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# Detection of Arc Flash and Arc Fault in DC System

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*Abstract*— Arc failures have always been a concern for PV systems. Rising safety regulations may soon necessitate the incorporation of arc fault detection methods into PV systems. Fires, shock hazards, and system failure can all result from arc faults. Because the signal to noise magnitude relation is low and the arc signal isn't periodic, existing techniques that rely on pattern identification in the time domain or amplitude detection in the frequency domain using an FFT Analysis don't perform well for arcs. Rippling remodel analysis, on the other hand, uses a time and frequency technique to look into target signals at different resolutions. A new approach based on rippling remodel for arc fault detection in DC systems is planned in this research. To evaluate the theoretical results of the intended methodology and provide standard FFT analysis of arcing faults, simulation models are created in MATLAB 2015 Simulink.

## I. INTRODUCTION

With associate increasing variety of numerous DC microgrid installations the analysis on specific safety aspects is gaining additional and additional importance. Besides the implementation of qualification processes of parts and installation, additionally an in-depth survey of safety and stability of management strategies should be conducted not just for massive scale, however additionally for small scale microgrids. Particularly thanks to the massive variety of worldwide solar PV systems installations and also the increasing use of battery systems inside the last years many investigations are applied regarding the explanations of reportable fireplace incidents and initiated analysis programs and commonplace specifications. Trendy electronic protection is cheap in various applications with voltages bigger than 20V so as to interrupt or to limit over- current. Particularly if galvanic isolation must be warranted in electrical circuit, the utilization of hybrid devices as a mixture of mechanical switchgear and power physics could be a state-of-theart-technology to stop contacts from erosive burning. If a special circuit style is employed, the fall of a change arc in an exceedingly parallel change chamber are often used as a voltage offer for the solid-state physics. during this case no separate feed-in is needed; the physics square measure energized solely throughout change operation and bypassed in on-state.

A main safety issue at higher system voltages is that the potential danger of fireplace and private injury caused by arc faults, that don't seem to be inside specific switchgear, however is also anyplace within the installation at loose contacts or at broken cables. Arc faults square measure a lot of dangerous and harder to sight within the case of DC compared to AC systems with perennial zero-crossings of current. Because of the utilization of storage systems duplex flow needs to be thought-about in safety ideas, specific breaking methods got to be established for faults inside distributed sources. Central and distributed management topologies and strategies for DCDC converters joined to DC buses and for inverters connecting to AC grids got to be tested for stability not solely within the vary of typical operative points. Conjointly potential cases of severe faults got to be enclosed in stability analysis so as to avoid a lot of serious secondary harm, e.g., because of over-current or to overvoltage.

## II. PROPOSED METHOD

### A. 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 application 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 [3].

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 [4]. Wavelet's 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.

## III. PROPOSED APPROACH IMPLEMENTATION

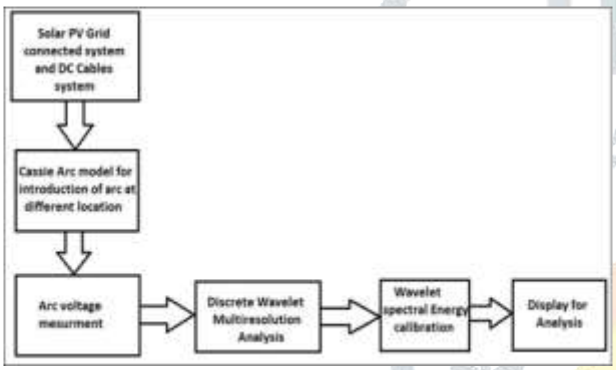


Fig. 1: Block diagram of proposed approach

Figure 1 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 multi-resolution analysis MATLAB block. Then we get detail and approximate signals after successful wavelet multi-resolution 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.

### *A. 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.

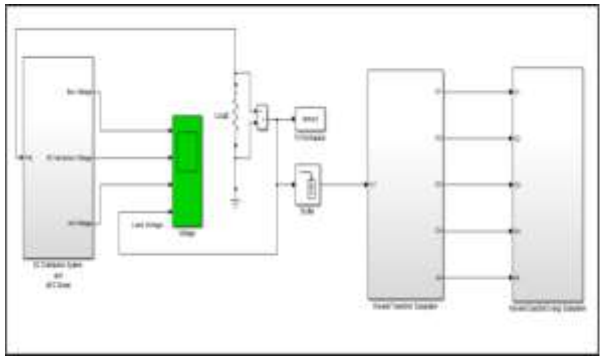

Fig. 2: MATLAB simulation model of proposed approach

Figure 2 shows the matlab simulink model of single arc model with wavelet multi-resolution analysis approach. In order to simulate the arcing condition, black box modeling is commonly used to describe the arc interaction with the electrical network. The black box models use voltage and current traces from a circuit breaker test, together with a select differential equation, to produce a mathematical model for the desired arc under study. Most published work using black box models is based on the well-known Cassie and Mayr models. just after source and after 20km of underground cable respectively.

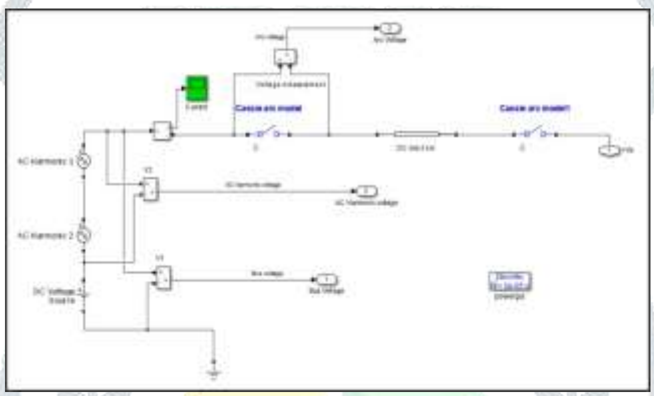

Fig. 3: Cassie arc model subsystem with two zone modeling using DC cable

Table 1: Underground Cable Specification In Matlab Simulink Model

| Parameter | Specification value |
|---|---|
| Resistance per unit length | 0.015 Ohm/km |
| Inductance per unit length | 0.792 mH/km |
| Capacitance per unit length | 14.4 nF/km |
| Length of cable | 20 km |

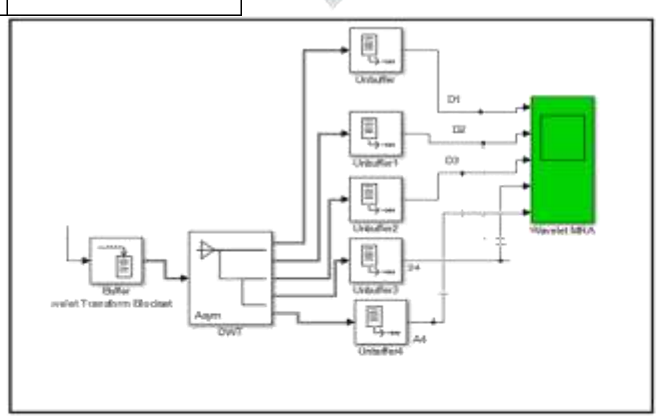


Fig. 4: Wavelet multi-resolution analysis subsystem MATLAB simulink model

Figure 4 shows the wavelet multi-resolution analysis MATLAB simulink subsystem blocks which provide the wavelet multi-resolution analysis of load voltage.

*B. Wavelet spectral energy calibration subsystem model*

Figure 5 shows the matlab simulink model of wavelet multi- resolution spectral energy calibration subsystem. In this system the spectral energy formula is implemented using simulink blocks shown in figure 6.4 while spectral energy formula is

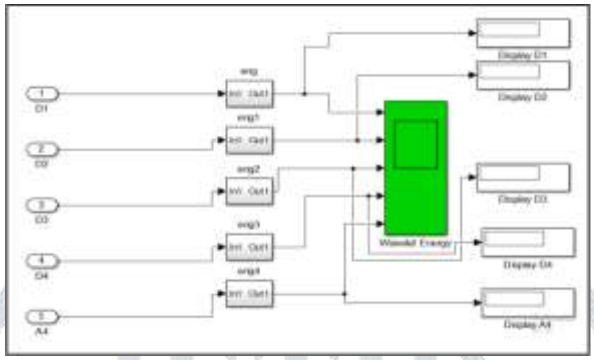

Fig. 5: Wavelet spectral energy calibration subsystem Simulation Results

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

*C. System and Arc parameter measurement*

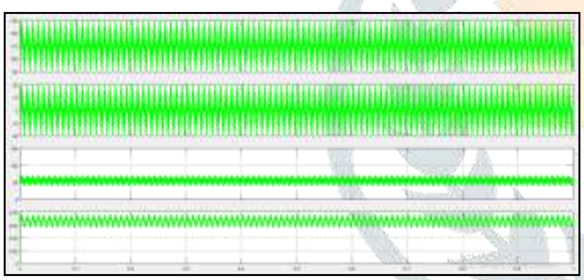

Fig. 6: Bus voltage, AC harmonics voltage, Arc voltage and dc load voltage during normal condition

Figure 7 shows DC bus bar voltage, AC harmonics voltage, arc voltage and DC load voltage during arc occurs in zone-1 at 0.3 sec simulation time. It is observed that there are variations and harmonics components present in arc voltage and load voltage. Also in DC bus voltage there are only switching ripples and inverter ripples presents no any other changes present in that voltages.

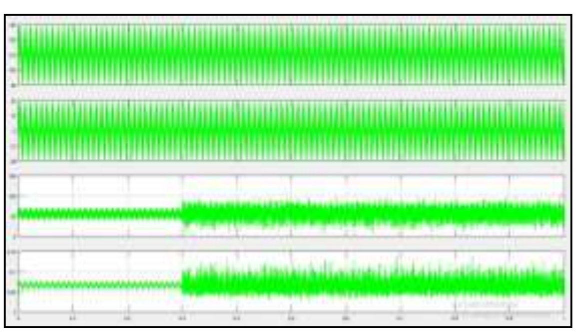

Fig. 7 Bus voltage, AC harmonics voltage, Arc voltage and dc load voltage during arc occurs in zone-1 at 0.3 sec simulation time

*D. Wavelet Multi-resolution analysis results*

Figure 8 shows the wavelet multi-resolution analysis window which shows the detail and approximate coordinator data during normal operation of dc cable. In this case arc is not strict or not consider for operation. So that in this case detail coordinator data that is D1, D2, D3, D4 and Approximation A4 is constant data throughout the operation. Db3 mother wavelet is used for multi-resolution analysis of wavelet transform.

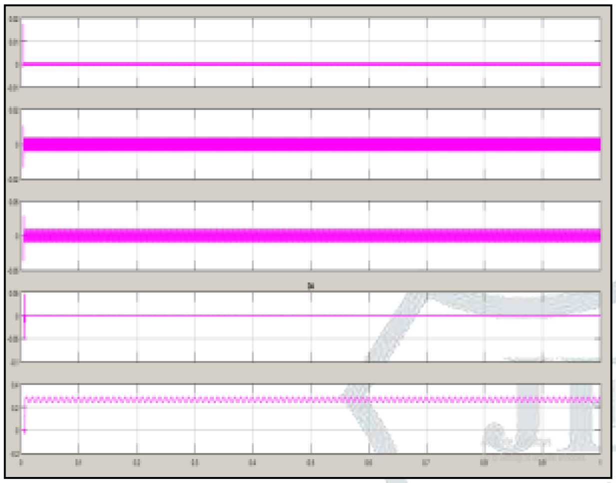

Fig. 8: Wavelet multi-resolution analysis details and approximate coordinators during normal condition

Figure 9 shows the wavelet multi-resolution analysis window which shows the detail and approximate coordinator data during arc flash occurs in zone 1 operation of dc cable. In this case arc is initiated in zone 1of DC cable. So that in this case detail coordinator data that is D1, D2, D3, D4 and Approximation A4 is constant before arc initiated while arc is initiated at time 0.4 sec time then coordinator data changes. Db3 mother wavelet is used for multi-resolution analysis of wavelet transform.

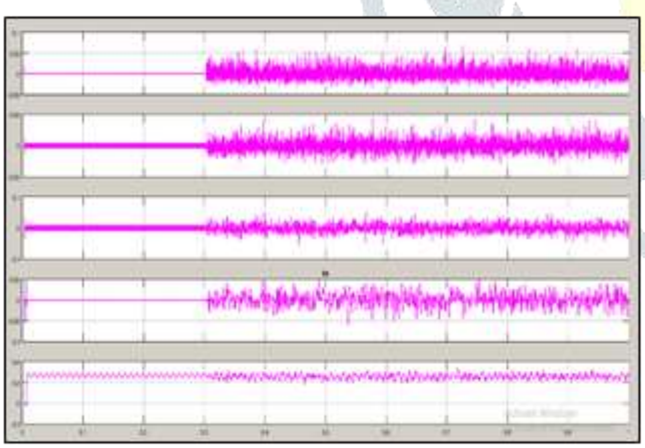

Fig. 9 Wavelet multi-resolution analysis details and approximate coordinators during arc fault or flash in zone-1 occur at 0.3 sec simulation time

Figure 10 shows the wavelet multi-resolution analysis window which shows the detail and approximate coordinator data during arc flash occurs in zone 2 operation of dc cable. In this case arc is initiated in zone 1of DC cable. So that in this case detail coordinator data that is D1, D2, D3, D4 and Approximation A4 is constant before arc initiated while arc is initiated at time 0.4 sec time then coordinator data changes. Db3 mother wavelet is used for multi-resolution analysis of wavelet transform

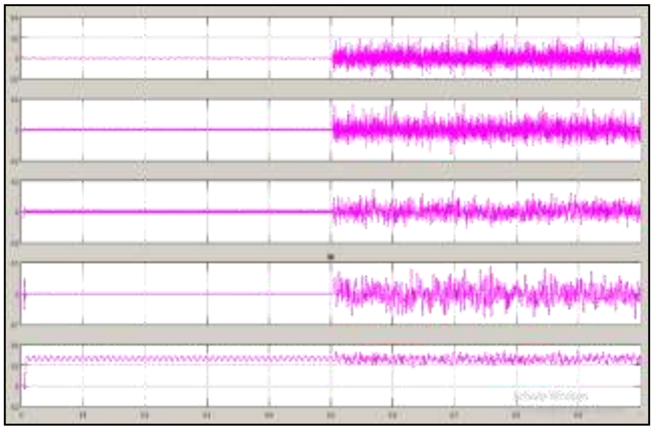

Fig. 10 Wavelet multi-resolution analysis details and approximate coordinators during arc fault or flash in zone-2 occur at 0.5 sec simulation time

*E. Wavelet spectral energy calibration results*

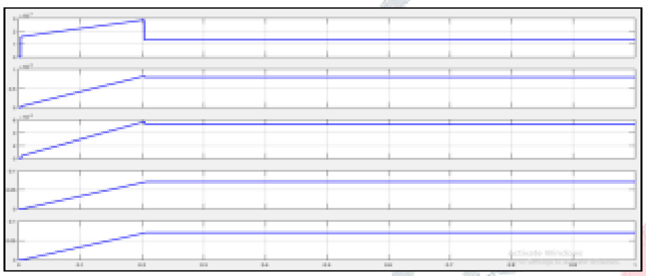

Fig. 12: Wavelet multi-resolution analysis details and approximate coordinators after spectral energy calibration during normal condition

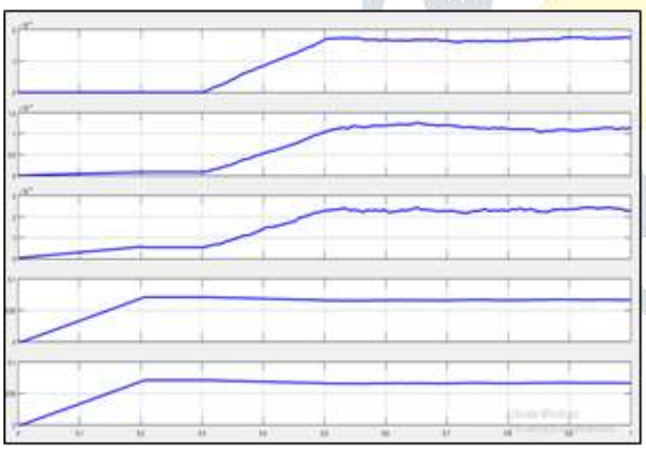

Fig. 13: Wavelet multi-resolution analysis details and approximate coordinators after spectral energy calibration during arc flash or fault occur in zone-1 at 0.3 sec simulation time

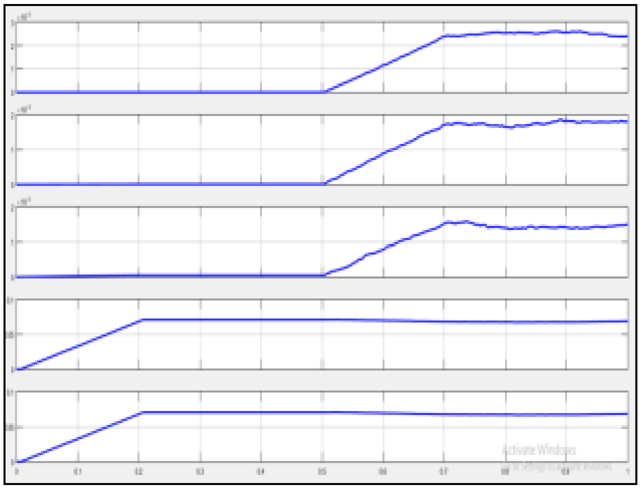

Fig. 14: Wavelet multi-resolution analysis details and approximate coordinators after spectral energy calibration during arc flash or fault occur in zone-2 at 0.5 sec simulation time

Figure 14 shows the wavelet spectral energy of detail signals D1, D2, D3, D4 and Approximate signal A4 at level 4 of multi-resolution analysis. In this window it is observed that spectral energy of signals is changes from 0.6 sec time duration and which is increased in case of normal condition energy and also more than zone-2 condition.

*F. FFT Analysis*

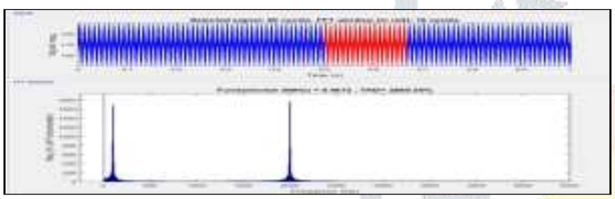

Fig. 15: FFT analysis of dc bus voltage during normal condition

Figure 15 shows that FFT analysis of dc bus voltage during normal and arc flash condition in model-2. It is observed that total harmonics distortion is 2889.50% due to inverter switching pulse and harmonics present in DC bus voltage which consider by using two AC sources.

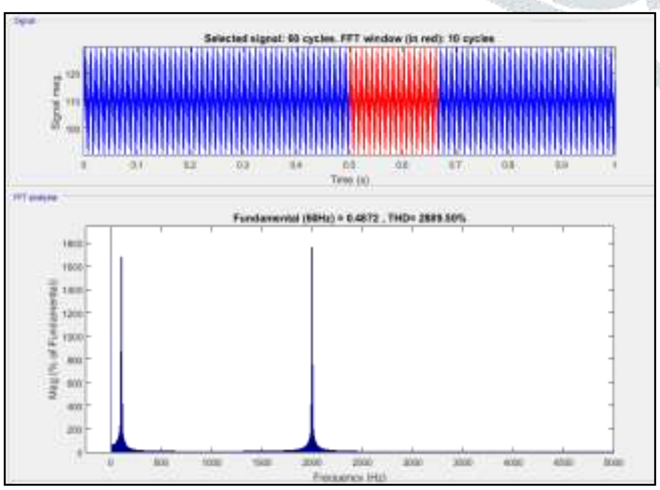


Fig. 16: FFT analysis of dc bus voltage during arc fault or flash occur in zone-1 at 0.3 sec simulation time

Figure 16 shows that FFT analysis of dc bus voltage during normal and arc flash condition. It is observed that total harmonics distortion is 2889.50% due to only inverter switching pulse and harmonics present in DC bus voltage which consider by using two AC sources.

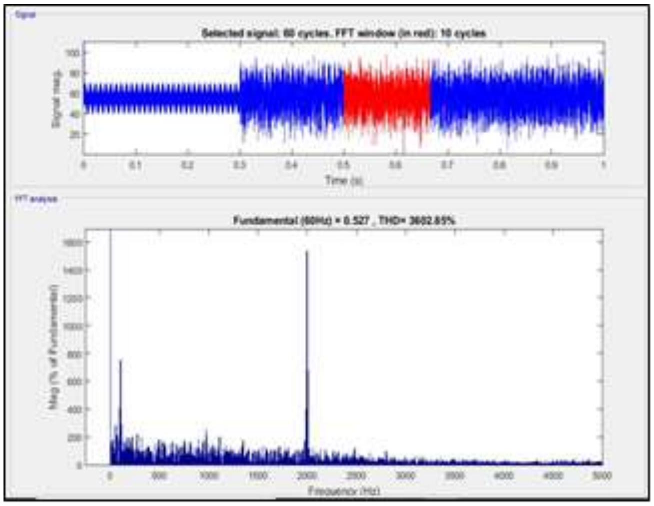


Fig. 17: FFT analysis of arc voltage during arc fault or flash occur in zone-1 at 0.3 sec simulation time in model-2

Figure 17 shows that FFT analysis of arc voltage during arc flash condition. It is observed that total harmonics distortion is 3602.85 % due to arc harmonics as well as due inverter switching pulse and harmonics present in DC bus voltage which consider by using two AC sources.

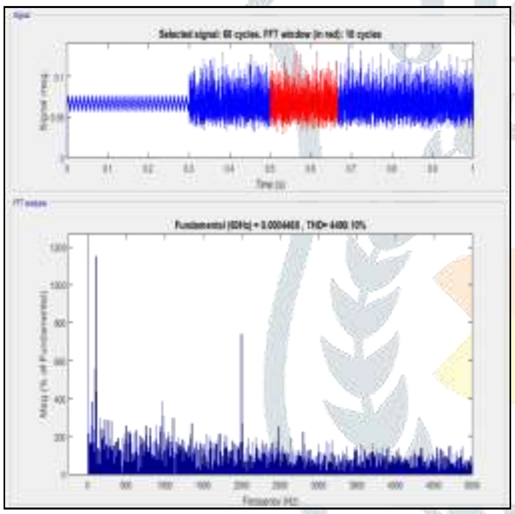


Fig. 18: FFT analysis of dc load voltage during arc fault or flash occur in zone-1 at 0.3 sec simulation time

Figure 18 shows that FFT analysis of dc load voltage during arc flash condition. It is observed that total harmonics distortion is 4490.10 % due to arc harmonics as well as due inverter switching pulse and harmonics present in DC bus voltage which consider by using two AC sources.

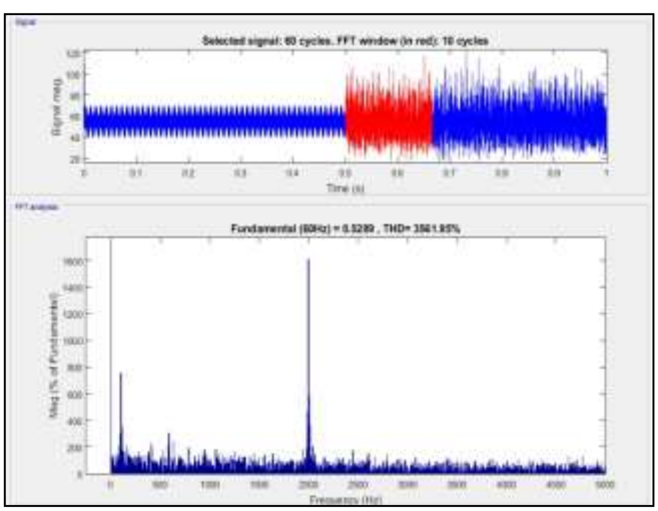


Fig. 19: FFT analysis of arc voltage during arc fault or flash occur in zone-2 at 0.5 sec simulation time

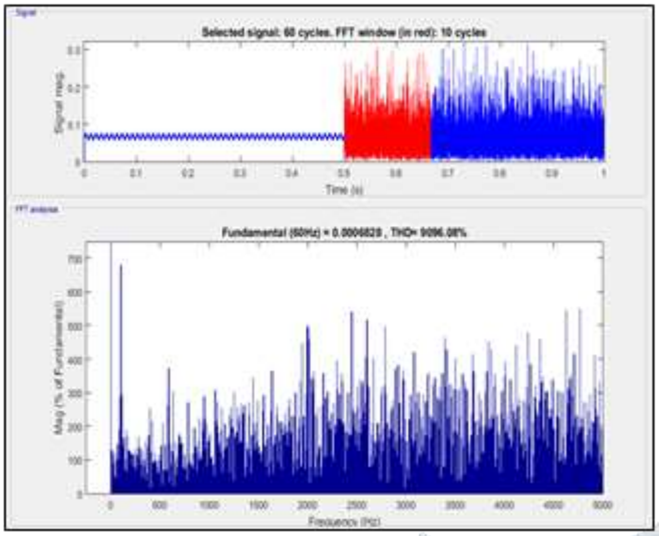

Fig. 19: FFT analysis of dc load voltage during arc fault or flash occur in zone-2 at 0.5 sec simulation time

Figure 20 shows that FFT analysis of arc voltage during arc flash condition. It is observed that total harmonics distortion is 3561.95 % due to arc harmonics as well as due inverter switching pulse and harmonics present in DC bus voltage which consider by using two AC sources.

Figure 20 shows that FFT analysis of dc load voltage during arc flash condition. It is observed that total harmonics distortion is 9096.08 % due to arc harmonics as well as due inverter switching pulse and harmonics present in DC bus voltage which consider by using two AC sources.

Table 2: FFT Analysis THD Calibration for All Models

| Conditions | Parameter | Total Harmonics Distortion (THD) |
|---|---|---|
| Normal Condition | DC Bus voltage | 2889.50 % |
| | Arc Voltage | 4582.59 % |
| | DC Load voltage | 2492.32 % |
| Arc in zone-1 | DC Bus voltage | 2889.50 % |
| | Arc Voltage | 3602.85 % |
| | DC Load voltage | 4490.10 % |
| Arc in zone-2 | DC Bus voltage | 2889.50 % |
| | Arc Voltage | 3561.95 % |
| | DC Load voltage | 9096.08 |

## IV 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.

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