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HIGH IMPEDANCE FAULT DETECTION AND CLASSIFICATION OF A DISTRIBUTION SYSTEM

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ABSTRACT:

High impedance faults (HIFs) are, in general, difficult to detect through conventional protection such as distance or over current relays. This is principally due to relay insensitivity to the very low level fault currents and/or limitations on other relay settings imposed by HIFs. Conventional protection relay system will not be able to detect the HIFs and trip the protection relay. HIFs on electrical transmission and distribution networks involve arcing and/or nonlinear characteristics of fault impedance which cause cyclical pattern and distortion. Therefore, the objective of most detection schemes is to identify special features in patterns of the voltages and currents associated with HIFs. Most conventional fault-detection techniques for HIF mainly involve processing information based on the feature extraction of post HIF current and voltage. Wavelet transform is best suited for HIF detection and for fault classification Neural networks is suited. This paper describes a new fault detection technique which involves capturing the current signals generated in a system under HIFs. The detection process is based on calculating the absolute sum of the wavelet transform detail coefficients for one period. Neural networks are used to discriminate HIFs from non fault conditions. Wavelet transform is used for the decomposition of signals and feature extraction. Principal component analysis (PCA) is applied for feature vector reduction and NN for classification. Fuzzy K nearest neighbour algorithm is also used to discriminate HIF from non fault conditions, this process also described in this work.

1. INTRODUCTION:

The high impedance faults result when an unwanted electrical contact is made with a road surface, sidewalk, sod, tree limb, some other surface or object which restrict the flow of fault currents to a level below that reliably detectable by conventional protection devices. The failure of HIF detection leads to potential hazards to human beings and potential fire hazards.HIF protection is primarily focused on the protection of people and property.

In the past two decades many techniques have been proposed to improve the detection of HIF in Power distribution systems. Some of these methods are mechanical methods, in these methods some devices are used to provide low impedance by catching the falling conductor. The installation and maintenance cost is very high. Electrical methods such as proportional relay algorithm, arc detection methods, Kalman filtering method, but each method has its own drawback. The early work examined arc frequency relaying and high frequency current detection but is not successful. The ratio ground relay was designed to trip for a fallen conductor, but the relay was more sensitive to earth faults than by simply measuring earth fault current. The Nordon HIF system monitored based on the third harmonic current calculations, but the system is installed on each breaker in the distribution system, but the cost increases. The reason for avoiding the power system frequency and its harmonics was that those signals vary substantially under normal as well as arcing conditions. Various techniques of fault detection encompass fractal techniques, expert systems, and dominant harmonic vectors. The availability of powerful microprocessors and signal processing algorithms has led to a wide range of new techniques to identify the waveforms associated with high impedance fallen conductor faults. The use of high frequency harmonics is not feasible in practical relay; the method that tries to reduce the limitation of frequency domain method is Wavelet transform method. So this work described a novel fault detection technique of HIF based on absolute sum of D1 coefficients by using different mother wavelets and suggested db4 is suitable for this purpose. The performance is tested under different fault resistances and fault distance. For classification data purposes traditional KNN (K nearest neighbouring algorithm) is used. But crisp KNN suffers some drawbacks. To eliminate these draw backs in this work described Fuzzy K Nearest Neighbour algorithm and neural networks.

2. MODEL OF SIMULATIONS:

The one-line diagram of a 50-Hz distribution system is given in Fig. 1. A transformer with rating11/25kV is connected to a 20-km transmission

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line and having a RL load with 5KW, 2KVAR, 25KV and non linear load (Universal bridge with snubber resistance and capacitance).The modelling of most distribution system components is quite straightforward. However, the most difficult model is HIF fault because most HIF phenomena involve arcing, which has not been accurately modelled so far. Some previous researchers have reached agreement that HIF is nonlinear and asymmetric, and modelling should include random and dynamic qualities of arcing. Modelling of HIF is very difficult,

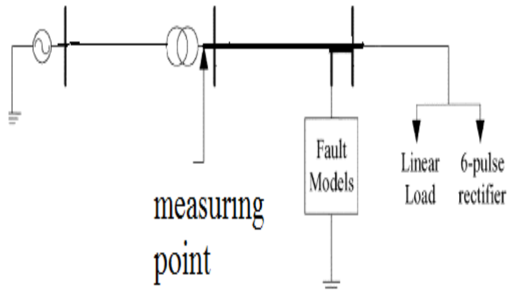

Fig1: One-Line diagram of a simulation model

because it involves an arcing which has not been modelled accurately so far. A new HIF model is used in this algorithm. Two diodes with two dc voltage sources are used to simulate HIF. It combines most advantages of previous models proposed and it remains simple and universal. Two diode fault model of HIF is shown in the fig2. This model comprises two DC

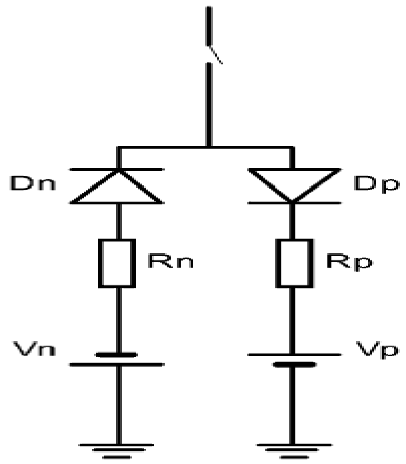

Fig2.Two diode fault model of HIF.

sources, which represent the inception voltage of air in soil and/or between trees and the distribution line. The two resistances represent the fault resistances: unequal values allow for asymmetric fault currents to be simulated. When the phase voltage is greater than the positive DC voltage the fault current flows toward the ground. The fault current reverses when the line voltage is less than the negative DC voltage .For values of the phase voltage between and no fault current flows.

3. Characteristics of HIF:

The high impedance faults have two main characteristics: the low fault currents and arcing. The first characteristic is happened because these faults produce little or no fault current. This fault current is furthermore reduced during the winter time in Cold Countries and therefore the detection of faults due to trees is more challenging. A typical characteristic of fault current is shown in fig3. The fault is simulated at 0.08sec (50Hz system with 512 samples per cycle).The second characteristic of high impedance faults is the presence of arcing phenomena as a result of air gaps due to the poor contact made with the earth or with an earthed object. These air gaps create a high potential over a short distance and arcing is produced when the air gap breaks down. However, the sustainable current level in the arc is not sufficient to be reliably detected. Part of this is due to the constantly changing conditions of the surface supporting the arc and maintaining high impedance. Therefore, a random electrical behaviour is an associated feature with the high impedance faults. As the arcing often accompanies these faults, it further poses fire hazard and therefore the detection of such faults is critically important. The characteristics of HIF current is shown in fig4. Due to the presence of arcing the V-I characteristics are non linear. The V-I characteristics of HIF is shown in fig5.

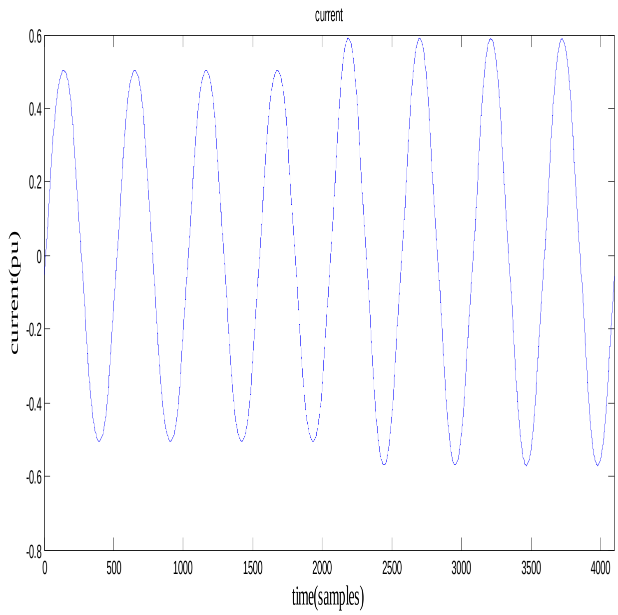

Fig3. Source current

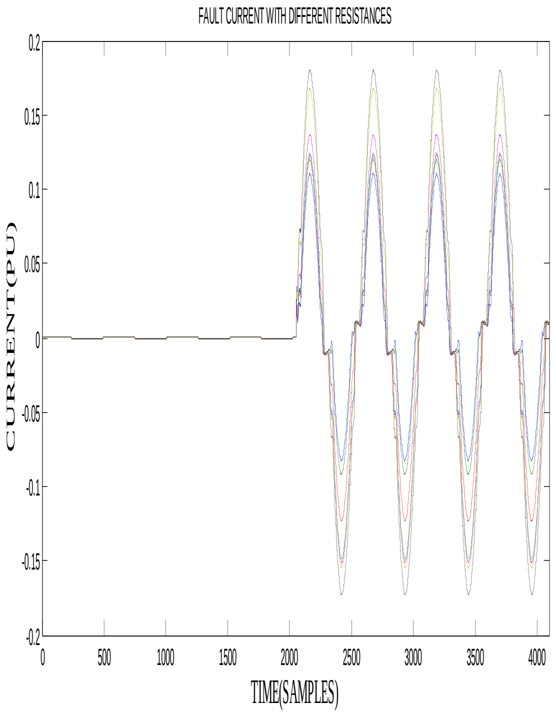

Fig4. Typical Fault Current with different resistances

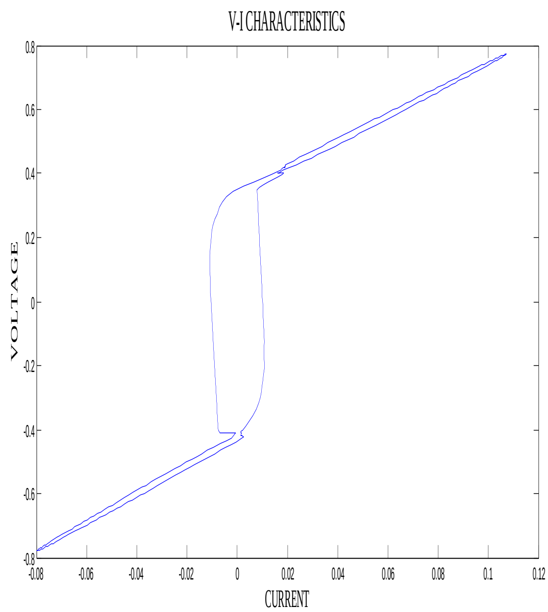

Fig5. V-I Characteristics of HIF

4. HIF DETECTION USING WAVELETS

The availability of powerful microprocessors and signal processing algorithms has led to a wide range of new techniques to identify the waveforms associated with high impedance fallen conductors faults. The Wavelet theory and its applications are rapidly developing fields in applied mathematics and signal analysis. The wavelet transform is a tool that divides up data into different frequency components, and then evaluates each component with a resolution matched to its scale. The wavelet transform is useful in analyzing the transient phenomena associated with transmission-line faults and/or switching operations. Unlike Fourier analysis, it provides time information, has the attribute of very effectively realizing non stationary signals comprising of low- and high-frequency components.

Wavelets transform converts amplitude versus time signal to scale versus time signal. Wavelet is a waveform of effectively limited duration that has an average value of zero. The actual implementation of discrete wavelet transform is done by multi resolution analysis. By MRA, a signal can be analysed is decomposed into a smooth approximation and a detail. The approximation is further decomposed into an approximation and a detail and the process is repeated. The decomposition of signal is obtained by successive high pass and low pass filtering of the time domain signal. The successive stages of decomposition are known as levels and the above procedure is known as sub band coding.

In this work a new method of HIF detection method is implemented. In the above section obtained current signal is decomposed by using db4 as mother wavelet and 25.6 KHz as sampling frequency. Some standard wavelets are Daubechies, Biorthogonal, Coiflets, and Symlets. By using db4 we can easily detect HIF. This is shown that the technique improves the performance of HIF detection by employing the absolute sum value based on the DWT.

Selection of mother wavelet for HIF detection should satisfy two conditions:

- A significant magnitude of d1 coefficient for detecting the fault.
- The classification ability between the faulted phase and healthy phases.

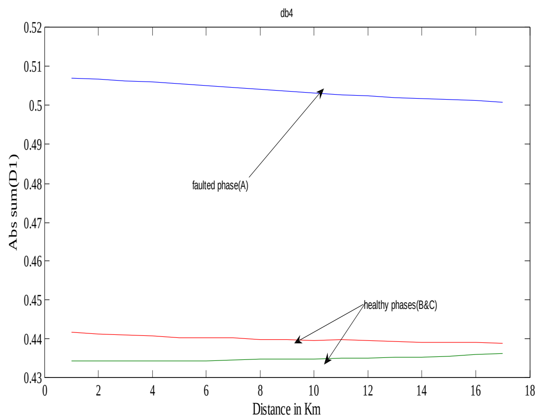

Fig6.db4 as mother wavelet

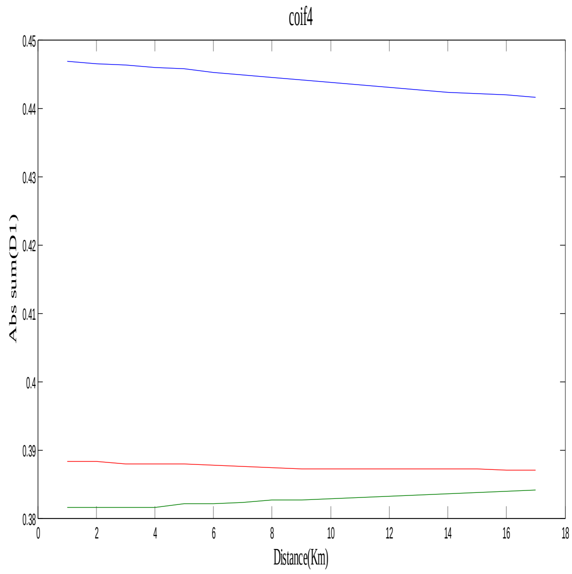

Fig7.Coif4 as mother wavelet

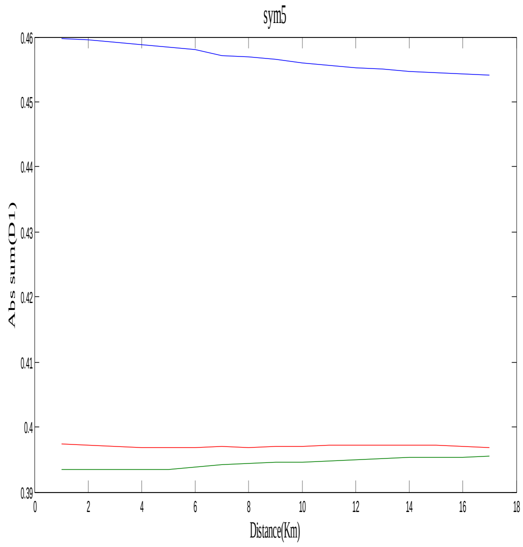

Fig8.Sym5 as mother wavelet

Selection of Mother Wavelet:

In order to select the most suitable mother wavelet, the absolute sum value (this is over a 1-cycle period at power frequency) of D1 coefficients based on wavelet analysis is adopted for this work. The waveforms shown in Fig. 6,7, and 8 which illustrate the absolute sum value of d1 coefficients of the three-phase current signals (as measured at the relaying point) for an "a"-earth HIF at a distance every 1 km,(2-18 Km)from fault point. Considering Fig. 6 (this is based on the db4 mother wavelet), it is clearly evident that the maximum sum value of d1 coefficients is significantly larger for the faulted "a"-phase than for the two healthy phases "b" and "c." This is also true when employing sym5, and bior3.1 mother wavelets, although the levels are somewhat smaller in the case of the former. However, when employing the coif4 mother wavelet, although there is a discernible difference between the levels attained for the faulted "a" phase and the two healthy phases, in comparison to the previous three mother wavelets considered, they are significantly lower. Also, equally important is that the differences in magnitudes between the faulted and healthy phases in the case of coif4 is much smaller than the corresponding other types of mother wavelets. So db4 selected as mother wavelet.

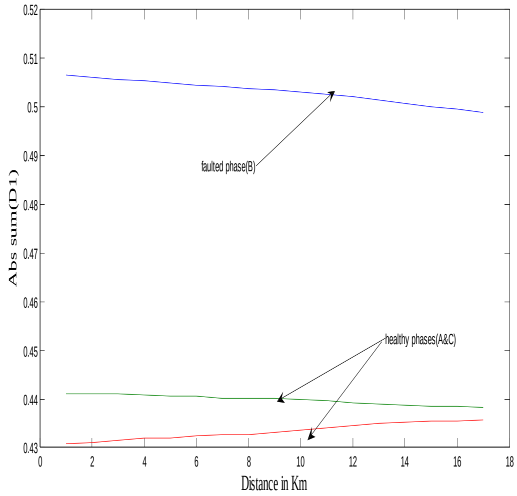

Fig9. Fault on B phase

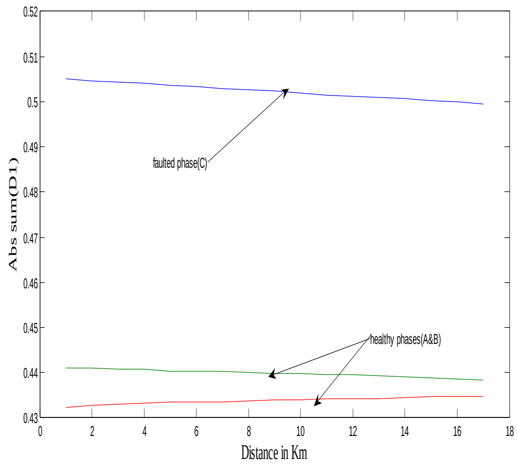

Fig10.Fault on C phase

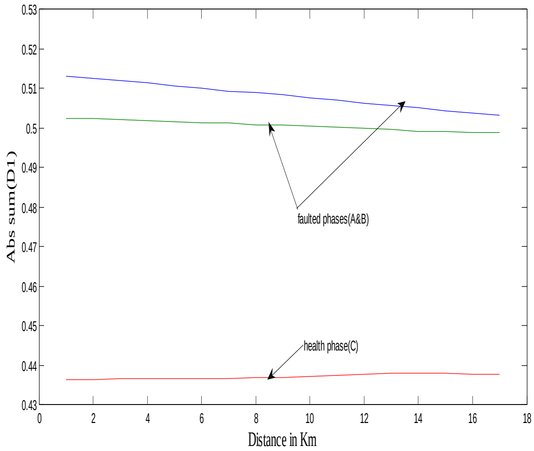

Fig11. Fault on two phases

From Figs 9, 10 &11, clearly irrespective of phase the faulted phase absolute sum of D1 coefficient is larger than the healthy phases (db4 as mother wavelet). For Wavelet analysis only one cycle data is sufficient to analysis. The only measurements required for the proposed detection algorithm is currents signals for each phase sampled at the rate of 25.6 KHz. It takes very less time and accurate method compared to harmonic analysis.

5. CLASSIFICATION OF HIF

A. Data collection:

In this collect the fault data by changing the fault distance, fault resistances and for non fault data changing the power factors and different load conditions. For the classification purpose 400 samples of fault data and 400 samples of non fault data is collected.

Wavelet transform is used for feature extraction. By using rbio3.1 mother wavelet, the coefficients of the first three levels of decomposition signals are used for feature extraction. The coefficients of these three levels were divided in to 10, 5 and 5 segments. Means of the absolute value of each segment were chosen as features. Thus, each extracted signal was mapped to a 20 dimensional space. Using Principal component analysis (PCA), reduce the data into 7 dimensional space.

B. Principal component analysis:

PCA is a way of identifying patterns in data, and expressing the data in such a way as to highlight their similarities and differences. The other main advantage of PCA is that once you have found these patterns in the data, and you compress the data, i.e. by reducing the number of dimensions, without much loss of information. Memory and computation time reduced. By using this data is reduced from 20 dimensional to 7 dimensional.

C. Fuzzy k nearest neighbour algorithm (FKNN):

Classification of objects is an important area of research and application in a variety of fields. The main disadvantage of traditional (crisp) set theory is that it implies a quality of precision and definiteness for a decision that may not be warranted. Then FUZZY comes into picture. In this work, first folded data and taking some data as known class data and other as unknown data. The membership value is calculated as dividing sum of product of nearest neighbours memberships and distance from nearest neighbours with sum of distance from nearest neighbours. The class in which the membership value is high the unknown sample is labelled as that class. Success rate is calculated as the number of times the error is zero divided by the total number of test samples. Total success rate is calculated as mean value of success rate. In this success rate is 96.7%.

D. Neural Networks (FFN):

Neural networks have been trained to perform complex functions in various fields, including pattern recognition, identification, and classification. First load the data from PCA (reduced data), consisting of input vectors. Corresponding targets are for non fault cases 1 and for fault cases 2. Now divide the data as training and testing. 60% or 70% of data for training and 40% or 30% for testing data was taken randomly. For this work, a two-layer network, with a tan-sigmoid transfer function in the hidden layer and a linear transfer function in the output layer. This is a useful structure for function approximation (or regression) problems. By using feed forward neural networks to the data, the data is classified successfully. The efficiency of procedure is calculated as the number of times error is equal to zero divided by the total number of test samples. The results of classification of HIF in both the cases as tabulated as follows.

METHOD USED FOR CLASSIFICATION	CLASSIFICATION EFFCIENCY
FKNN	96.7%
FEED FORWARD NEURAL NETWORKS	98.3%

Table1

CONCLUSIONS:

- High impedance faults associated with arcs and fire hazards. So High impedance fault detection is good challenging task in power system. In this work Wavelet transform based efficient algorithm is implemented based on absolute sum of detail coefficients by using db4 as mother wavelet and 25.6 KHz as sampling frequency. For classifying High impedance faults, Principal component analysis is used for data reduction without loss of much information, Fuzzy K Nearest Neighbour algorithm and Feed Forward Neural Networks are used for classification purpose.

- The proposed algorithm is capable of detecting the arc type HIF with higher accuracy. This algorithm for fault detection is simpler and faster than any previous algorithms. Time for execution of this algorithm is negligible compared to the harmonic calculation analysis. In this algorithm training is relatively fast so updating with new data is possible. Most of the cost is for simulation, collection of data, algorithm development. So the cost is very low.

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