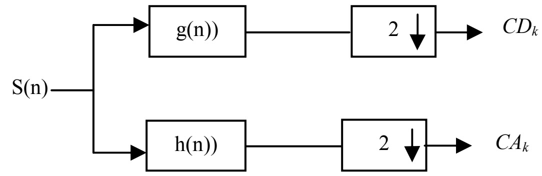


Fig. 2: First level of WT

In DWT function, the time scale of the digital signal is determined based on techniques of digital filtering. Filters with various cutoff frequencies at wide variation of scales are used to analyze this signal passing through it. The function of a DWT for a given signal *f(t)* with respect to a mother wavelet Ψ *(t)* is represented by equation:

$$DWT(m,k) = \frac{1}{\sqrt{a0^m}} \sum_n f(t) \Psi(\frac{k-nb0a0^m}{a0^m}) \quad (2)$$

where Ψ is the mother wavelet, a is the dilation parameter and b is the translation parameter. The two parameters (a, b) are associates of an integer value for m parameter, k is the integer variable by nature that indicates to a specific number of samples in an input signals of the wavelet, $(c = a0^m)$ and $(d = nb0a0^m)$ are produce a new set of expanded mother wavelets (daughter wavelets) depend upon original mother wavelets (Jamil *et al*., 2015). The generalized equation for deriving approximation coefficients and detail coefficients for wavelet decomposition is given in Eq. (3, 4) respectively. Figure 2 represents the first level used for detection (Wali *et al*., 2013):

$$CA_K = \sum_{i=0}^{M-1} S_{i+2*K} * h_i \quad (3)$$

$$CD_K = \sum_{i=0}^{M-1} S_{i+2*K} * g_i \quad (4)$$

where,
K from 0 to N (no. of samples of the signal)
M = The number of wavelet coefficient

Determining the PS of an interval indicate or illuminates which frequencies enclose the signal's control. The degree is the delivery of power standards by way of a task of regularity wherever "power" is deliberated to be situated the average of the signal. This is the square of the WT'S magnitude. In this study the PS of a time signal is computed using the function WT by Eq. 5 (Brigham, 1988):

$$PS = \frac{1}{N} \sum_{n=0}^{N} (CA_K)^2 \quad (5)$$

where,
X (n) = Approximation coefficients of signals
N = Number of Samples

Table 1: Condition working

Event	Simulation operation
CB working	Load usual: 30-100% of full load, Sending and receiving capacitor operative: 2.1 MVAR, exciting sending and receiving capacitor: 0, 4.2 MVAR.
Load working	Load usual: 30-100% of full load, exciting sending/receiving capacitor: 0, 4.2 MVAR.
NL working	Load standard: 30-100% of full load, exciting sending/receiving capacitor: 0, 4.2MVAR.

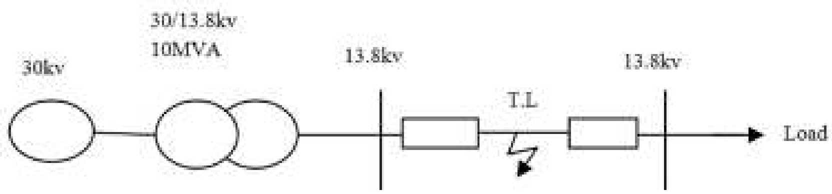


Fig. 3: Single line diagram of distribution feeder

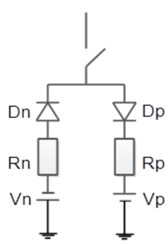


Fig. 4: HIF model

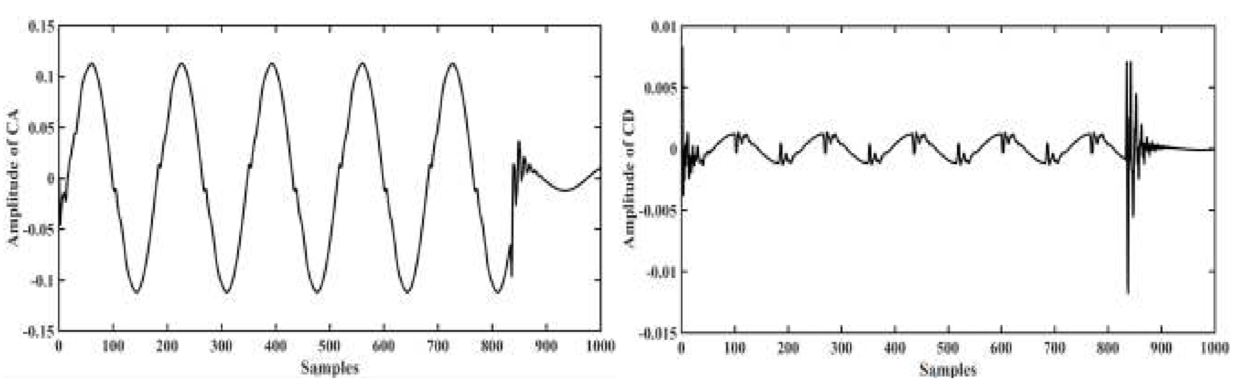
Distribution feeder: A distribution system in Fig. 3 is a single line diagram modeling with MATLAB/ Simulink in different state.

The generator which attached to the transformer in the system generates 30kv. The voltage ratio of transformer is 30/13.8 KV. The simulation system is running at 13.8 KV. This model is driven with LL, NL and variation load. The NL is presented with 6-pulse rectifier. The HIF reasons arcing and nonlinear activities like usual situations in feeder such as enhance capacitor, fluctuating load and transient. The displaying system has been sequentially running with LL and NL, the NL acts in the load when current wave does not vary directly with the load voltage waveform. While the voltage and current waves increase and decrease together in LL. The transient phenomena are caused by capacitor switching like HIF waveform. Therefore it is really essential to work out every HIF behaviors which matching with these conditions. Numerous conditions have been considered with this type as in Table 1.

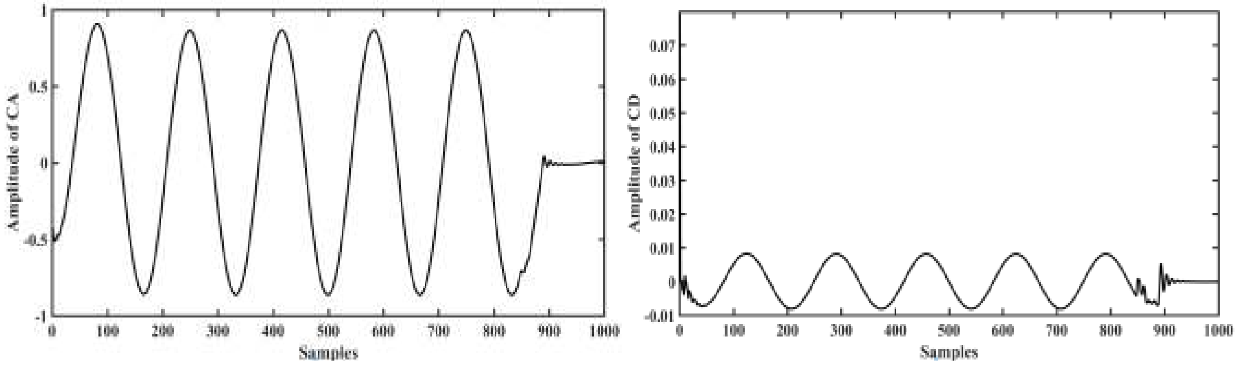
HIF simulation: The HIF typical in Fig. 4 is discovered at 2003. The scientists wanted to acquire model of HIF has waveform nearest to the real waveform in the past. After many experiments they proposed a new model of HIF which has two resistances varying between 300Ω and 1500Ω, two diodes and two direct current voltages varying between 1kv and 10kv (Sedighi, 2014).

RESULTS AND DISCUSSION

Signals extraction: In the modeling system, several working condition usually happening in the distribution system have been running with MATLAB/Simulink. The significant idea dealing with this system is to differentiate between HIF and any likability signals. This study matches with the current signals of feeder to acquire the characteristics of HIF. WT mode is used for signals extraction. The arrangement is contracting with fault signals which are occupied from feeder. A several waveforms are achieved in changed situation and parameters. When the simulation of all condition obtained, the signals extracted by using WT with first level. All the kind signals of HIF, LL, CB and NL extracted by WT corresponding approximate and details coefficients (ca,cd) are shown in Fig. 5 to 7.

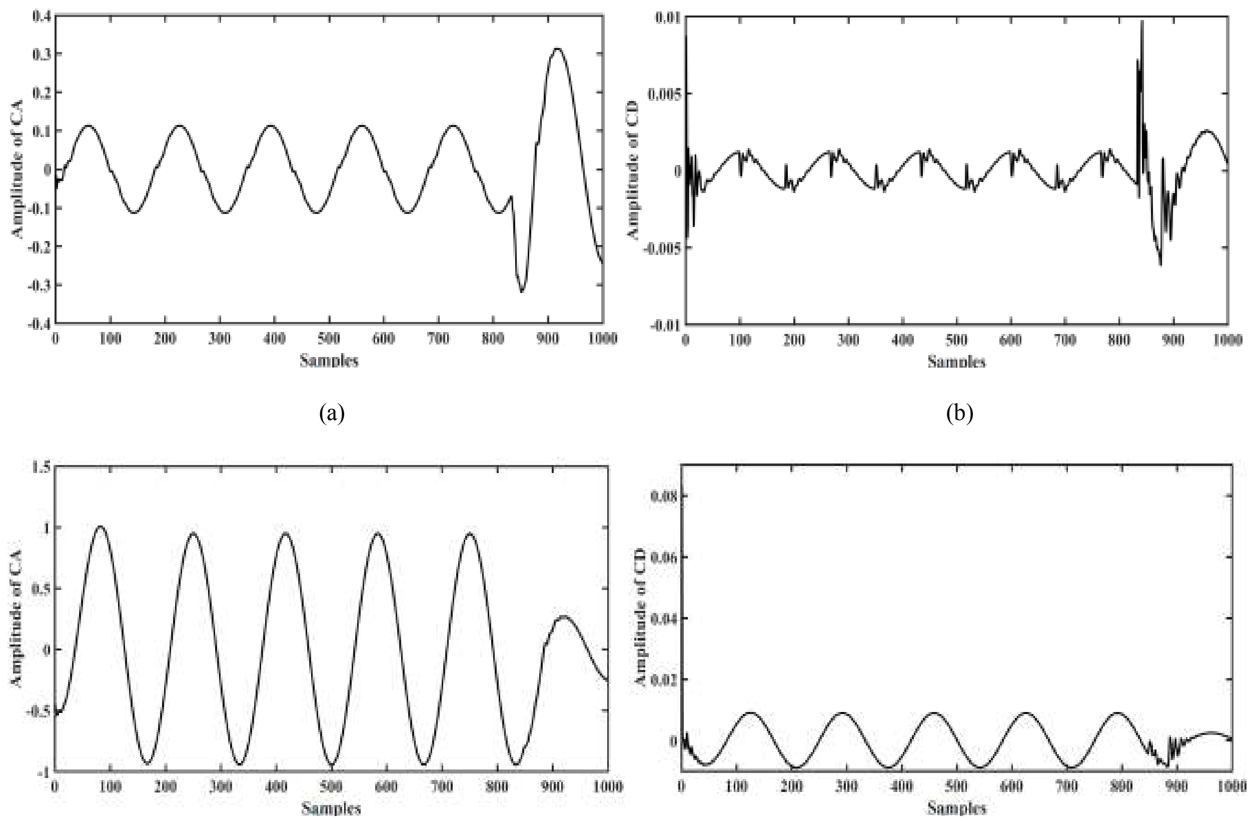


(a) (b)



(c) (d)

Fig. 5: a and b are the approximate and detail coefficient of HIF with LL. c and d are the approximate and detail coefficient of normal working LL



(c) (d)

Fig. 6: a and b are the approximate and detail coefficient of HIF with CB. c and d are the approximate and detail coefficient of normal working CB

Detection results: The WT followed by PS is a new simple technique to detect HIF and has a lot of benefits different from other techniques because it detect the fault with short time, less data and the detection take placed with first level of WT without training or testing. There are 250 signals of HIF and 750 of different events in the system. All these cases analyzed by WT to extract the approximate coefficient which process by PS techniques to distinguish HIF and identify it from other cases as in Table 2.

Figure 8 shows the detectable of HIF and no fault states for CB, LL and NL. This figure shows the HIF region bounded by PS less than 0.15 values, while the no fault region is greater than 0.3.

The comparison of the result of this research with other researchers is shown in Table 3. Hong and Huang

Table 2: Results of PS

HIF			Normal working		
LL	NL	CB	LL	NL	CB
0.049	0.127	0.085	0.300	0.3931	0.3318
0.029	0.11	0.064	0.301	0.3936	0.3325
0.019	0.099	0.053	0.302	0.3941	0.3332
0.014	0.094	0.047	0.303	0.3946	0.3339
0.01	0.088	0.043	0.306	0.3951	0.3346
0.008	0.086	0.041	0.31	0.3956	0.3353
0.0065	0.085	0.039	0.313	0.3961	0.336
0.0054	0.084	0.038	0.315	0.3966	0.3367
0.0045	0.084	0.037	0.319	0.3971	0.3374
0.0039	0.084	0.007	0.32	0.3976	0.3381
0.0034	0.083	0.007	0.321	0.3981	0.3388
0.003	0.083	0.006	0.322	0.3986	0.3395

Table 3: Literature review corresponding the accuracy detection

Reference	Types of detection	Accuracy
Banejad and Ijadi (2014)	Discrete wavelet transform and fuzzy function approximation	94.19%
Ghaderi *et al*. (2015)	Support Vector Machine	93.6%
Abdulhamid *et al*. (2012)	Artificial Neural Network	97.5%
Hong and Huang (2014)	Genetic Algorithm	98.4%
Present work	Power spectrum based on wavelet	100%

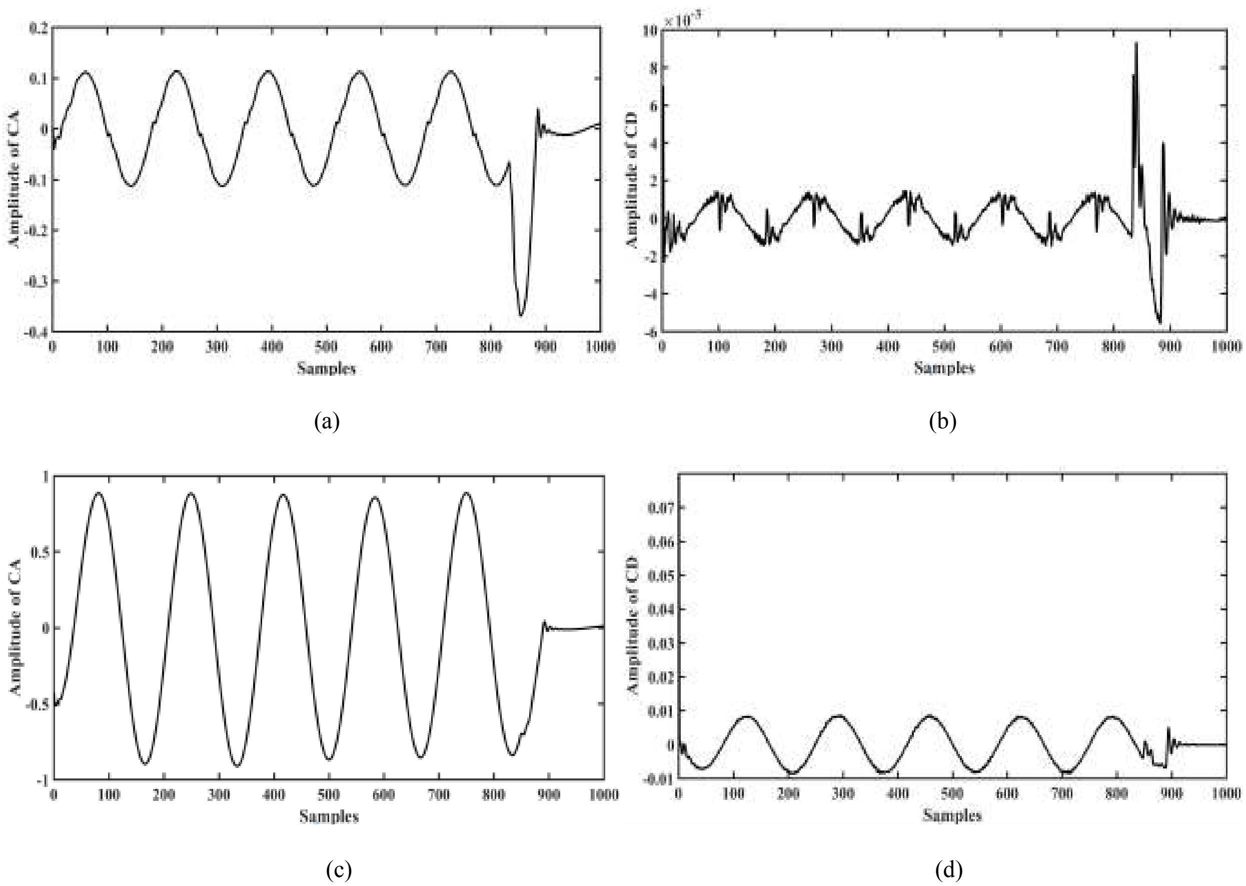


Fig. 7: a and b are the approximate and detail coefficient of HIF with NL. c and d are the approximate and detail coefficient of normal working NL

(2014) got 98.4% detection by using Genetic algorithm while Ghaderi *et al*. (2015) achieved 93.6% based on Support Vector Machine. This research gained 100% detection based on PS of approximate signal of WT.

CONCLUSION

In this study, HIF and other cases in feeder are running by MATLAB /Simulink All the signals

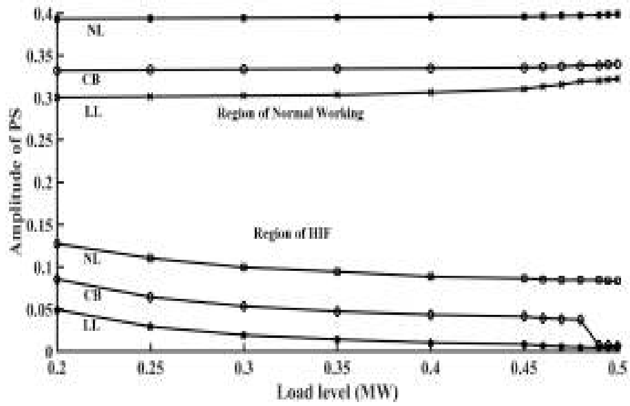


Fig. 8: Detection level

acquired during the simulation evaluated and extracted by WT which can differentiate when HIF take places, the new technique of WT followed by PS has ability to recognize between fault and non-fault current of distribution system. The proposed algorithm distinguishes between HIF, CB, NL and any normal condition on feeder. This method can be developed and improved by using other HIF model with similar waveforms.

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