ARC FAULT AND FLASH SIGNAL ANALYSIS IN DC DISTRIBUTION SYSTEMS

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Abstract - *In DC electricity distribution systems and dc microgrids, an oversized variety of electrical connectors and long wire runs square measure expected. Combined with the high dc voltage, deterioration of the wire insulation because of aging or different circumstances like mammal bites and abrasion because of chaffing with trees, building walls, or passage throughout installation will cause electrical arcs to occur. These dc arcs could end in shock hazard, fires, and system failure or fault within the microgrid.*

In this paper, a new approach victimization WT base spectral energy calibration for arc fault analysis in dc systems is projected. The method of detection associate arc fault involves solar PV output voltage analysis and so feature identification. Simulation models area unit synthesized to review the theoretical results of the projected methodology and Fourier analysis remodel analysis on arcing faults. Experimental information from the dc system of a electrical phenomenon array is additionally shown to validate the approach.

Key Words: DC arc, arc flash and fault

1. INTRODUCTION

In Photovoltaic (PV) systems, an oversized variety of electrical connectors and long exposed wire runs are required to make the series and parallel connection of individual PV modules into strings and arrays. Combined with the high DC voltage, deterioration of the wire insulation because of puncture from placental bites and abrasion from vibration will cause arc faults to occur which can lead to shock hazard, fires, and system failure in electrical phenomenon (PV) and different direct-current (DC) systems like a microgrid [1]. DC electrical arcs in PV systems, illustrated in Figure one, is series faults - caused by a separation within the current path like because of a broken wire or loose connective, or a high-impedance association like because of corrosion of Associate in Nursing electrical terminal or connector; or parallel faults – electrical discharges between conductors of various potential presumably caused by abrasion of wiring insulation once mounted to the mounting frame because of thermal enlargement, vibration, nesting rodents, or failure inside the PV module [2, 3].

The problem of arcing faults exists for small-scale residential systems additionally as large-scale utility systems and may cause vital threats to human safety. As long as this drawback exists, the PV business can have vital considerations concerning liability and also the impact upon widespread adoption of electrical photovoltaic energy. Thus, arc fault detection is very vital for reliable and safe system operation [4, 5] and may be a necessity for prime penetration of PV [6].

Even a lot of vital to notice is arc flash, the pre-fault (before a sustained arc forms) events of sparking and insulator breakdown. Arc flash might solely last for a brief length (less than a second), however is Associate in Nursing early indicator of insidious arc faults. Investigation of arc flash may be a troublesome drawback as a result of in contrast to a fastened "hard short" fault during which high current flows through a metal-to-metal association [7], arc flash involves short-run current flowing through ionizing air or on Associate in Nursing particle path and in PV and different finite energy systems might not draw sufficiently high RMS current, or have a high enough I2t energy to trip a thermal or magnetic electrical fuse, notably underneath low light-weight (reduced generation) conditions.

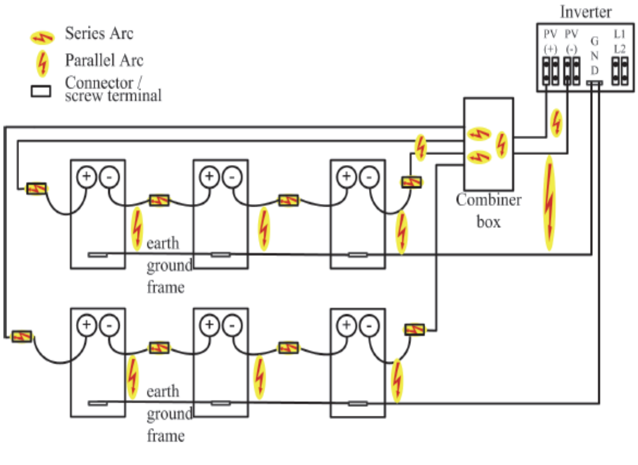

Fig-1: Example of locations where arcing may occur in a PV Array

Because of distributed capacitance of the PV array, noise from electrical converter shift, and different magnetic attraction interference, its potential this arcing might go entirely unobserved [8]. An additional complication to detection is that arcs aren't periodic, and therefore might not have simply recognizable amplitude or frequency signatures for pattern recognition techniques. Spectral analysis victimization Fourier techniques to decompose the frequencies of a sustained arc or fastened fault needs a linear system and a stationary signal [9] and thus isn't capable of police investigation arc flash.

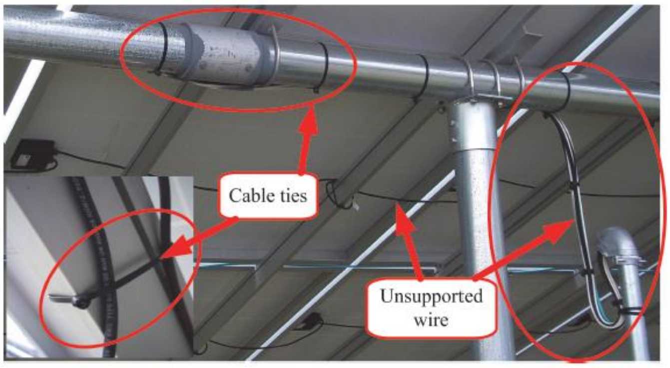

Fig-2: Example of dc wiring in a ground-mounted PV array

2. PROPOSED METHOD

2.1. Wavelet transform

Wavelet transform not like the FFT, it permits time localization of various frequency elements of a given signal. Thanks to the wide selection of signals and issues encountered in power engineering, there are a unit varied applications of rippling rework, like fault detection, load foretelling, and power grid activity. Additionally, data regarding power disturbance signals is usually a mix of options that area unit well localized temporally or spatially like power grid transients. This needs use of versatile analysis strategies so as to handle signals in terms of their time-frequency localization that is a wonderful space to use the special property of wavelets [10].

The rippling analysis procedure relies on a rippling model operate, known as a "mother rippling" – it provides a localized signal process technique to decompose the differential current signal into a series of wavelet elements, every of that could be a time-domain signal that covers a particular band [11]. Wavelets area unit notably effective in approximating functions with discontinuous or sharp changes like power grid fault signals. With correct selection of the mother wavelet, wavelet transformation could be a smart tool for fault detection and have distraction.

There are many sorts of wavelets, like Harr, Daubechies 4, Daubechies8, Coiflet 3, and Symmlet8, to call a replacement. One will select among them counting on the actual application. The wavelet transform incorporates a digitally implementable counterpart, the discrete wavelet transform (DWT), almost like the Discrete Fourier transform (DFT) implementation of the continuous-signal Fourier remodel. The DWT is outlined as

$$c(j,k) = \sum_{n\in Z,\, j\in N,\, k\in Z} s(n)\, g_{j,k}(n)$$

Where C(j,k) is the corresponding wavelet coefficient, n is the sample number, s(n) is the signal to be analyzed and gj,k(n) is the discrete scaling function (also called the father wavelet), which for dyadic-orthonormal wavelet transform is defined by

$$g_{j,k}(n) = 2^{-j/2} g(2^{-j} n - k)$$

The auxiliary function to this is the wavelet function (also called the mother wavelet). With this initial setting, there exists an elegant algorithm, the multi-resolution signal decomposition (MSD) technique, which can decompose a signal into levels with different time and frequency resolution. At each level *j*, approximation and detail signals *Aj* (represented by linear combinations of father wavelets at *j*th level) and *Dj* (represented by linear combinations of mother wavelets at *j*th level) can be created.

The words "approximation" and "detail" are justified by the fact that *Aj-1* is an approximation of *A1*, taking into account the "low frequency" of Aj, whereas the detail Dj corresponds to the "high frequency" correction.

As shown in Figure 3, for a reference level J, there are two categories of details: 1) those details associated with indices j ≥J correspond to the scales 2-j/2 ≤ 2-J/2, which are the fine details; and 2) the other details correspond to j < J and are the coarse details, which define an approximation of the signals which signify that *s* is the sum of its approximation *AJ* improved by the fine details [20].

$$s = A_J + \sum_{J>j} D_j$$

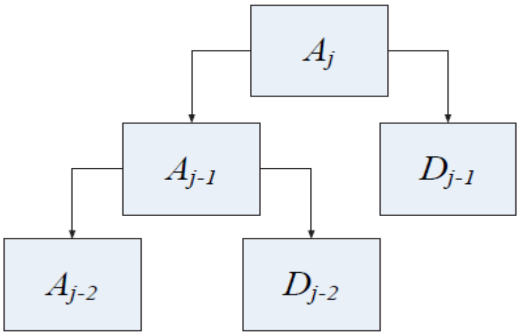

Fig-3: Wavelet decomposition tree

2.2. Cassie Arc Model

Circuit-breaker's performance in power system is analyzed by representing the circuit-breaker characteristics by a operate of electrical parameters like current/voltage, and mixing with, although difficult, facility circuit. For such functions, supposed "Black-box modeling" is applied, in which, despite of actual circuit-breaker hard-ware like contact form, pressure, range of snapping point, etc., a function of electrical parameters is introduced. Within the chapter, as being popularly used equations, Mayr arc model and cassie arc model are concerned.

In Cassie arc modeling, the assumptions are:
-Heat loss depends on the arc flow (convection loss).
-Heat loss, hold on heat, and electrical conductance phenomenon area unit proportional to the cross section space. Then, because the result, the subsequent is obtained.

$$\frac{1}{G}\frac{dG}{dt}=\frac{1}{\theta}\left(\frac{E^2}{E_O^2}-1\right)\text{.........................(1)}$$

Where, E = Arc voltage,
E0 = Constant,
θ= Arc time constant,
G = Arc conductance.

The above assumptions correspond to relatively high current of arc, such as higher than several hundred A, so Cassie arc model is applicable to higher current of arc. Introducing to EMTP-TACS, following rewriting is useful.

$$G_O = G^2(G=\sqrt{G_O})$$

$$G_O=\frac{I^2}{E_O^2}\frac{1}{1+\theta_s}$$

For steady state, i.e. d/dt = 0, arc voltage E equal constant E0. Therefore, as the equation is to be applied to relatively long time interval of high current region, to introduce just appropriate E0 value is important. As an example, so called zero skipping current breaking near a synchronous generator is taken up.

3. PROPOSED APPROCH IMPLEMETATION

Figure 4 shows the block diagram of proposed approach arc fault and arc flash analysis of solar PV dc grid system using wavelet based spectral energy calibration. In these system cassie Arc model are utilized for development of DC arc at different location of solar grid system. After DC arc simulation in solar grid system then arc voltage was measures and send to the wavelet multiresolution analysis matlab block. Then we get detail and approaximate signals after successful wavelet multiresolution analysis then send that signal for spectral energy calibration. In future that spectral energy value for different arc fault condition will be utilized for classification of fault zone in DC grid system.

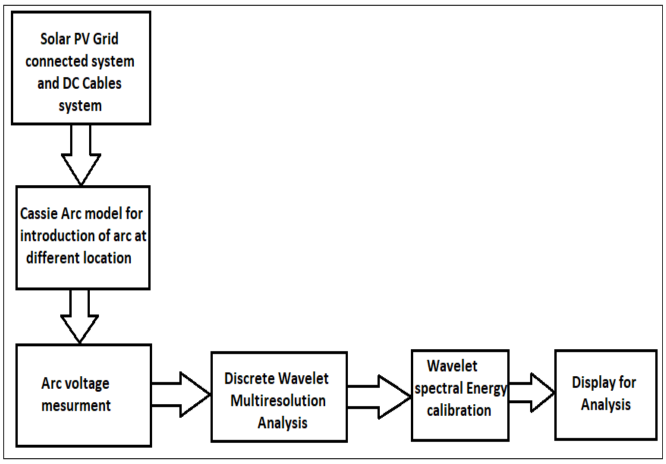

Fig-4: Block diagram of proposed approach

3.1. MATLAB Simulation model

MATLAB Simulation model was enforced in MATLAB 2015 software system version. Simulink model of the PV array dc system with one 120 Hz double-frequency line ripple (ac voltage 2), a 2 KHz switch ripple (ac voltage 1), and series arcing (Cassie arc model details square measure listed in Table I). The arc model at first behaves as a electrical conductance with the worth 1e4 Siemens till the arc "switches on," then it's ruled by equation (1). This simulates the separation of the electrodes that initiates the arc.

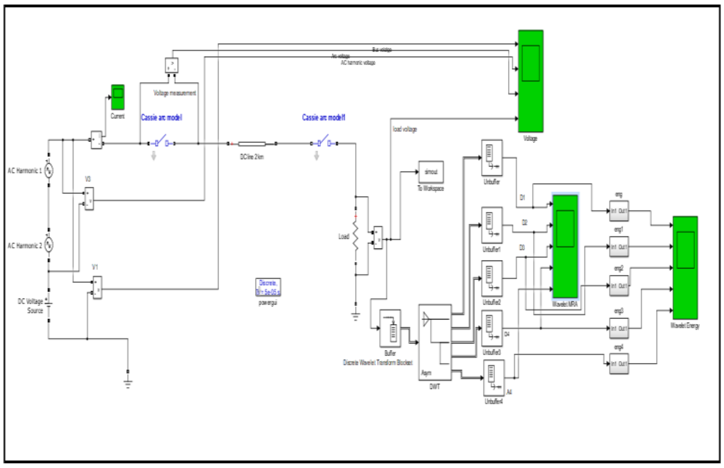

Fig-5: MATLAB simulation model of proposed approach

Table-1: Parameters used with the cassie arc model

tau	1.2e-6 Sec
Uc	100 Volt
g(0)	1e4 Sec
Contact separation start time for fault zone location	0.2 Sec

3.2. Wavelet and Filter Banks

Multiresolution signal analysis exploitation DWT will be enforced by filter banks wherever a moving ridge and a scaling perform are related to a high-pass and a low-pass filter, severally. As shown in Figure 3, on every level of decomposition, the signal is split into a lower frequency part and the next frequency part. With II moving ridge filters (WT), solely the low-frequency half is additional rotten. As compared, binary wavelet transform filters (wavelet packets), that split each low- and high-frequency parts on every level, result in rotten signals with associate degree equal information measure.

3.3. Selection of mother wavelet

The criteria for selecting the mother wavelet adopted in this paper are summarized in [12] and [13] are as follows.
1) The wavelet function should have a sufficient number of vanishing moments to represent the salient features of the disturbances.
2) The wavelet should provide sharp cutoff frequencies to reduce the amount of leakage energy into the adjacent resolution levels.
3) The wavelet basis should be orthonormal.
4) For applications where the information lasts for a very short instant, wavelets with fewer numbers of coefficients are better choices; on the other hand, for signal signature spread over a longer period of time, wavelets with larger numbers of coefficients tend to show smoother results.
There are several well-known families of orthogonal wavelets. An incomplete list includes Harr, Meyer family, Daubechies family, Coiflet family, and Symmlet family [39]. Daubechies wavelets are chosen in this paper due to their outstanding performance in detecting waveform discontinuities [13], [14].

4. MATLAB SIMULATION RESULTS

MATLAB Simulation results are classified in three sections, first section shows results for arc parameters, second section shows the results regarding wavelet multiresolution analysis for different arc fault locations, and third section shows result of wavelet spectral energy calibration for different fault condition.

4.1. Arc parameters results

Figure 6 to 8 shows the source voltage, harmonics voltage in source supply, arc voltage and load voltage for normal condition, when arc flash at zone 1 and when arc flash at zone 2 respectively. In these result it is clear that during normal condition voltage across arc model is nothing but normal supply voltage. When fault takes place at zone 1 and zone 2 that time arc voltage increases their magnitude as shown in figure 7 and 8 respectively for zone 1 and zone 2 respectively.

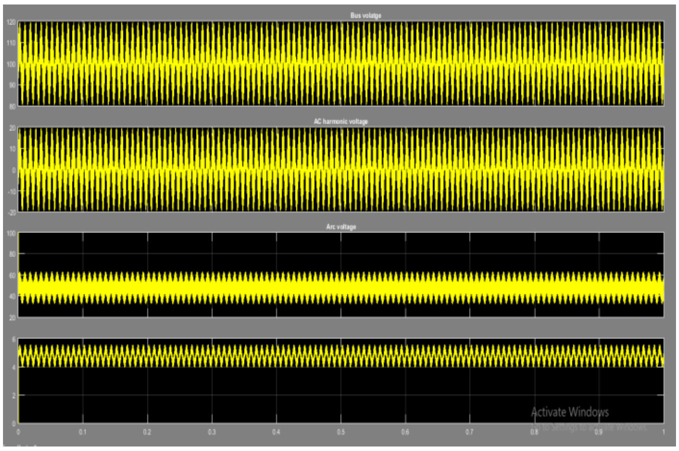

Fig-6: Result of DC source voltage, Harmonics voltage, Arc voltage and load voltage during normal condition

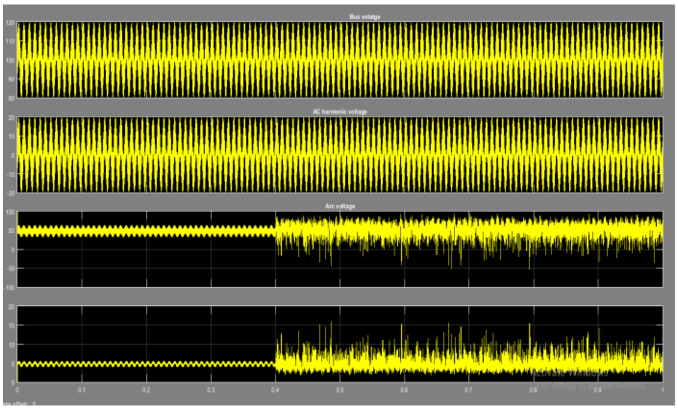

Fig-7: Result of DC source voltage, Harmonics voltage, Arc voltage and load voltage during arc takes place in zone 1

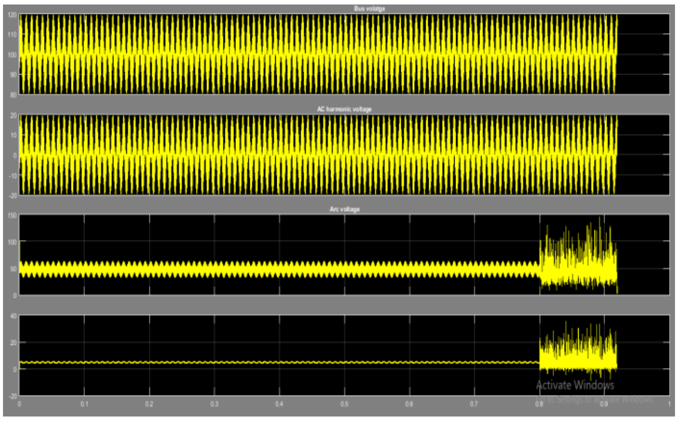

Fig-8: Result of DC source voltage, Harmonics voltage, Arc voltage and load voltage during arc takes place in zone 2

4.2. Wavelet Multiresolution analysis results

Figure 9 to 11 shows the wavelet multiresolution analysis of load voltage during normal condition, when arc flash takes place at zone 1 and when arc flash takes place at zone 2 respectively. In which detail signals D1, D2, D3, D4 and A4 signals are available for different frequency band ranges. In which it is observed that during normal condition high frequency components are very less as compared with arc flash conditions at zone 1 and zone 2.

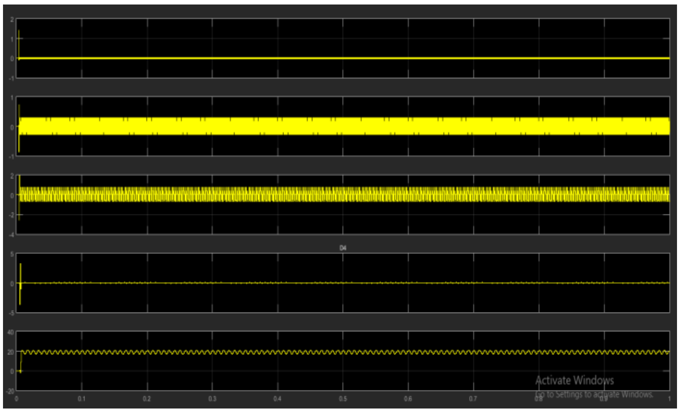

Fig-9: Wavelet multiresolution analysis results of details D1, D2, D3, D4 and Approximation A4 signal during normal condition

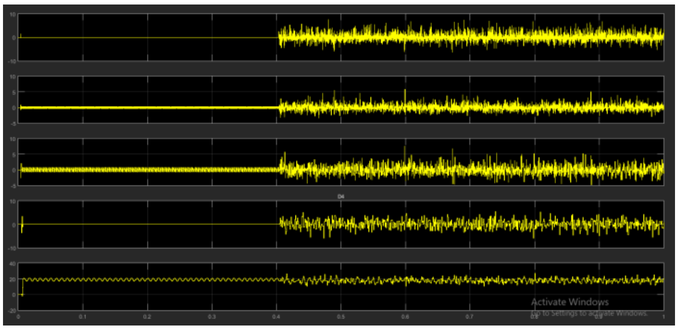

Fig-10: Wavelet multiresolution analysis results of details D1, D2, D3, D4 and Approximation A4 signal during arc flash takes place at zone 1

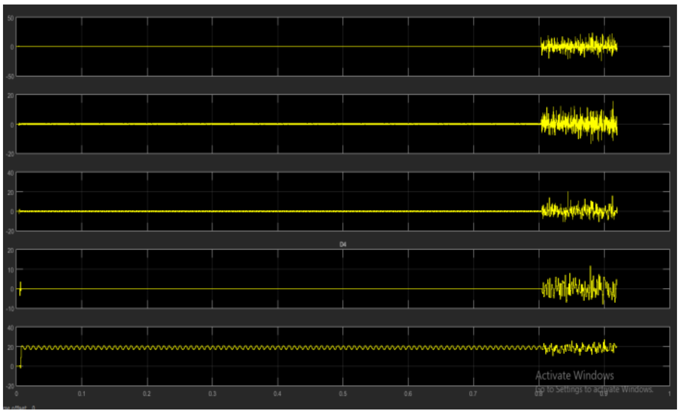

Fig-11: Wavelet multiresolution analysis results of details D1, D2, D3, D4 and Approximation A4 signal during arc flash takes place at zone 2

4.3. Wavelet spectral energy calibration results

Figure 12 to 14 shows the wavelet spectral energy of wavelet multiresolution analysis of details and approximation signals during normal condition and arc flash conditions. In which it observed that during normal condition energy of signals are normal around 0.04 to 0.1 range but during arcing fault condition these is more that 0.1 ranging.

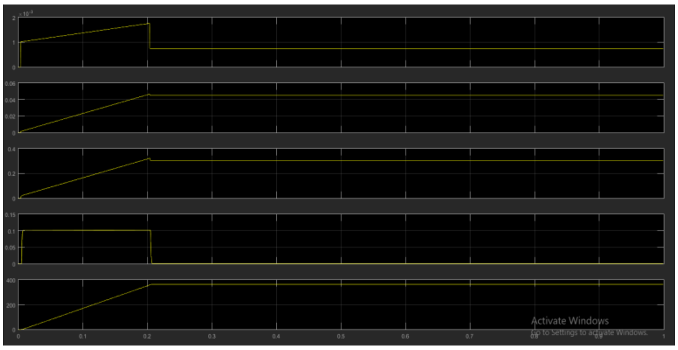

Fig-12: Wavelet spectral energy of Detail D1, D2, D3, D4 and A4 signals during normal condition

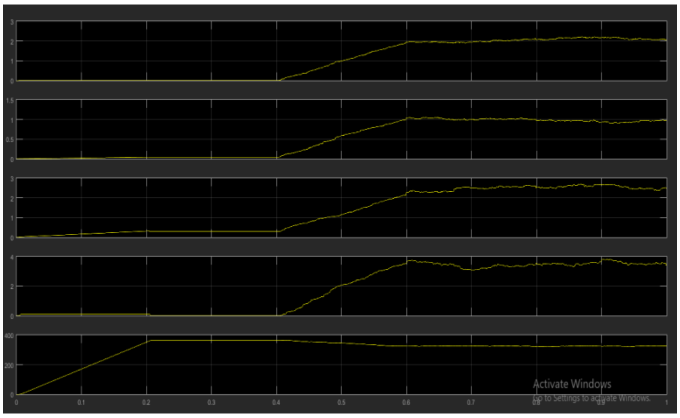

Fig-13: Wavelet spectral energy of Detail D1, D2, D3, D4 and A4 signals during arc fault takes place at zone 1 at 0.4 second simulation time

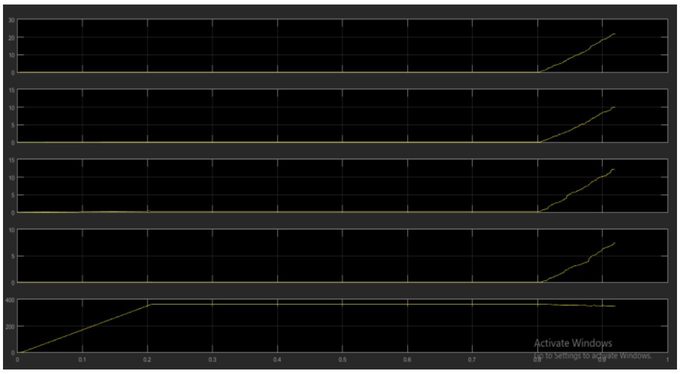

Fig-14: Wavelet spectral energy of Detail D1, D2, D3, D4 and A4 signals during arc fault takes place at zone 1 at 0.8 second simulation time

5. CONCLUSION

This paper has proposed a new approach for arc analysis in dc microgrid systems based on WT. The fundamental feasibility of applying WT has been presented. The presence of switching harmonics and ambient electrical noise can mask the arc signal, making detection of an arc difficult. Fourier analysis is usually not able to discover transient signals and abrupt changes like sudden arc faults and arc flashes. If the duration of the arc flash lasts for a very short period of time in comparison with the sampling window of FFT, it is likely that the arc flashes will not be observable.

However, WT is extraordinarily effective with detecting the exact instant the signal changes. The results suggest that the WT approach is not just capable of analyzing arc fault in dc systems but that it also provides a more readily detectable signal and better performance than the FFT method.

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