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HIF Detection and Classification in Distribution Systems using Wavelet Transforms

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Abstract*: High Impedance Faults (HIF) are generally occurs on distribution line. HIFs are, by and large, hard to recognize through traditional assurance, for example, distance or over current relays. This is primarily because of hand-off inhumanity toward the low level fault currents as well as constraints on other hand-off settings forced by HIFs. Regular assurance hand-off framework won't have the option to distinguish the HIFs and excursion the security transfer. HIFs on electrical transmission and dissemination systems include arcing as well as nonlinear attributes of flaw impedance which cause repeating example and contortion. Subsequently, the goal of most discovery plans is to recognize extraordinary highlights in examples of the voltages and current related with HIFs. Most traditional flaw discovery strategies for HIF for the most part include preparing data dependent on the component extraction of post HIF current and voltage. Wavelet transform is most appropriate for HIF location and for fault classification. This paper depicts another shortcoming location procedure which includes catching the present sign created in a framework under HIFs. The identification procedure depends on ascertaining the total entirety of the wavelet transform detail coefficients for one period. Wavelet transform is utilized for the disintegration of sign and highlight extraction.

Keywords: About High impedance faults, Distribution lines and Wavelet transform.

I. INTRODUCTION

The HIF detection is a long standing issue. The issue natures have been examined since the mid 1970's with the desire for discovering a few qualities in the waveform for down to earth location. The HIF result when an undesirable electrical contact is made with a street surface, walkway, grass, tree appendage, some other surface or question which limit the progression of issue flows to a level underneath that dependably noticeable by ordinary assurance gadgets..

The HIF have two primary qualities: the fault currents and arcing. The main trademark is happened in light of the fact that these flaws produce practically zero faults current. This fault current is moreover diminished throughout the winter time in cool nations and subsequently the recognition of flaws because of trees is all the more testing [1].

The second attribute of HIF is the nearness of arcing

marvels because of air holes because of the poor contact made with the earth or with an earthed item. These air holes make a high potential over a short separation and arcing is created when the air hole separates. In any case, the manageable current level in the curve isn't adequate to be dependably distinguished. Some portion of this is because of the always changing states of the surface supporting the circular segment and keeping up high impedance. In this manner, an arbitrary electrical conduct is a related component with the HIFs. As the arcing frequently goes with these issues, it further stances fire risk and subsequently the location of such blames is basically significant [2-3].

From the earliest starting point of power distribution, the power framework protection engineer has been tested with the identification of HIFs. The IEEE Power System Relay Committee working gathering on High Impedance Fault Detection Technology characterizes HIFs as those that "don't deliver enough deficiency current to be recognizable by regular over current relays or circuits". All things considered, it ought to be noticed that though conventional security is intended to ensure the power system, High Impedance fault protection is primarily focused on the protection of people and property. The run of the mill HIF is the point at which a conductor physically breaks and tumbles to the ground. The break in the conductor will for the most part bring about either a drop in load on the influenced feeder or conceivably a transitory over current condition as the falling conductor quickly interacts with an emphatically grounded item [4-5]. Once on the ground, the subsequent electrical mark is especially a component of the reached surface. Surfaces, for example, solid, grass, soil, and wet surfaces when all is said in done will bring about an "arcing shortcoming" with RMS issue flows in the scope of 10 to 50 amps while surfaces, for example, dry sand and black-top will bring about a consistent low degree of current flow. Arcing faults comings bring about an entirely determinable and recognizable example while the marks exhibited by the last surfaces present a test to verify and solid location.

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A related sort of HIF is the point at which the conductor doesn't break, yet comes into contact with grounded protests either through a disappointment of the conductor mounting framework, protection disappointment, or unintentional contact with some outside component, for example, a tree appendage. These deficiencies will as a rule display the equivalent "arcing" signature as a wrecked conductor lying on the ground; nonetheless, the occasion won't be gone before by any adjustment in central current.

A third sort of occasion is a drooping conductor. In spite of the fact that not in fact an "fault", it presents an extensive open wellbeing peril. In this condition, a conductor hangs low enough to empower human or other contact. Note that this kind of occasion offers no electrical mark for detection. The frequency of brought down conductors is a point for exchange as most events are not logged by field teams. Best appraises are that between 5% to 10% of all circulation framework fault occasions are brought down conductors [6-8].

This electrical HIF discovery strategy measures the third harmonic current phase angle with respect to the fundamental voltage. There is a particular phasor relationship between the third harmonic current and the faulted phase voltage.The gadget figures and stores the normal encompassing third harmonic current phasor. At the point when a flaw happens, the new third harmonic current phasor is vectorially subtracted from the put away worth. A HIF is given if the size is above setting and edge coordinates a foreordained an incentive for a brought down conductor. The gadget obtains current and voltage esteems from the relaying current and voltage transformers [9-10]. Regularly, one unit is introduced in every distribution breaker. Units have been in administration since the mid 1990's.

II. DETECTION OF HIF

HIFs are, all in all, hard to identify through regular assurance, for example, distance or over-current relays. This is chiefly because of transfer harshness toward the low level flaw flows and additionally confinements on other hand-off settings forced by HIFs. This sort of fault for the most part happens when a conductor contacts the parts of a tree having high impedance or when a messed up conductor contacts the ground. On account of an over-current relay, the low degrees of current related with HIF are beneath the affect ability settings of the relay. On account of a distance relay, which depends on an estimation of impedance to blame dependent on the deliberate voltages and currents, the exactness of the estimation can be altogether influenced by the high-impedance faults. HIFs, but remarkable, should in any case be precisely distinguished and evacuated. This is all the more so in perspective on the way that separated from compromising the dependability represent a danger of flames and jeopardize life through the probability of electric shock.

Most customary deficiency discovery strategies for HIF principally include preparing data dependent on the element extraction of post-HIF current and voltage. A few scientists lately have displayed results planned for identifying HIF all the more successfully. Up to this point, the calculations created incorporate the present proportion strategy [3], the high-recurrence technique, the off-symphonious current strategy, the neural system and Kalman sifting strategy. S.J. Huang has proposed a HIF identification method for dispersion frameworks, which utilizes a Morlet wavelet change approach. Be that as it may, every one of these strategies improves shortcoming discovery partly, yet every ha its downsides also. Up to this point, a couple of strategies (some accessible as business items) have been exposed to very broad testing so as to find out their adequacy under various framework and faults conditions.

It is notable that customary Fourier change based strategies (i.e., those which depend absolutely on range examination of Fourier change) don't have the inalienable time data related with fault initiation.. The wavelet transform, then again, is valuable in breaking down the transient wonders related with transmission-line flaws as well as exchanging activities. In contrast to Fourier examination, it gives time data, has the trait of successfully acknowledging non-stationary sign including low-and high-recurrence segments, (for example, those regularly experienced in control frameworks systems) using a variable windows length of a sign. The focal points (especially as far as expanded unwavering quality and steadfastness) of a wavelet change, which has time and recurrence data not at all like the Fourier change, especially in the recognition of HIFs, are in this manner clear, and one of these methods is the subject of this paper. It ought to be noticed that in spite of the fact that wavelet examination is more perplexing than other sign handling systems, it is obviously appropriate for managing non-stationary flag, for example, those experienced under HIF arcing flaws. This, thusly, improves precision and unwavering quality in deficiency discovery and the highlights can be applied to influencing issue area methods. This paper depicts another shortcoming location procedure which includes catching the present sign created in a transmission line under HIFs. It is demonstrated that the procedure improves the presentation of HIF recognition by utilizing the supreme total worth dependent on the DWT. The recognition procedure is performed through sign deterioration, limit of the wavelet change coefficients, and span time. Edge esteem is controlled by weighting the supreme total an incentive for one period in a moving window plan and this structures the premise of complex choice rationale for the impediment of an excursion choice.

III. DISCRETE WAVELET TRANSFORM (DWT)

Wavelet Transform

The fault current signals are non stationary in nature. In this way, regular Fourier transform and brief time Fourier transform are insufficient to manage such signals. The Wavelet hypothesis and its applications are quickly creating fields in applied science and sign investigation. The wavelet transform is a device that splits information into various recurrences segments, and afterward assesses every part with a goal coordinated to its scale. The wavelet transform is valuable in breaking down the transient wonders related with transmission-line shortcomings or potentially exchanging tasks.

Wavelet examination is the separating of a sign into moved and scaled adaptation of the first (or mother) wavelet. Scaling a wavelet implies extending (or packing) it. Moving a wavelet basically implies postponing its beginning.

We have seen that the CWT enables us to play out a multiresolution investigation of a specific sign. In any case, the CWT has some significant downsides that make it unfeasible for genuine sign preparing applications:

• The CWT is profoundly excess to the extent the remaking of the sign is concerned. This is because of the way that a ceaselessly adaptable arrangement of wavelet capacities is not even close to an orthonormal basis1.

• The CWT of a sign is a consistent sign and hence it is made out of an unbounded number of terms.

• For most capacities, the CWT has no investigative arrangements and they can be determined just numerically

So as to tackle the previous issues the Discrete Wavelet Transform (DWT) was presented. The DWT fills in as the CWT however picking just certain scales and positions. The common method to test the time-scale plane is to take tests on the non-uniform framework characterized by (t, s) = (nt0, s_0-m) t0>0 s0>0

The discrete wavelet transform (DWT) is defined as

$$DWTX(m,n;Y) = \sum_{-\infty}^{+\infty} x(u)\, y_{m,n}(u) \quad 1$$

Where Yn, m (u) = sm/2 Y (sm0 , u − nt0). The most characteristic decision (s0 = 2, t0 = 1) compares to the dyadic examining of the time-scale plane. Utilizing such a testing we acquire, that the group of particles Yn, m (u); m, n Z structure an orthonormal premise.

The filter bank approach for the DWT:

In 1986, Mallat shows that the difference of information between the approximation of a signal at the resolutions 2j+1 and 2j can be extracted by decomposing this signal on a wavelet orthonormal basis of L2(Rn). In L2(R) an orthogonal dyadic multiresolution representation is a chain of closed subspaces indexed by all integers

$$\ldots\ldots V_{-2} \subset V_{-1} \subset V_0 \subset V_1 \subset V_2 \ldots\ldots$$

Subject to the following three conditions

• Completeness: limn→∞ Vn = L2(R) lim n→−∞ Vn = {0}

• Scale Similarity: f (t) Vn f (2x) Vn+1

Translation Seed: V0 has an orthonormal basis consisting of all integral translates of a single scaling function φ (t):{φ (t −k):nZ}. Similarly, if W0 denotes the orthogonal complement of V0 in V1, W0 is also orthogonally spanned by the integer translates of a single translation seed ψ (t). This function ψ (t) is the wavelet function of our decomposition scheme.

If W0 denote the orthogonal complement of V0 in V1

$$\varphi(t) \in W_0 \subset W_1$$

$$\psi(t) \in V_0 \subset W_1$$

The two sequences {g0 [k]}, {g1 [k]} such that

$$\varphi(t) = g_0[k]\varphi(2t-k) \quad 2$$

$$\psi(t) = g_1[k]\varphi(2t-k) \quad 3$$

In general, for any j Z the relations between Vj and Wj with Wj+1

$$\varphi(2jt) = g_0[k]\varphi(2j+1\,t-k) \quad 4$$

$$\psi(2jt) = g_1[k]\varphi(2j+1\,t-k) \quad 5$$

Equations (4) and (5) are referred to as two-scale relations and define the relation between the scaling functions and the wavelets at a given scale with the scaling function at the next higher scale. By taking their Fourier transform, we have

$$\varphi(\omega) = G0(z)\ ^{\varphi(\omega)} \quad 6$$

$$\psi(\omega) = G1(z)\ ^{\psi(\omega)} \quad 7$$

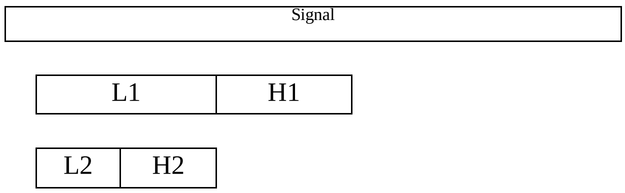

Figure1. Splitting of MRA subspaces

Where

$$G0(z) := 1/2\ \ g0[k]zk \quad 8$$

$$G1(z) := 1/2\ \ g1[k]zk \quad 9$$

With z = $e^{-jW/2}$. Expansions of (3.5) and (3.6) lead to

$$\varphi(\omega) = \sum_{l=1}^{\infty} G0e^{-j\,w2l} \quad 10$$

$$\psi(\omega) = \sum_{l=2}^{\infty} G1e^{-jw2l} \quad 11$$

From expressions (10) and (11) it is direct the structure of a productive calculation for ascertaining the wavelet disintegration of a sign dependent on a channel bank of progressive sets of high go (from the wavelet capacity) and low go (from the scaling capacity) quadrature reflect channels (QMFs).

A symmetrical Mallat-Meyer MRA compares to a symmetrical channel keep money with the investigation channels:

$$G0 = \{g0[k] : k\ \ Z\}\quad G1 = \{g1[k] : k\ \ Z\}$$

Where {g0[k]}kZ and {g1[k]} kZ are the 2-scale connection coefficients.

The combination channels G′ 0, G′ 1 are only the time inversions of the examination channels The general multi goals decay of a sign x(t) relates to the emphasis of the 2-channel investigation save money with the φ coefficients of x as the info information.

So as to diminish the computational weight the examining frequency ought not to be excessively high yet it ought to be sufficiently high to catch the data of fault. By haphazardly moving the purpose of fault on transmission line, progressively number of simulations was being completed utilizing MATLAB/SIMULINK. The created current signal for each case is broke down utilizing wavelet transform. An examining frequency of 12.5 kHz is chosen.

Daubechies wavelet Db4 is utilized as mother wavelet since it has great execution results for control framework shortcoming examination. Detail coefficients of fault current sign in sixth level (d6), gives the recurrence parts comparing to second and third music. On this premise, summation of sixth level detail coefficients of the three stage flows Ia, Ib and Ic are being utilized with the end goal of location and arrangement of flaws in the transmission line.

Selection of mother wavelet for HIF detection

As a subsequent advance in fault-detection method, choice of the mother wavelet is fundamental to upgrade the exhibition of HIF identification system to separate the valuable data quickly. For the procedure considered here, this procedure prompts an exact order between the blamed stage and the sound stage in the principal example, along these lines fundamentally improving the exhibition and speed of the HIF location process. As referenced in the previous segment, the mother wavelets considered are db4, bior3.1, coif4, and sym5. For correlation of the exhibitions accomplished utilizing distinctive mother wavelets, two conditions are analyzed as pursues:

A huge extent of d1 coefficient for recognizing the fault and the order capacity between the faulted phase and the healthy phase.

So as to choose the most reasonable mother wavelet, the greatest aggregate worth (this is over a 1-cycle period at control recurrence) of d1 coefficients dependent on wavelet investigation is received for this work. Consider, for instance, the waveforms appeared in Figure which show the most extreme entirety estimation of d1 coefficients of the three-stage current sign (as estimated at the handing-off point) for "an"- earth HIF a ways off. As a matter of first importance, considering (this depends on the db4 mother wavelet), it is obviously clear that the most extreme whole estimation of d1 coefficients is essentially bigger for the blamed "a"- stage than for the two solid stages "b" and "c." This is likewise evident when utilizing sym5. Mother wavelets [as obvious from in spite of the fact that the levels are fairly littler on account of the previous.

Be that as it may, while utilizing the coif4 mother wavelet, despite the fact that there is a perceivable contrast between the levels achieved for the blamed "a" stage and the two sound stages, in contrast with the past three mother wavelets considered, they are fundamentally lower. Additionally, similarly significant is that the distinction s in sizes between the blamed and solid stages on account of coif4 is a lot littler than the relating different sorts of mother wavelets as evident from the diagrams appeared in Figure-4, and this is valid for all issue positions. In this way, with respect to the determination of the mother wavelet, the straightforward model received in this depends on the extents of the summated coefficients d1 and the distinctions in sizes between the blamed and solid stages. In this regard, after a progression of studies utilizing the previous d1 coefficients conveyance approach, the db4 and sym5 are fitting for identification of HIF in transmission line. The db4 mother wavelet is picked for this examination.

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 hase and healthy phases.

Fault-detection algorithm

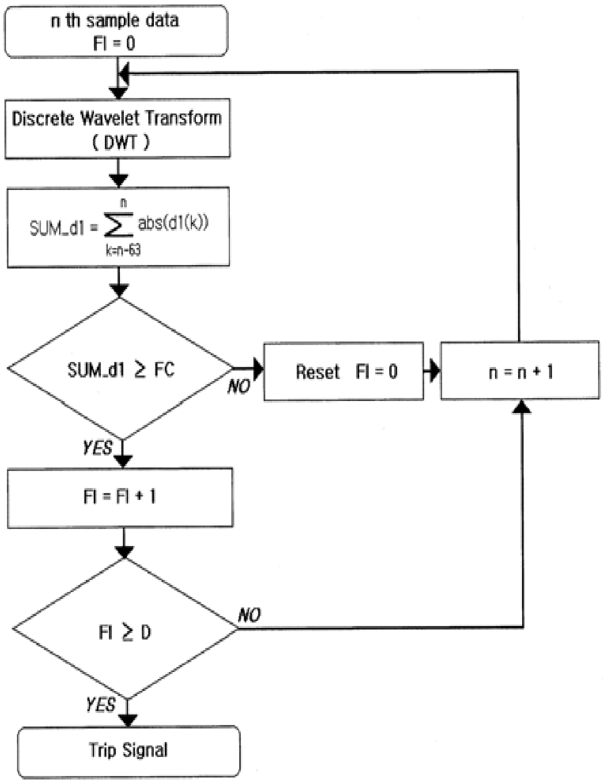

Figure2. Flow chart- fault-detection technique

IV. SIMULATION RESULTS

The simulation model for HIF analysis is shown in Figure3. In the simulation model the first block represents a three phase equivalent source. The block for voltage and current measurement captures all the voltages as well as currents during the simulation. The two blocks representing distribution line. Between the line blocks, high impedance type of fault is created. The last block represents a 3 phase load consisting of resistance and inductance, and non linear load consisting of 6pulse rectifier.

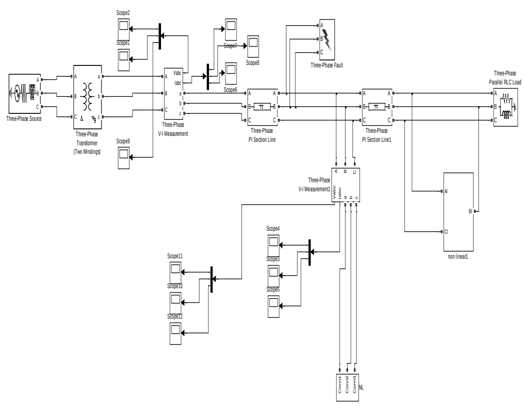

Figure3. Simulation model of the Distribution system

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Table1: Distribution System data

Three phase source	11KV, 50 Hz, 0.8929 Ω, 0.01658 H
Three phase transformer	10 MVA, 50 Hz, 11/25 KV
	R1=R2=0.002p.u, X1=X2=0.08p.u
Transmission line	20 Km, R1=0.04273Ω/Km,R0=0.7953 Ω/Km
	L1=0.933(mH/km), L0=4.1264(mH/km)
	C1=0.01274(μF/km),C0=0.00775(μ F/km)
RL Load	5KW, 2 KVAR, 25 KV
Non linear load	Universal bridge,Snubber resistance=1e5Ω, Capacitance=500 F

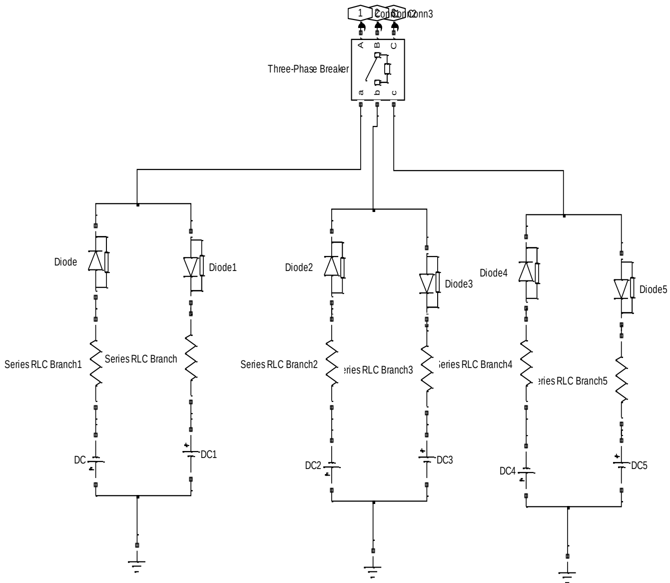

Figure4. Two diode fault model of high impedance faults

Another HIF model is utilized in this algorithm. Two diodes with two dc voltage sources are utilized to recreate HIF. It joins most preferences of past models proposed and it stays basic and all inclusive. Two diode shortcoming model of HIF is appeared in the Figure3.3. This model involves two DC sources, which speak to the initiation voltage of air in soil as well as among trees and the circulation line. The two protections speak to the shortcoming protections: inconsistent qualities take into consideration awry deficiency flows to be recreated. At the point when the stage voltage is more noteworthy than the positive DC voltage the flaw current streams toward the ground. The deficiency current switches when the line voltage is not exactly the negative DC voltage.

Typical values of Vp, Vn, Rp, Rn :

Vp= 3588, 4075, 5472, 6092, 6180, 6348, 6883 V.

Vn= 3847, 4626, 4783, 4911, 6155, 8011, 8634 V.

Rp= 208, 215, 235, 244, 245, 247, 255 Ω

Rn= 212, 223, 225, 227,245,271,280

The above power system with two diode fault model of HIF is simulated. The fault occurred at 0.08sec. The voltage and current at the measuring point is obtained as follows.

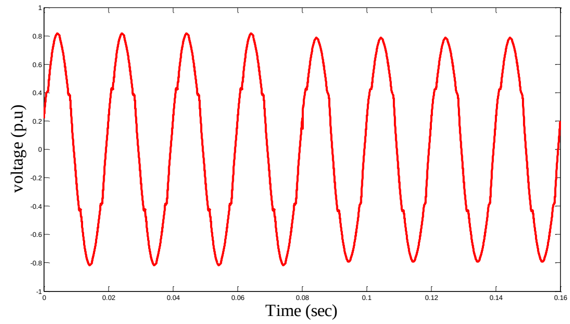

Figure5. Source voltage under HIF

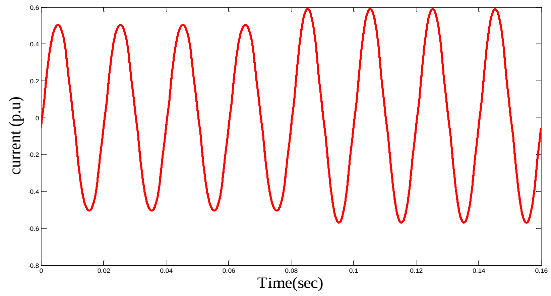

Figure6. Source current under HIF

From Fig.5 and Fig.6, clearly the voltage reduction is less and the increase in current is very less at fault point which is very sensitive to detect the conventional relays.

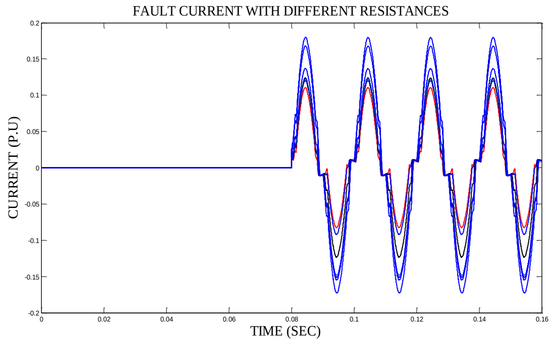

Figure3.6. Typical Fault Current with different resistances

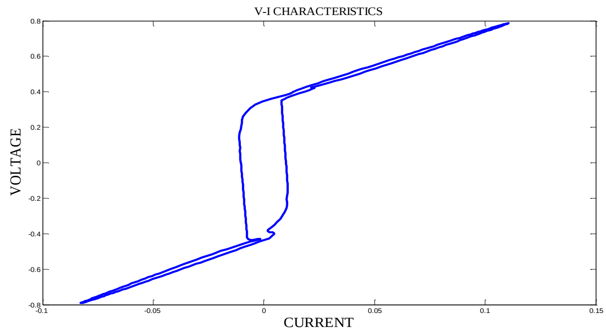

Figure7. V-I Characteristics of HIF

As earlier explained that HIF associated with arcs, so the v-i characteristics are clearly non linear from fig7.

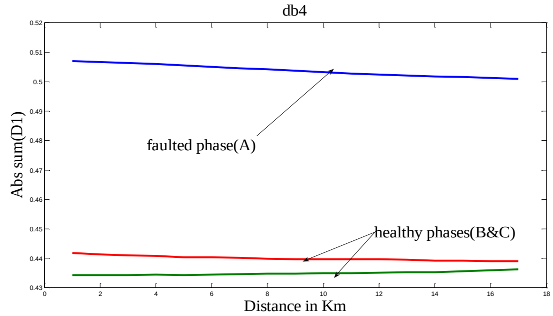

Figure8 db4 as mother wavelet

So as to choose the most reasonable mother wavelet, the supreme entirety esteem (this is over a 1-cycle period at control recurrence) of D1 coefficients dependent on wavelet investigation is embraced for this work. Consider, for instance, the waveforms appeared in Fig.8 which delineate the outright total estimation of d1 coefficients of the three-stage current sign (as estimated at the transferring point) for "an"- earth HIF a ways off each 1 km,(2-18 Km)from issue point. Considering Fig.8 (this depends on the db4 mother wavelet), it is plainly obvious that the greatest aggregate estimation of d1 coefficients is essentially bigger for the blamed "a"- stage than for the two sound stages "b" and "c." However, while utilizing the coif4 mother wavelet, despite the fact that there is a perceivable contrast between the levels accomplished for the blamed "a" stage and the two solid stages, in contrast with the past three mother wavelets considered, they are fundamentally lower. Likewise, similarly significant is that the distinctions in sizes between the blamed and sound stages on account of coif4 is a lot littler than the comparing different kinds of mother wavelets. So db4 selected as mother wavelet.

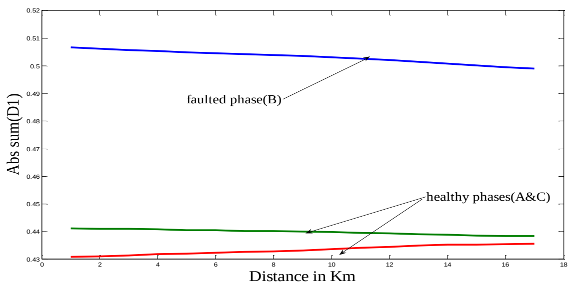

Figure9. Fault on B phase

From Fig9, clearly irrespective of phase the faulted phase absolute sum of D1 coefficient is larger than the healthy phases.

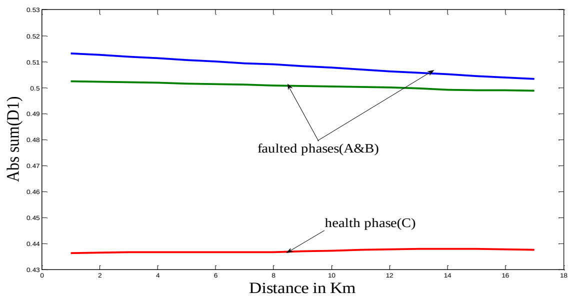

Figure10. Fault on two phases

From Fig10, the fault on two phases, the absolute sum of D1 coefficients is clearly larger than healthy phase.

V. CONCLUSION

High Impedance Faults related with curves and fire risks. So High Impedance Fault location is a decent testing errand in control framework. In this work Wavelet transform based proficient calculation is actualized dependent on total of (d1) detail coefficients by utilizing db4 as mother wavelet and 25.6 KHz as examining frequency. This work shows db4 is the best mother wavelet for the analysis. Absolute sum value of d1 coefficients of three phase current signals at a distance 1 Km, from fault point is calculated. It is clearly indicates that the absolute sum value for faulted phase is larger. Based on this HIF is easily detected. This algorithm gives good percentage of results for detection and classification of HIF.

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