International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 3 Issue 9, September- 2014

Development of Fault Detection Algorithm for High Impedance Faults in Distribution Network using Multiresolution Analysis

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Abstract- ***This paper represents a high impedance fault detection algorithm using Multiresolution signal analysis. Wavelet transform is a signal processing technique, used for detection of faults in distribution systems. The wavelet transform is applied for the analysis of the power system transients, because of the ability to extract information from the transient signal simultaneously in both time and frequency domain. This paper aims to prove that the Wavelet Transform is a reliable and computationally efficient tool for distinguishing between high impedance fault current and normal current condition. The simulated results presented clearly show that the proposed technique for power distribution system facilitates the accurate discrimination between the high impedance fault current and normal current. A Simulink model of a radial distribution system for normal operation and high impedance fault condition are developed. The simulated current signals are decomposed using the wavelet transform and the detailed coefficients are extracted which is then fed into the Mat lab program for discrimination among the both operating conditions of a radial distribution system. This paper presents an approach based on a combination of Simulink and Discrete Wavelet Transforms for detection of HIF fault in a radial distribution system.***

Key words: HIF, Multi resolution analysis, Mat lab, wavelet Transforms

I. INTRODUCTION

A distribution feeder is a very important component of a power distribution system. Any fault on a feeder side causes disturbance in distribution of power to the consumers. Hence its reliable operation and proper functioning is very important factor for the electric utilities in order to give continuous power supply to the customers. Hence the faults on feeder side are to be cleared very fast especially High Impedance Faults (HIF). Otherwise it will result in service interruptions which reduce system reliability, dependability and continuity. In addition to this HIFs can result in fires in the premises of households, electric shock to the personal. Hence it becomes responsible for electric utilities to detect, identify and clear the faults as fast as possible.

The detection of HIFs is important as HIFs result in very low currents which are often not detectable by conventional overcurrent relays. A HIF occurs, when a conductor breaks and falls on a nonconducting surface such as asphalts road, sand, grass or a tree limb producing a very small current. These faults are difficult to detect when the impedance at the point of fault is high enough to limit the fault current to the region unprotected by conventional over current devices.

The majority of HIFs occur at distribution voltages of 11KV and below and it is very difficult to detect the HIFs at the lower voltages. There have been several methods developed for arcing fault detection. In [1] HIF fault detection was proposed using low frequency spectrum of current. In [2] a fault detection algorithm for HIF using a root mean square current was presented. In recent years a wavelet transform method has been proposed for HIF in the distribution networks [3-4].

II. STATEMENT OF PROBLEM

High-impedance faults (HIFs) are difficult to detect in distribution networks through conventional protection schemes such as overcurrent and earth fault relays, as non-conductors present high impedances to current flow due to their material, so a fault of this type will not appear to the protection equipment as an abnormal condition.

The high impedance faults result when an unwanted electrical contact is made with a road surface, sidewalk, tree limb, some other surface or object which restrict the flow of fault currents to a level below the operating value of over current or earth fault relay The failure of HIF detection and classification may lead to potential hazards to human beings and potential fire [5].

HIFs on electrical distribution feeders involve arcing and nonlinear characteristics of fault impedance which causes distortion in the measurement of current signal. The typical fault current levels for different surface material are given in Table I [6]. Downed conductors on dry asphalt dry sand may not be detected, since both surfaces may not produce arcing. On the other hand, reinforced concrete provides the most arcing.

S. No	Type of Surface	Fault Current
1.	Dry asphalt	0
2.	Dry sand	0
3.	Concrete (non-reinforced)	0
4.	Wet sand	15
5.	Dry sod	20
6.	Dry grass	25
7.	Wet sod	40
8.	Wet grass	50
9.	Concrete (reinforced)	75

In odere to simulate HIF for a distribution network a HIF model is considered

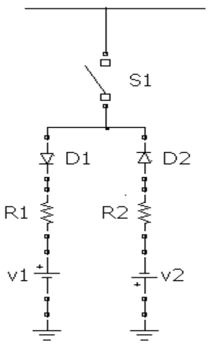


Figure 1: HIF Model

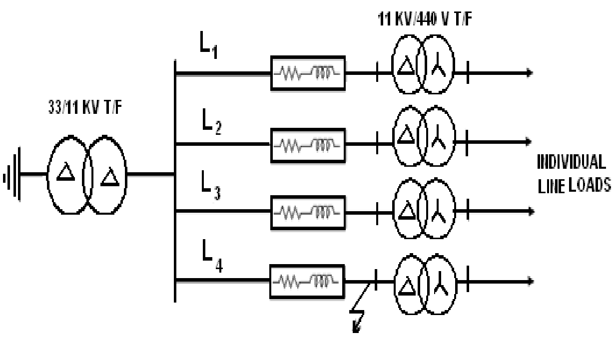


Figure 2; single line diagram of the distribution system

III. Wavelet Transforms

A wavelet is a waveform of effectively limited duration that has an average value of zero.

The definition of discrete wavelet transform for a given signal x (t) with respect to a mother wavelet Ψ (t) is shown in Eq. 1.

$$\text{DWT}(f, m, n) = \frac{1}{\sqrt{a_0^m}} \sum_{k=-\infty}^{\infty} x(t)\psi\left(t - \frac{a_0^m n b_0}{a_0^m}\right) \quad (1)$$

a_0^m, $nb_0a_0^m$ are the scaling and shifting parameters respectively.

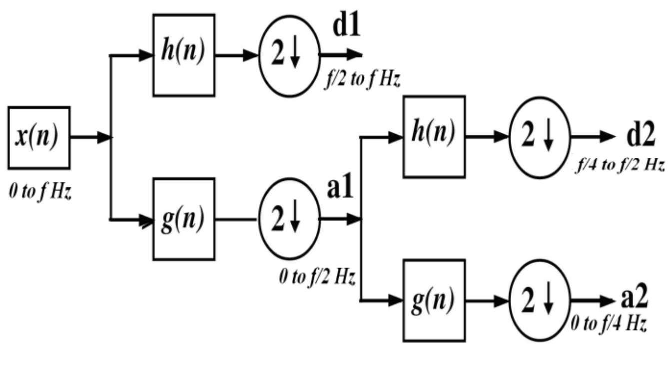
MRA is one of the tools of discrete wavelet transform which decomposes the original signal into two other signals which represents a smooth and detailed version of the original signal. This algorithm is developed by Mallat [7]. MRA is effective for analyzing the information of the signals. The DWT is computed by analyzing the signal at different frequency band with different resolutions by decomposing the signal into coarse approximation and detail information[8]. Let x[n] be a discrete time signal, where n is an integer and this signal will be passed through low and high pass filters to find the coarse and detail approximations respectively. If the low pass filter is denoted by its weighted sequence g[n], the output signal of low pass filter is then down sampled by 2 to produce the coarse approximation signal a[n] for the original signal x[n] and is written as

$$a[n] = \sum_{n} x[n].g[2k-n] \quad (2)$$

The high pass filter is denoted by its weighted sequence h[n], the output signal of high pass filter is then down sampled by 2 to produce the detail signal d[n] for the original signal x[n] and written as

$$d[n] = \sum_{n} x[n].h[2k-n] \quad (3)$$

The decomposition process can be done with successive approximations so that the original signal is broken down into many lower resolution components. Fig. 4. illustrates the procedure of wavelet decomposition for two levels with the bandwidth of the signal at each level. Let x[n] be a discrete time signal with sample rate of f Hz, where n is an integer and this signal will be passed through low and high pass filters to find the coarse and detail approximations respectively. The highest frequency component detail signal (d1) will be f/2 Hz. The band of frequencies represents the d1 signal will be f/2 Hz to f Hz. Similarly the band of frequencies in detail signal (d2) will be f/4 to f/2 Hz. The band frequency of low pass filter output, approximate signal (a1) will be in the range of 0 to f/2 Hz. Similarly, the band of frequencies of an approximate signal (a2) will be 0 to f/4 Hz.



Figure; 3 Wavelet Decomposition tree

IV. FAULT DETECTION ALGORITHM

The fault detection algorithm for synchronous generators is given below.

Step 1: Obtain the Current signal from the 11 KV Bus terminals of distribution network.

Step 2: The signal is analyzed for the required level of decomposition using wavelet from the wavelet family, for example three, four or five levels.

Step 3: Identify the fault through interpretation of wavelet coefficients

Step 4: Distinguish an HIF and normal operation.

V. RESULTS

A power system network with four feeders connected to load and source through distribution line of 10Km shown in the Fig. 1. is considered for simulation studies This power system network is developed in MATLAB7® using SIMULINK software and is shown in Fig. 4.

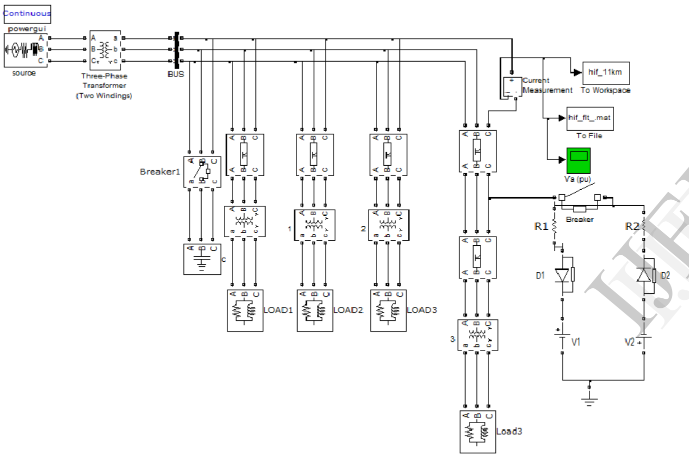


Fig.4. Simulink model for the High impedance fault simulation

The current signals are collected from 11kv distribution feeder through current transformer and these current signals are analyzed for the required level of decomposition using suitable mother wavelet. Here db4 mother wavelet is used. We analyzed these current signals for five levels. When we observe these signals in fault conditions there is a spike in d2 ,d3 and d4 coefficients. The PCA method is an optimal statistical technique to capture signal variability. The data matrix constructed to the signal obtained under normal conditions from samples of system output and PCA model is obtained using SVD. Same procedure is applied for fault condition and PCA model is constructed. Using the obtained PCA model faults are detected by the value of Q.

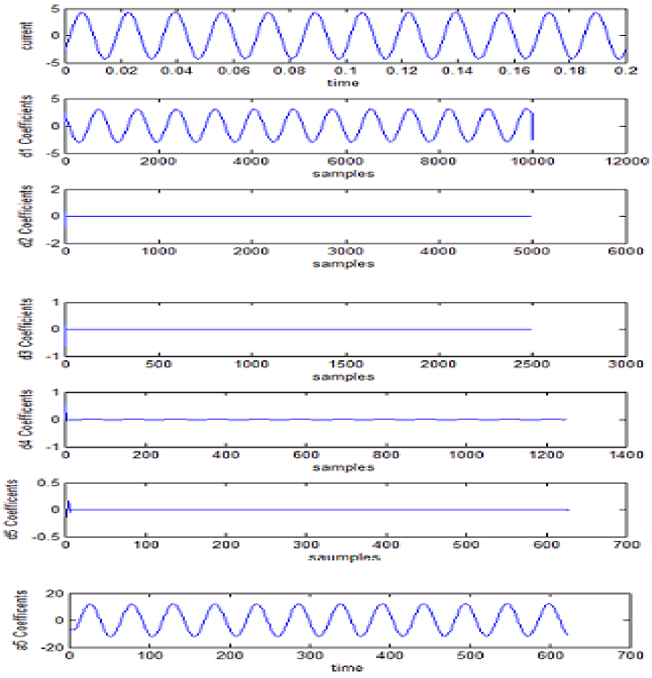


Figure 5: MRA of normal current for a distribution network

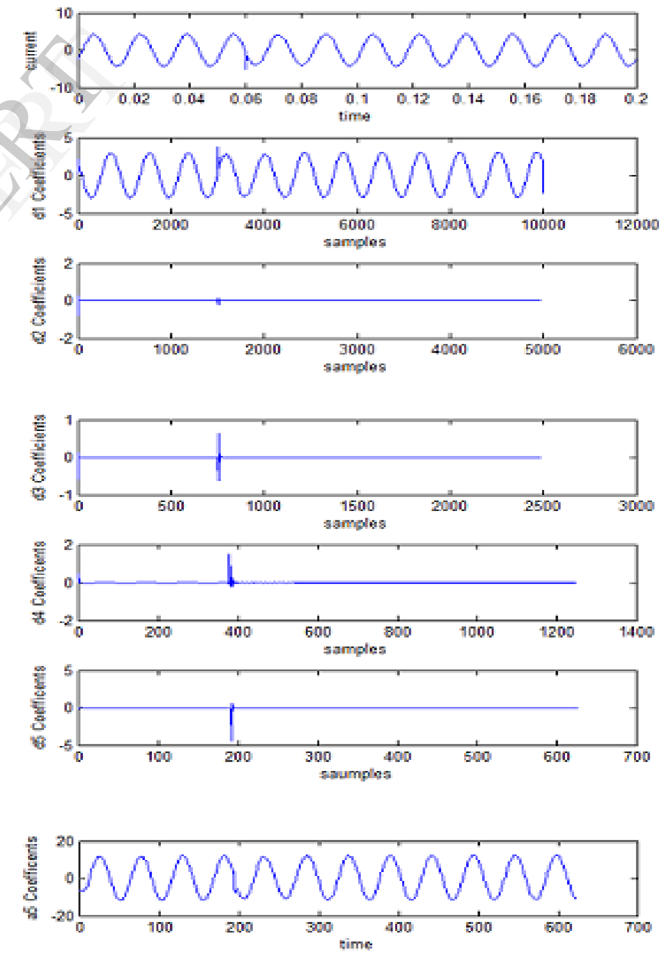


Figure 6: MRA of Hif current at 6km of a distribution network

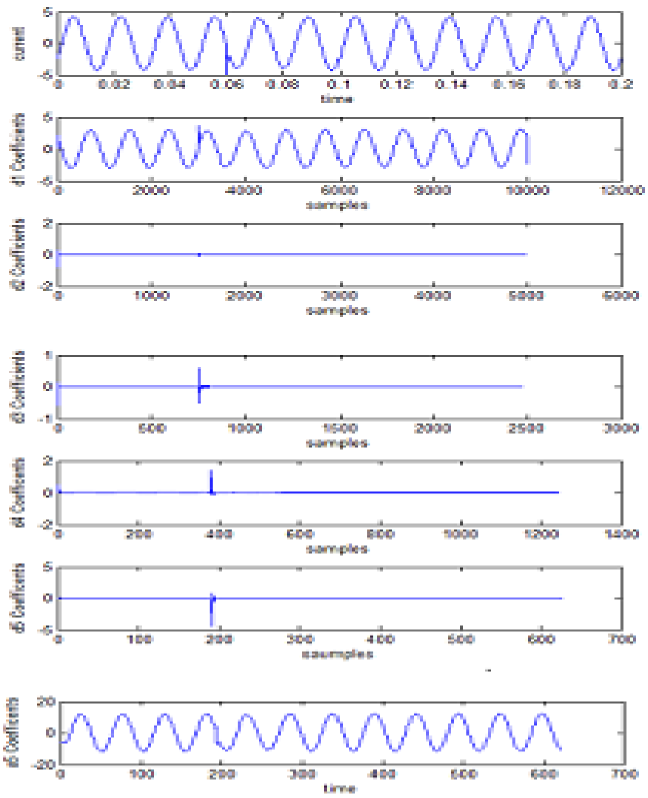


Figure 7: MRA of Hif current at 8 km of a distribution network

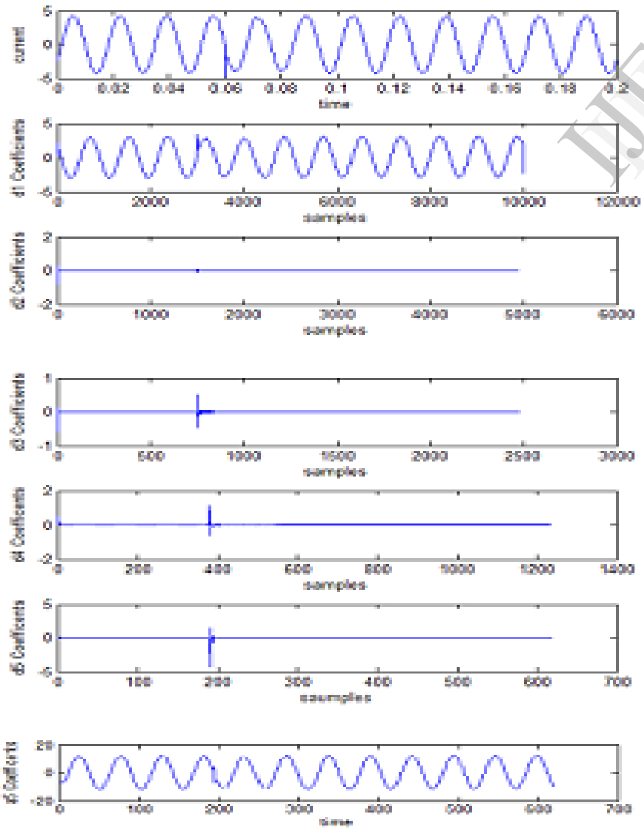


Figure 8: MRA of Hif current at 11 km of a distribution network

VI.CONCLUSIONS

The wavelet transform decomposition breaks up the signal into both time and frequency allowing for a complete and efficient description of the signal. This information is very critical in detecting the high impedance fault. It is observed from coefficients that fault is seen to be localized. The wavelet transform is applied to normal current operation and high impedance fault condition for distribution feeder at 6km, 8km and at11km. These currents are decomposed with 5th level DWT. As seen from results the decomposition of the fault phase currents are has larger value of magnitude. This cannot be detected by conventional relays. By this multiresolution signal decomposition analysis we can easily detect the difference in frequency characteristics and the duration of the transient event between normal non fault events and high impedance fault. In this analysis db4 wavelet is used.

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