Wavelet based Fault Classification in a Microgrid Integrated Power System for Zone Protection Scheme

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***Abstract*—With the growing integration of distributed generation, distribution networks have evolved toward the concept of microgrids. Microgrids can be operated in either the grid connected mode to achieve peak shaving and power loss reduction or the islanded mode to increase the reliability and continuity of supply. These two modes of operation cause a challenge in microgrid protection, because the magnitude of fault current decreases significantly during the transition of a microgrid from the grid-connected mode to the islanded mode. A wavelet based multi resolution analysis is used to find the detailed coefficients of these signals which are utilized to calculate fault index.**

Keywords—Microgrid, Wavelets, Fault, Protection

I. INTRODUCTION (*HEADING 1*)

During the last decade, the concept of microgrid has emerged as a remarkable way of integrating sustainable energy sources in the electric network. Its main benefits lie in that it supplies power locally, reduces grid investment due to lower network capacity requirements, reduces operation costs and losses, reduces the peak load and increases reliability [1]. However, along with these benefits, microgrids have also raised a number of challenges, amongst them the issue of protection [2]. The advent, and increasing popularity, of distributed generation (DG) in distribution systems has added to the complexity of the protection coordination problem. Introducing DG into the distribution system will cause changes in the short circuit magnitudes and directions, and therefore the existing protection scheme may not be able to perform its coordination function correctly [2]. In [3], it has been shown that the fault current contribution will depend on the type of DG present in the system. There are two main issues the microgrid has to address with regard to its protection [3]: Firstly, the determination of the time when it should be islanded from the main grid in response to abnormal conditions that the utility may experience; secondly, the provision of properly coordinated and reliable protection system so that it can reliably trip in the event of a fault within it.

In the past decades, the development of fault diagnosis for the power system has progressed with the applications of wavelet transform. However, the work rarely mention about the location of fault on multi terminal. Wavelet transform analyzes transient voltage and current signals associated with faults both in frequency and time domain. In this paper, Wavelet Multi Resolution Analysis is used for detection, classification and location of faults on transmission lines. Detail D1 coefficients of current signals using Bior1.5 wavelets are used to detect, classify and location of fault.

II. WHAT IS MICROGRID

A microgrid is a localized group of electricity sources and loads that normally operates connected to and synchronous with the traditional wide area synchronous grid (macro grid), but can also disconnect to "island mode" — and function autonomously as physical or economic conditions dictate.

In this way, a microgrid can effectively integrate various sources of distributed generation (DG), especially Renewable Energy Sources (RES) - renewable electricity, and can supply emergency power, changing between island and connected modes.

Control and protection are challenges to microgrids. A very important feature is also to provide multiple end-use needs as heating, cooling, and electricity at the same time since this allows energy carrier substitution and increased energy efficiency due to waste heat utilization for heating, domestic hot water, and cooling purposes (cross sectoral energy usage).

III. WAVELET THEORY

Wavelet Transform (WT) is a linear transformation much like the Fourier transform, however with one important difference: it allows time localization of different frequency components of a given signal. So, it is a mathematical technique used in signal analysis. Wavelet analysis is particularly efficient where the signal being analyzed has transients or discontinuities, e.g., the post fault voltage/current waveform. In wavelet transform, the analyzing functions, which are called Wavelets, will adjust their time width to their frequency in such a way that, higher frequency wavelets will be very narrow and lower frequency ones will be boarder. Wavelet transform is a tool that cuts up data or functions or operators into different frequency components, and then studies each component with a resolution matched to its scale [12].

The Discrete Wavelet Transform is easier to implement than Continuous Wavelet Transform is computed by changing the scale of the analysis window and shifting the window in time or multiplying the signal and the information of interest is often a combination of features that are most speedy. This requires the use of analysis methods sufficiently in which it is versatile to handle signals in terms of their localization of time frequency. Frequency based analysis has been common since Fourier's time. These results in a very wide frequency spectrum in the analysis of transients Fourier techniques cannot simultaneously achieve good localization in both time and frequency resolution for a transient wave. The main advantage of WT over Fourier Transform is that the size of analysis window varies in proportion to the frequency analysis at which WT can offer a better compromise in terms of localization.

Fig 1. Analysis of signal using wavelet transforms. The wavelet transform decomposes transients into a series of wavelet components having each of which corresponds to a time domain signal that covers a specific octave frequency band containing more detailed information. Such wavelet components appear to be useful for detecting and classifying the sources of surges [12]. Hence, the WT is feasible and practical for analyzing power system transients and disturbances [13]. Power transmission line protection is one of the most important concerns for the power utilities set of basic functions called Wavelets, are used to decompose the signal in various frequency bands, which are obtained from a mother wavelet by

dilation and translation [14]. Hence the amplitude and incidence of each frequency can be found precisely. Given, a function f(t), its continuous wavelet transform (WT) be calculated as follows

$$wt(a,b) = \frac{1}{\sqrt{a}} \int x(t) g\left(\frac{t-a}{b}\right) dt$$

Where a and b are the scaling (dilation) and translation (time shift) constants respectively, and ψ is the wavelet function which may not be real as assumed in the above equation for simplicity. The selection of mother wavelet is based on the type of application. In the following section a novel method of detection and classification of faults using Multi Resolution Analysis of the transient currents associated with the fault is discussed [14].

IV. SYSTEM INFORMATION

Fig. 1 depicts the layout and the main parameters of a three phase, three-wire, 34.5 kV, 60 Hz test microgrid simulated using PSCAD/EMTDC. The utility grid is represented by a voltage source with the short-circuit capacity of 900 MVA. This microgrid can include a combination of the following DG units:

– DG1: This is a 10.75 MVA, 4.16 kV SG unit at bus 3. This unit is normally open in the grid-connected mode

– DG2: This is a 7.5 MVA (or 5 MVA), 4.16 kV ECDG unit at bus 7 (or bus 4), It represents either a solar-photovoltaic or a Type-4 wind unit. This DG is equipped with a braking chopper circuit to satisfy the fault ride-through requirements of grid codes.

– DG3: This is a 7.5 MVA (or 5 MVA), 4.16 kV IMDG unit at bus 7 (or bus 4). The generators are either squirrel cage induction generators (SCIGs) or doubly-fed induction generators (DFIGs)

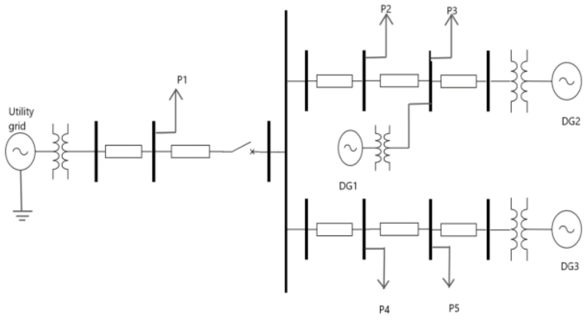


Fig.1: Single line diagram for proposed Fault classification in Microgrid power System

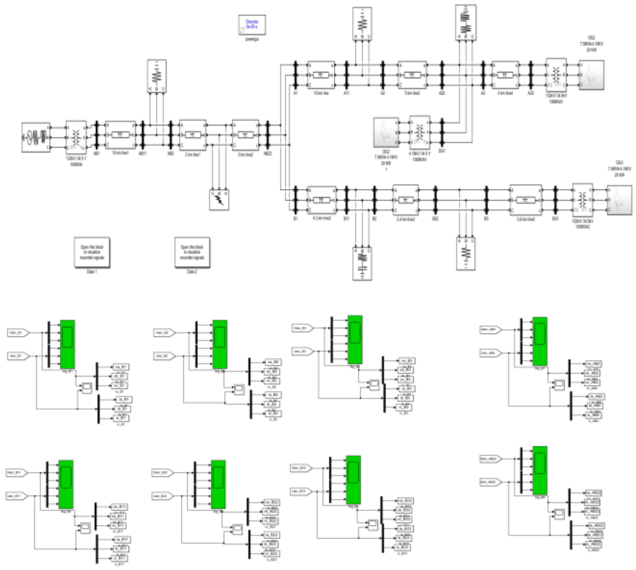
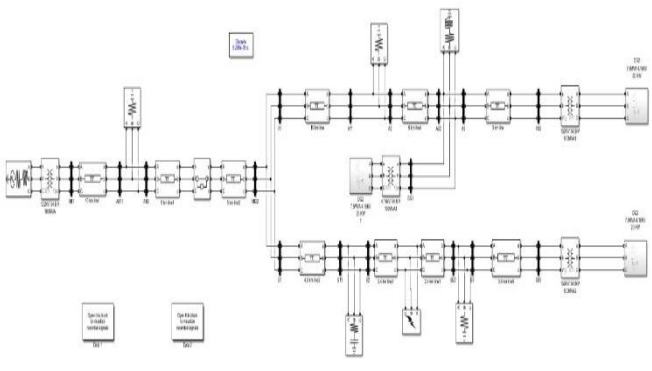


Fig. 2: Simulation diagram for proposed Fault classification in Microgrid power System



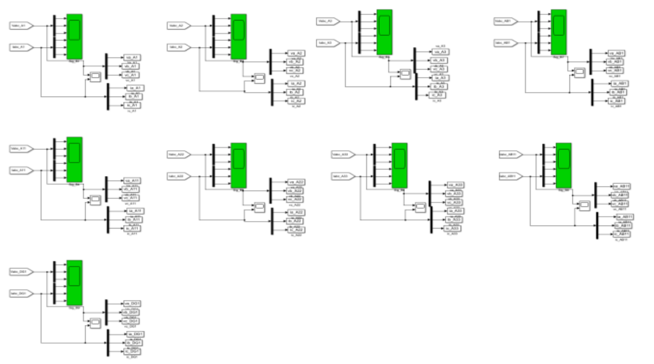
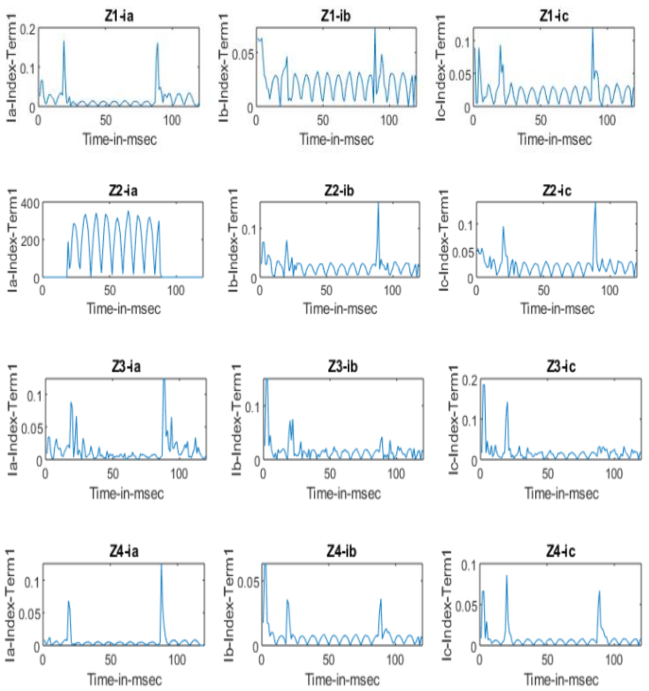


Fig. 3: Simulation diagram for proposed Fault classification in Microgrid power System in Ilanding mode

V. Result Description

The system is equipped with a three DG’s. The network is connected with two DG’s sources with 7.5MW capacity and each source is transferred through a 34.5kv/132kv transformer. The two DG’s sources, DG2 is connected to Bus- A33 and other source DG3 is connected to Bus-B33. Third DG is connected to bus-DG1. Zone 1 is from bus A1 to A11. Zone 2 is from bus A2 to A22. Zone 3 is from bus A3 to A33. Zone 4 is from bus B1 to B11. Zone 5 is from bus B2 to B22. Zone 6 is from bus B3 to B33. Zone 7 is from bus AB1 to AB11. Zone 8 is from bus AB2 to AB22. Symmetrical and unsymmetrical faults are applied on these two conditions both islanding and grid connected mode, the results are seen below.

From these results more faults should be occur on one zone and faults are observed and the fault impact on remaining zones are observed. Determined all LG, LL, LLG and LLL faults on the transmission line and Variation of all fault indices are successfully obtained for both islanding mode and grid connected mode.



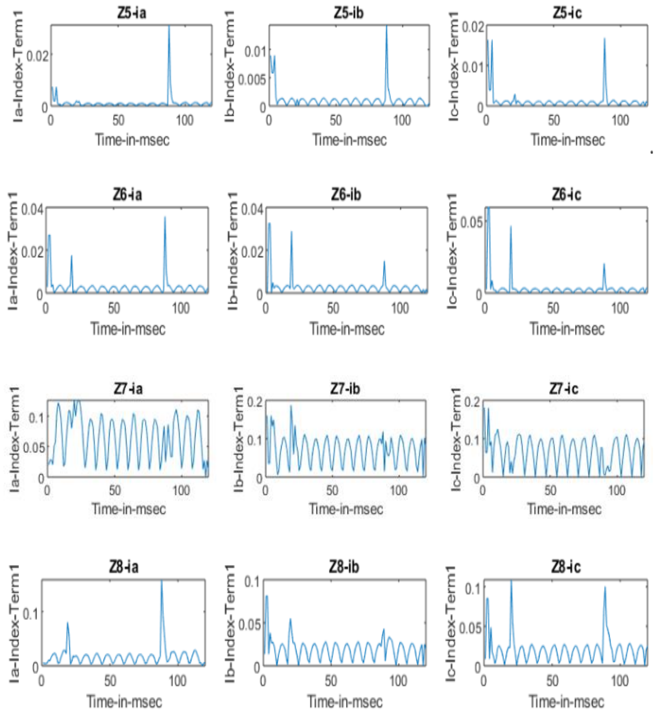
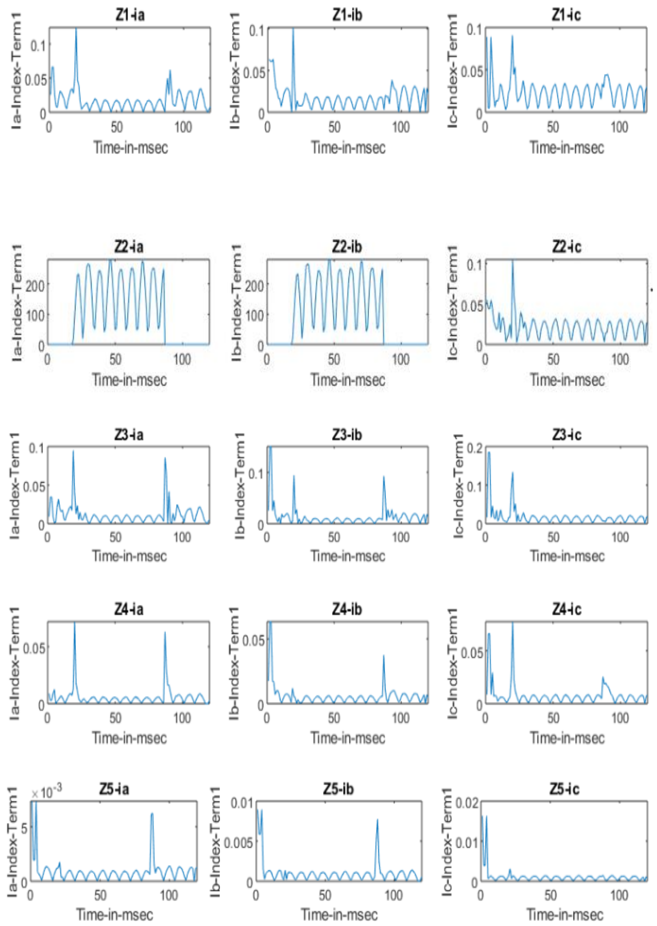


Fig 5.1- LG Fault is created at Zone 2 and its impact on other Zone in System



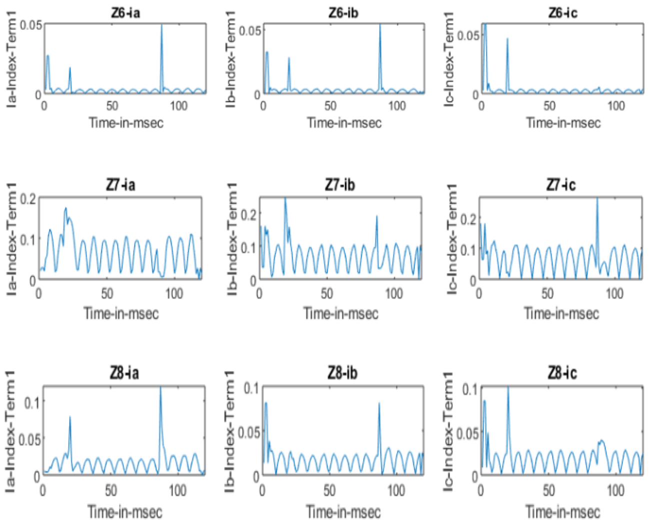
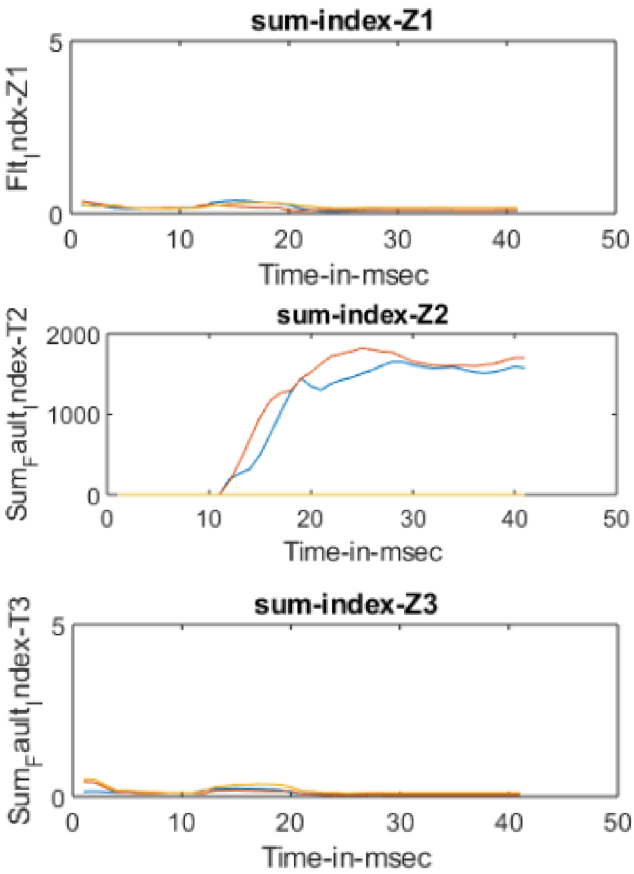


Fig 5.2- LL Fault is created at Zone 2 and its impact on other Zone in System



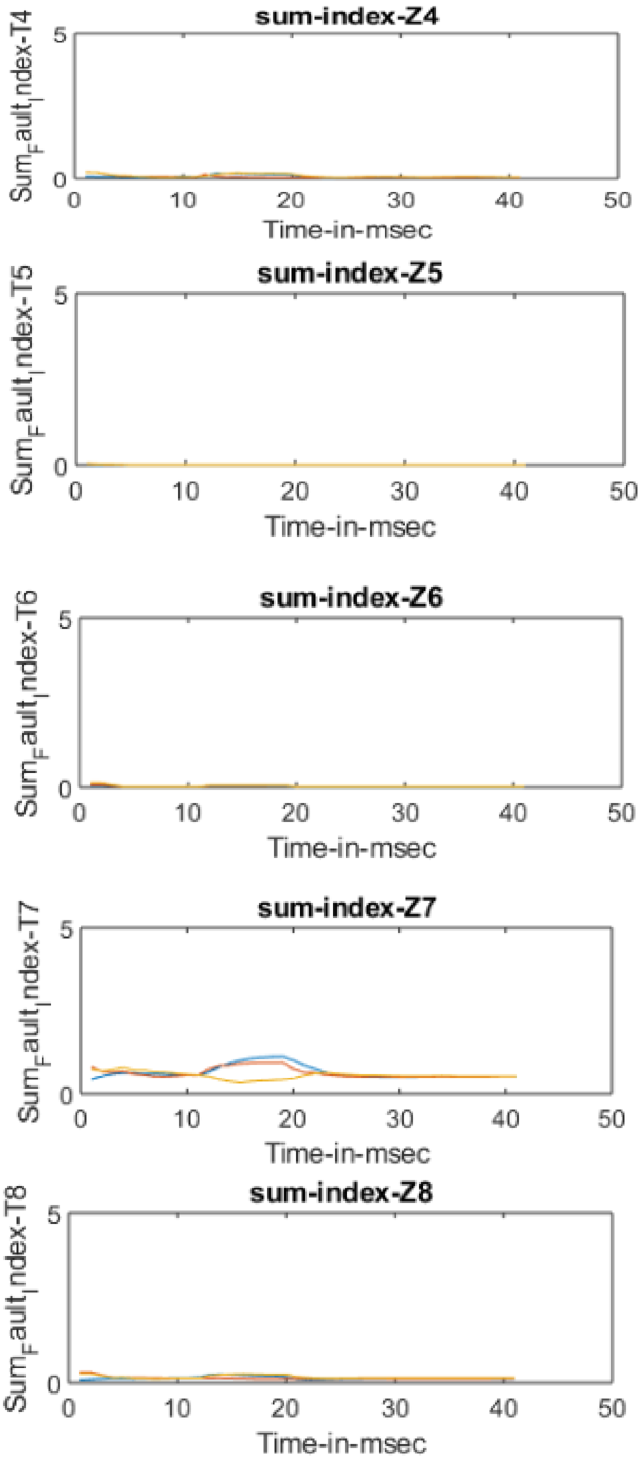
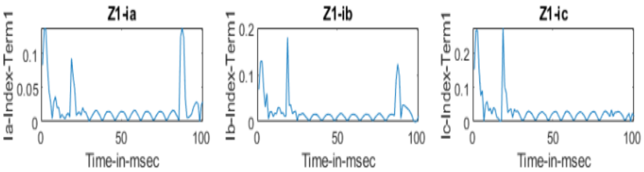


Fig 5.3-Sum of Index terms in LG Fault is created at Zone 2 and its impact on other Zone in System



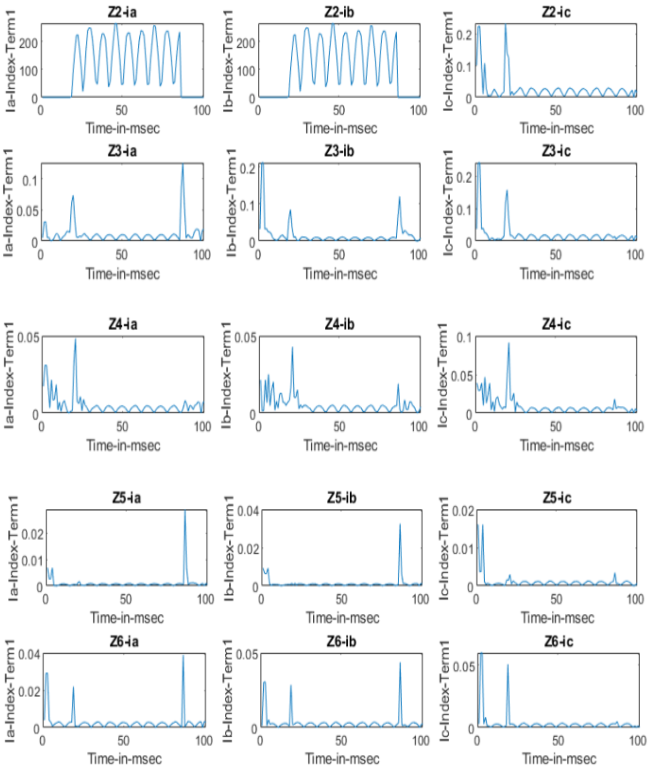
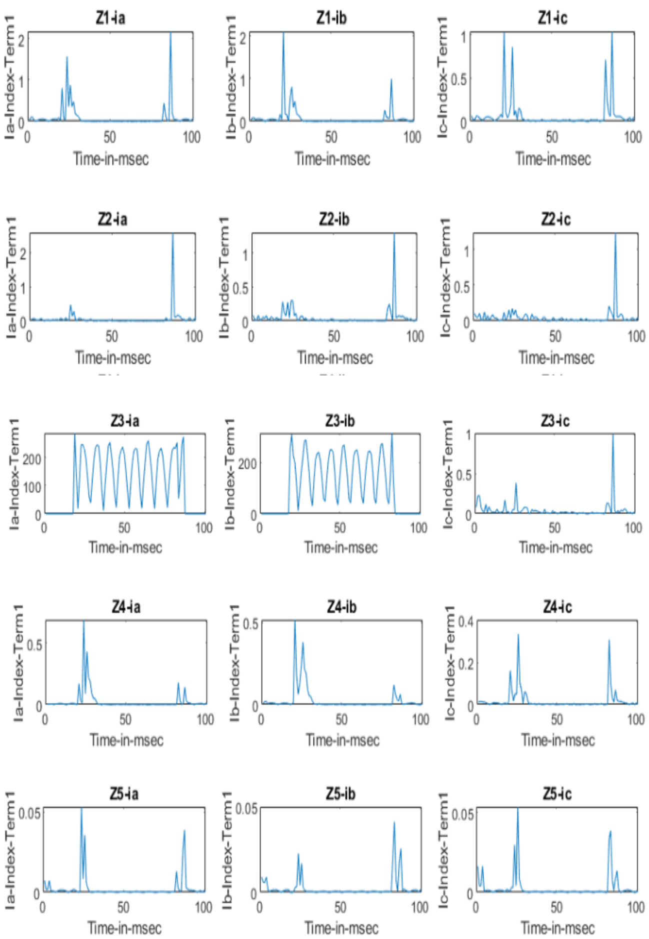


Fig 5.4 - LL Fault is created at Zone 2 and its impact on other Zone in Islanding System when Zone 7 and Zone 8 are separated



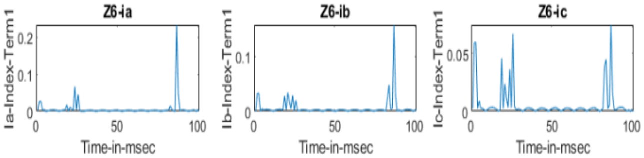
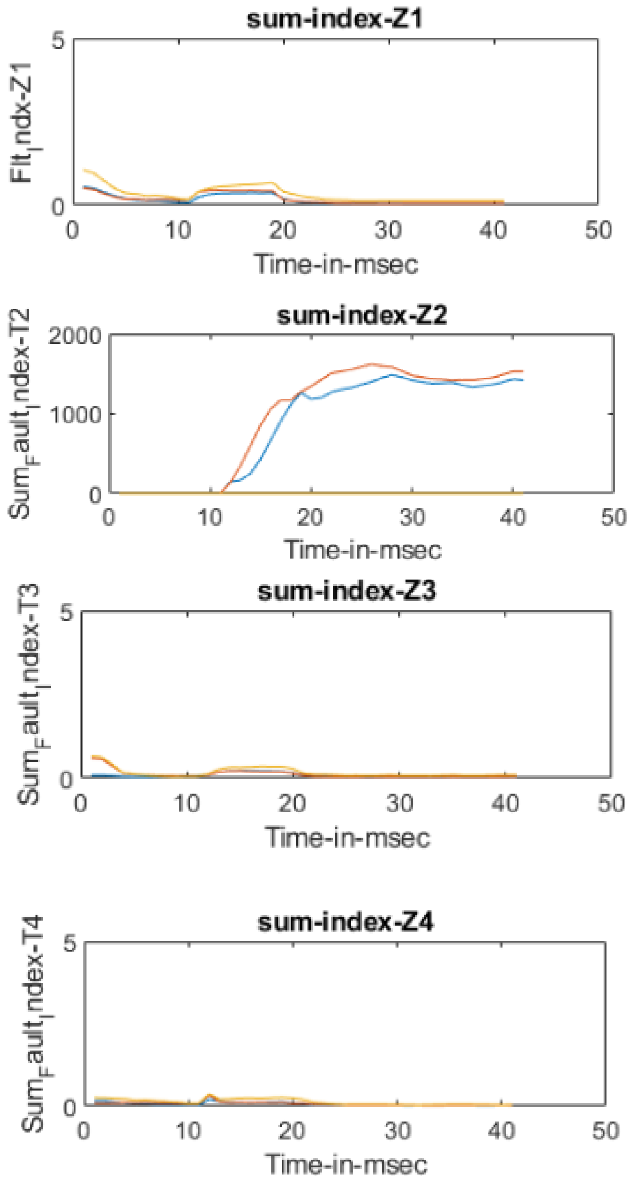


Fig 5.5 - LL Fault is created at Zone 3 and its impact on other Zone in Islanding System when Zone 7 and Zone 8 are separated.



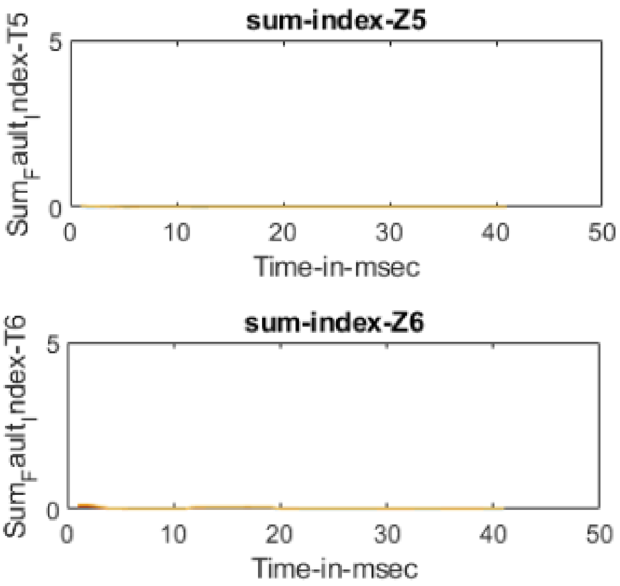


Fig 5.6- Sum of Index terms in LG Fault is created at Zone 2 and its impact on other Zone in System .

VI. Conclusion

In this system under the faulty conditions circuit breaker will isolate the system for main grid and the rest of the system is operated based under DG's. Detection of fault disturbances using Wavelet Transform Current signal extracted at different zones is being processed through the above techniques under different fault and operating scenarios. It is observed that WT transform detected the fault instant very accurately. By analysing the fault waveforms using Bior 1.5 mother wavelet, the proposed method discriminates all faults viz., single phase to ground, double phase with and without ground, three phase with and without ground at different distances in zone with in less than a half cycle.

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