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Smart Grid Islanding Detection using solar PV

Saika Muntaha Bari, Sumaiya Rahman, Refat Ara Urmi, Farjana Akhter Bristy, M. Raquib Ehsan

Abstract— Power system equipped with distributed generation (DG) is a recent development with the advent of the availability of distributed electric renewable sources such as solar photo-voltaic (PV).Grid becomes smart with the provision of monitoring its performance through optimization and self-healing capabilities. In the presence of DG, such smart grid needs to detect the situation when the conventional utility grid supply fails and DG is in islanding mode, i.e., the DG continues to provide power to the load that does not match to its capacity. Such islanding situation, if exists, is dangerous with the regards to the safety as it may destroy user's equipment and utilities and harmful for the entire grid system. For this reason islanding detection is a mandatory as it occurs unusual occurrences like potential damage of existing system, utility liability concerns, reduction of power quality and power reliability.Therefore, in this thesis an algorithm is proposed for the detection of islanding and other different faulty conditions such as DG tripping or sudden load change condition using passive detection technique using Wavelet transform. Using symmetrical components like negative sequence analysis the proposed algorithm is able to differentiate different faulty condition including islanding. We have analyzed negative sequence voltage and current through DWT (Discrete Wavelet Transform). We have found change in d1 coefficient of negative sequence voltage and current for different islanding and non-islanding condition and it is shown in color codes. For different color code d1 coefficient is different. So, islanding and other faulty conditions are easily clarified. Wavelet Transform is a new technique and it's easier to detect islanding and other conditions. We can easily notice about the islanding and the technique is highly effective to save the power system from damages. New innovative ideas of technology will give us an inspiration to go further.

Index Terms— Distributed generation (DG), Islanding, Discrete Wavelet Transform (DWT), Daubechies Wavelet 4 (db4), Negative Sequence Component, Threshold level, Color Code.

1 Introduction

Power system protection is undoubtedly a basic concern for different kinds of faults that is responsible for unwanted potential harm of equipment and lessen power quality and reliability. Islanding is a great problem as it occurs when the main grid is isolated from the utilities and the distributed generators (DG) continue to power the location where the main grid is not working. Our thesis proposes an islanding detection method for a smart grid power system .The main grid is connected with Photovoltaic which is a distributed generator. Our main objective is to detect the unhealthy condition of a power system so the engineers can take steps to save grid from any kind of damages.

An electrical grid is a mutually connected network for providing electricity from suppliers to consumers. First, the generating stations produce electric power. Then comes high-voltage transmission lines transfer power from distant sources to demand centers, and at last distribution lines that provide individual customers [1].

Power stations may be placed adjacent to a fuel source, at a dam site, or to take advantage of renewable energy sources, and are often separated from heavily populated areas. They are the backbone of the whole system providing its credit economically. The electric power which is produced is boost up a higher voltage-at which it connects to the transmission network. Transmission network will move the power long distances, sometimes across international boundaries. On arrival at a substation, the power will be reduced from a transmission level voltage to a distribution level voltage. After exiting the substation, it works on the distribution wiring. At last, when returning at the service location; the power is stepped down from distribution voltage to prescribed service voltage.

Electricity generation is the way of generating electric power from other fundamental energy sources. Typically measured per-year, it involves all energy gathered from every energy source we use, applied towards humanity's aim. Energy Consumption has deep implication for human kind, illuminating the world with the power of technologies.

DG (distributed generators) generally refers to small-scale (1 kW – 50 MW) electrical power generators that develops electricity to local areas and can support the grid nearby. DG technologies have potential benefits as it produces zero or near-zero pollutant emissions, Reliability and power quality, reduce pressure on distribution and transmission line, lower capital cost for the small size of the DG.

Different types of natural calamities like wind storms, falling trees, brownouts, and lightening all threaten the grid, and when it fails, it typically leaves thousands of customers (or millions in extreme cases) without power for longer time periods. A distributed generation system with micro grids can localize the effects of these failures, reducing the number of people affected.

Big power plants - whether they are based on fossil fuels, nu-

- *Saika Muntaha Bari is currently pursuing master degree program in computer science & engineering (EEE) in United International University, Bangladesh. E-mail:saika.bari.15@gmail.com*
- *Sumaiya Rahman is currently pursuing master degree program in electrical & electronic engineering (EEE) in University Technology Malaysia, Malaysia. E-mail:sumaiya_r@yahoo.com*
- *Refat Ara Urmi is currently acting as instructor in electrical & electronic engineering in United International University, Bangladesh.. E-mail: urmi6508@yahoo.com*
- *Farjana Akhter Bristy is currently working as assistant engineer in an engineering institution, Bangladesh.E-mail:farjana0309@gmail.com*
- *M. Raquib Ehsan is acting as Research Associate in EEE deptartment, United International University, Dhaka, Bangladesh.*

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clear energy, or renewable energy – become more expensive to establish and have very long financial terms and conditional issues. That means the utilities are slower to adopt new technologies. On the other hand, if we establish several smaller plants based on renewable sources, we can easily decommission them a little at a time.

If we build a large wind farm with turbines, that have an expected life of 30 years. Turbine efficiency is gradually being sophisticated over time by a lot of brilliant brains, but it is too costly to replace an entire farm at once. Whole turbine system consist an array of distinguished turbine unit - each unit affects its neighbors we cannot simply replace a new turbines with newer models. Smaller wind farms are more applicable in this case.

Distributed generation allows us to use a variety of power generating technologies, decreasing our dependence on any one resource. Condition of islanding specifically is defined as when a section of the non-utility generation system is separated from the main utility system but non-utility generation system still continues to power the certain area. Islanding can be threatening to utility workers, who may not readily understand that the circuit is still powered. For this reason, distributed generators must detect islanding and stop producing power [4].

2 Related Work

Synthesis of Distributed Generations (DGs) in the distribution network is expected to play an increasingly important role in the electric power system groundwork and market. As more DG systems become part of the power grid, there is an increased safety peril for personnel and an increased risk of damage to the power system. Despite the favorable aspects grid-connected DGs can supply to the distribution system, a critical demanding concern is islanding detection and interception.

Islanding operation is a condition that occurs when a part of a network is disconnected from the remainder of power system but being energized by interconnected DG units to the distribution system, which normally consist multiple DGs with diverse technologies. Misstep to trip islanded DG can lead to a number of problems for these resources and the connected loads, which affects power quality, safety and operating problems. Therefore, the current industry approach is to disconnect all DR's promptly after the occurrence of islands. The disconnection is usually performed by a special protection scheme which is called islanding detection relays which can be implemented using various techniques.

Islanding detection techniques may be classified as passive or active. Passive techniques use information at the DG side to determine whether the DG system is isolated from the grid. The advantage of passive techniques is the implementation does not have an impact on the normal operation of the DG system. Active techniques induce an external perturbation at the output of the inverter. These tend to have a faster response and a smaller non-detection zone distinguished to passive approaches. However, the power quality (PQ) of the inverter can be degraded by the perturbation. Recently pattern recognition method based on Wavelet Transform has been found to be an effective tool in monitoring and investigating power system disturbances including power quality assessment and system protection against faults. This paper analyzes the time-localization property of Wavelet transform for islanding detection by processing major negative sequence components of voltage and current signals is measured at the target DG area. As negative sequence components contributes vital information in case of unbalanced conditions in power system, thus equal approach has been considered for the proposed islanding detection technique which is regulated to disturbance when islanding process is being initiated such as deviations in voltage, frequency and active power etc. The negative sequence components of the electrical signals are extracted from the derived voltage and current signal at the target DG locations. The one cycle negative sequence voltage and current signal are treated through Wavelet transform (db4). The time-frequency information determined at the level-1decompositions (d1) localizes the equivalent islanding events. Further to set a threshold for detecting islanding circumstances from non-islanding ones, the standard deviations and change in energy of the d1 level coefficients for one cycle are computed.

Further to know the effect of negative sequence impedance in the islanding detection, the same is found out at the target DG location. It is noticed that time variation of the negative sequence impedance provides effective islanding detection distinguished to non-islanding situations. Further, the standard deviation of the negative sequence impedance for one cycle data exposes the islanding conditions accurately over non-sanding ones. Thus the above two techniques based on negative sequence components contribute effective islanding detection techniques, which has edge over some earlier techniques.

3 Methodologies

3.1 Proposed Islanding Detection Method:

There are some new techniques which we have developed for islanding detection. We used Negative sequence component and d1 coefficients for islanding detection. In this paper, a wavelet transform-based approach is proposed to detect the occurrence of islanding events in distributed generation systems.

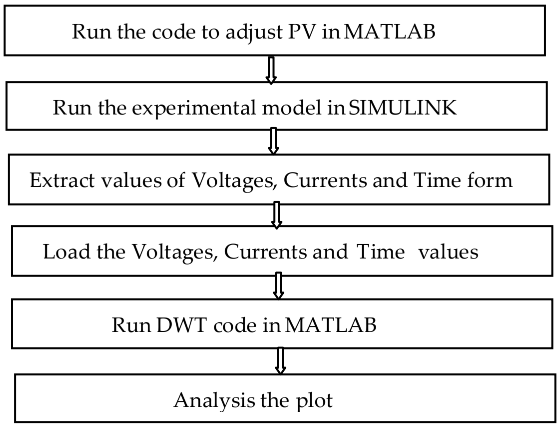

Fig1: Steps of proposed methodfor detecting Islanding

3.2 Matlab/Simulink Model

For better understanding, a simulation model is inevitable and a must to be implemented for observing the case.

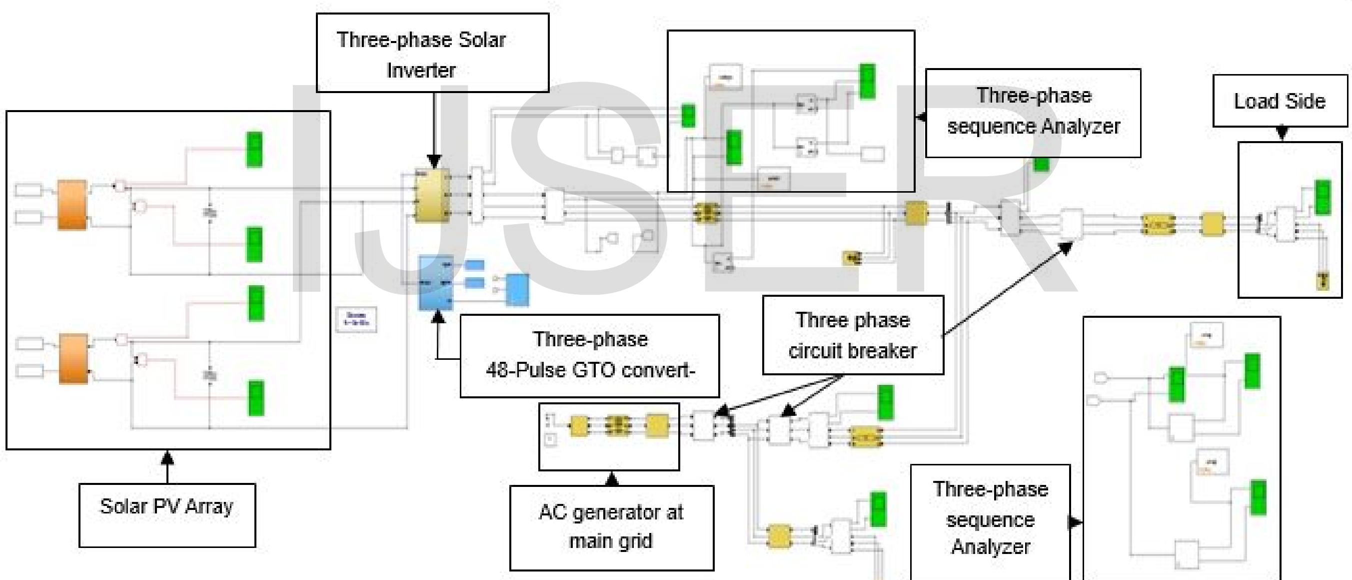

Fig 2: MATLAB Simulink model

It is important that the model exhibits a real system in all vital parts. The behavior of the simulated system and the real scenario should be judged. How this has been achieved that is described in the following. Our emphasis has been put on solar PV and induction generators. The reason for this is the ongoing extension of wind power. At the starting, we consider a model that is shown below. This model is set having 9MW photo voltaic. The model is well suited for observing harmonics and control system dynamic performance over relatively short periods of time.

9MW photo voltaic consists of two 4.5 MW PV module connected to a 13.8 KV grid and transmission line 80 KM. 4.4MW resistive load is connected. We have Three-Phase 48-Pulse GTO Converter to convert the signal DC to AC.

Both voltage and current signals are revived from the target DG location for islanding conditions and non-islanding conditions (other disturbances). To create islanding situation we placed a circuit breaker at Main grid side. After a certain time this breaker is opened and then main grid is isolated from the DG side. Grid failure is a primary concern as there are many issues in DG that are responsible for this disturbance. So we need to know about other conditions. Possible conditions are Islanding conditions, sudden load change, DG cut off. Conditions may vary in operating loading at normal, minimum, maximum different loading conditions. The loads are varied at the DG end as well as at the main grid. The model is simulated at 200 kHz (infinite samples on 60 Hz base frequency). Both current and voltage signals can be revived from DG location.

3.3 Different condition of Islanding

Condition-1:

Both the three phase circuit breaker at DG & Main Grid is in closed conditions. That is the normal condition. We get sinusoidal wave forms of current and voltage at DG end.

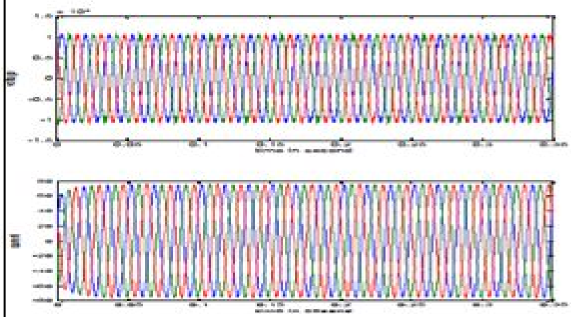

Fig 3: Three-Phase Voltage and Current Signals under Normal Condition retrieved at the target DG location

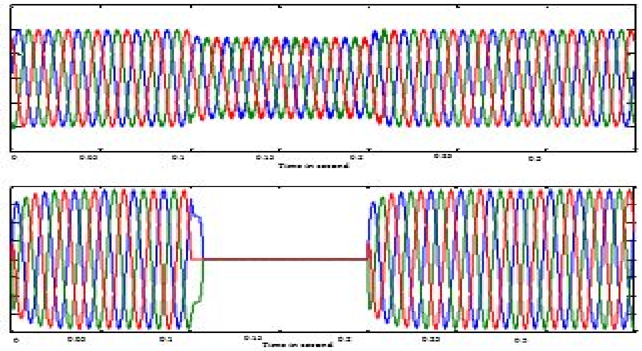

Fig 5: Three-Phase Voltage and Current Signals under DG Trip Line Condition retrieved at the target DG location

Condition-2:

In Islanding condition the circuit breaker is closed primarily but after 0.1 to 0.2 (transition time) the circuit breaker is open. Three phase circuit breaker is permanently closed at DG side.

The distributed generation system is totally separated from the remainder part of power system when the three phase circuit breaker is turned off.

However any abrupt change deviant from normal condition indicates disturbance in a healthy system. Our proposed method serves as an inevitable alternative as increasing number of installed distributed generation system. Islandng detection of protective relays are our main concern and we manage to provide a good result .Utility engineer’s security is well assured. We observe that both time and frequency data are well informed.

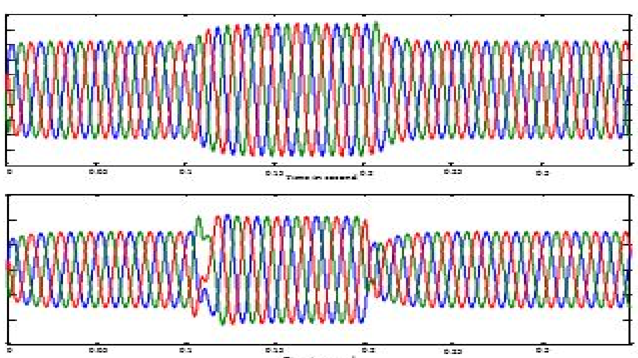

Fig 4: Three-Phase Voltage and Current Signals under Condition retrieved at the target DG location

Condition-3:

In DG line trip condition at first the circuit breaker is closed but after 0.1 to 0.2 (transition time) the circuit breaker is open at DG side. Three phase circuit breaker is permanently closed at Main grid side.

Condition-4:

In sudden load change condition where abruptly load is changed up to 50%. We added load with a circuit breaker that is initially opened and closed with transition time 0.1 to 0.2 at DG side.

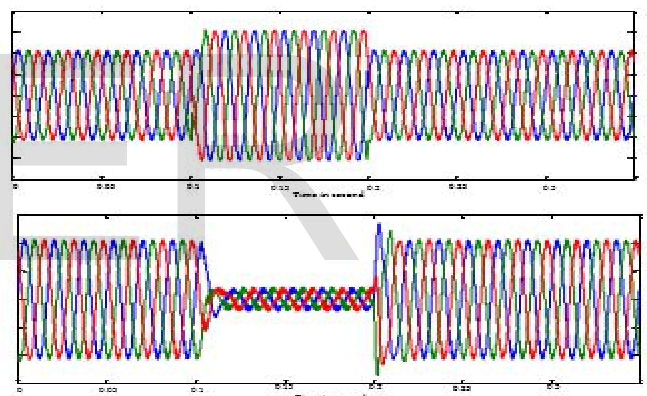

Fig 6: Three-Phase Voltage and Current Signals under Sudden Load Change Condition retrieved at the target DG location.

3.3.1 Wavelet Transform:

Our work is purely based on wavelet transform to observe the parameter variations of interests. Here Daubechies wavelet is our prime concern. Such an approach strengthen our gist and it is predictable that any abrupt change occurred in the measured signal would be effectively captured; hence increasing their liability of islanding-detection. The main disadvantage of passive islanding detection technique is large NDZ (None Detecting Zone) which can be recovered by wavelet transform.

3.3.2 Negative Sequence Component:

Negative-sequence is one of three major factors used in the symmetrical component analysis of three-phase power systems. Symmetrical components are used to measure unbalanced conditions on a three-phase system by calculating only

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a single-phase circuit. This greatly facilitates the process of calculating fault quantities for phase-to-ground, phase-to-phase and phase-to phase-to-ground faults on power systems. And symmetrical components reside of positive, negative, and zero-sequence quantities. Generally, positive-sequence quantities are those present during balanced, three-phase conditions [1].

Negative- sequence factors are a measure of the amount of unbalance existing on a power system. Negative-and zero-sequence quantities are mostly present in substantial levels during unbalanced, faulty conditions on a power system. Since zero and negative sequence quantities are only present in relatively large values for faulted conditions, they are often used to determine the faulty condition exists on a power system. Negative-sequence can be performed to detect phase-to-ground, phase- to-phase and another common phase-to phase-to-ground faults. Zero-sequence can be used to detect phase-to-ground and phase-to phase-to-ground faults.

3.3.3 Discrete Wavelet Transform (DWT):

In numerical analysis and functional analysis, a discrete wavelet transform (DWT) is any wavelet transform for which the wavelets are discretely sampled. As with another wavelet transforms, a key advantage it has over Fourier transforms is temporal resolution: it includes both frequency and location information (location in time) [19].

3.3.4 Threshold level:

We have set a “Threshold level” to differentiate among the four conditions. In this case level or scale 3 has been chosen because of significant unlikeness. Also, we know that at lower scale frequency is higher. When islanding occurs frequency becomes very high so analyzing the level where frequency is high helped us to detect islanding.

3.3.5 Color Code:

It has been discussed that the value of coefficient classifies which condition has occurred at DG side. Range of coefficient is identified by range of color code. For example, if the color is dark blue the value of coefficient is zero so normal condition which means no disturbance has occurred. If the color is red, the value of coefficient is higher, therefore, disturbance like islanding has occurred.

3.3.6 Daubechies Wavelet 4 (db4):

The utmost available used set of discrete wavelet transforms was formulated by the Belgian mathematician Ingrid Daubechies in 1988. This formulation is based on the use of reappearance relations to generate progressively finer discrete samplings of a definite mother wavelet function; particular resolution is twice that of the previous scale. In her seminal paper, Daubechies exacts a family of wavelets, the first of which is the Haar wavelet. Interest in this field has exploded since then, and many alternations of Daubechies' original wavelets were developed [1]. Wavelets localize the information in the time–frequency plane which is relevant for the analysis of non-stationary signals. WT divides up data, functions into distinct frequency quantities, and then studies each component with a resolution matched to its scale. In this paper, the voltage and current signals are used as the input signals of the wavelet analysis. Daubechies4 (dB4) mother wavelet, is employed since it has been exhibited to perform well. The islanding of the study cases is detected through discrete wavelet transform (DWT) [3].

4 Islanding Detection using Wavelet Transform:

4.1 Analysis of Negative Sequence Voltage Components:

The negative sequence currents and voltages are processed through Wavelet Transform (db4) for time localization of the islanding event. The negative sequence voltage for different islanding and non-islanding conditions are shown in Fig. 7(a), 7(b), 8(a), 8(b).

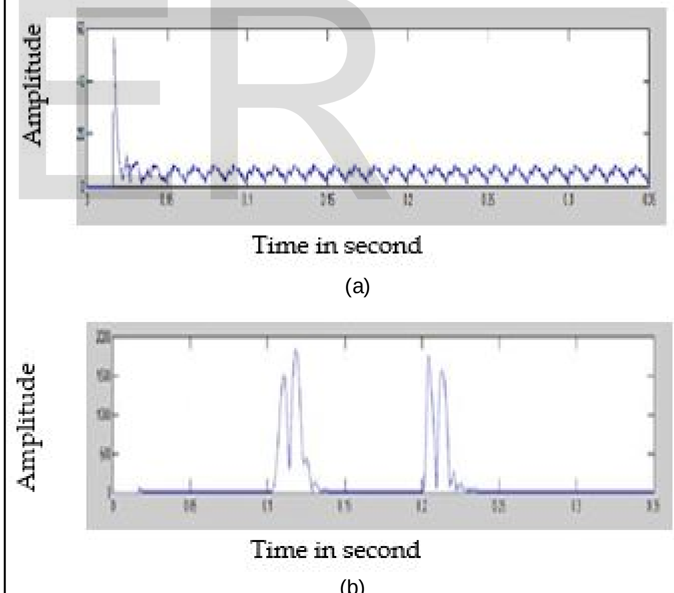
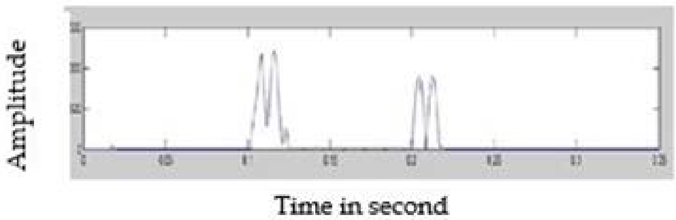
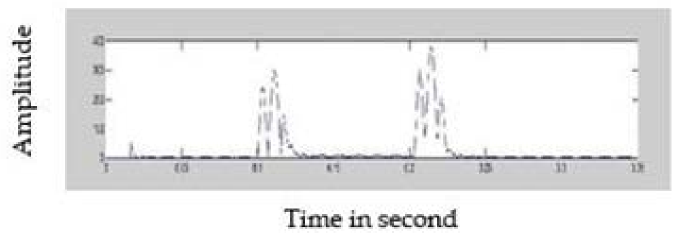


Fig 7: (a) Negative Sequence Voltage Component at Normal condition.

Fig 7: (b) Negative Sequence Voltage Component at Islanding condition



(a)



(b)

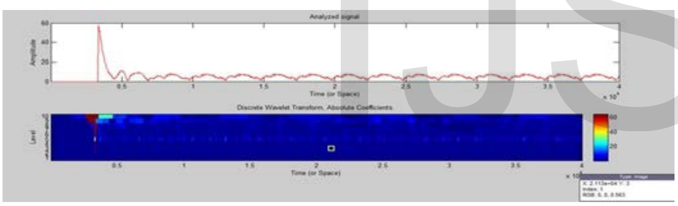
Fig 8: (a) Negative Sequence Voltage Component at DG line trip condition

Fig 8: (b) Negative Sequence Voltage Component at Sudden load change condition.

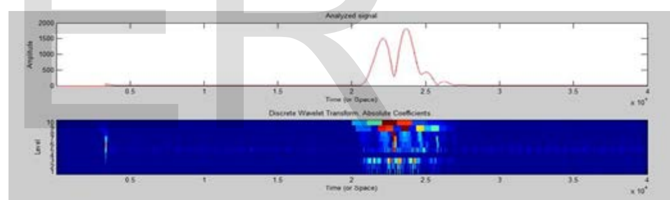
4.2 DWT to Negative Sequence Voltage Components:

d1 coefficients for different islanding and non-islanding conditions are shown in Fig. 9(a),9(b),9(c),9(d). DWT and color code plays vital role here.

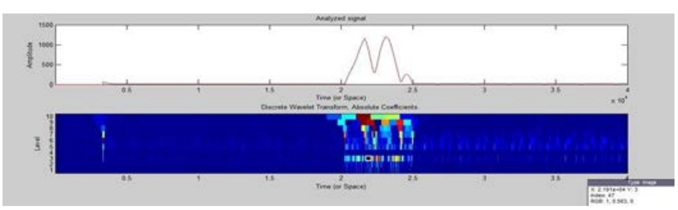
From our analysis using DWT it has been clearly understood that by applying it we can differentiate islanding events from other ones. In Fig 9(a) 1st part shows the analyzed portion and 2nd part in the DWT part which shows dark blue color all over, therefore, the value of coefficient is zero and so no disturbance has occurred. In Fig 9(b) in DWT part at the starting of islanding we can see red color appears at threshold level which is the highest value of coefficient. By this value we can know islanding has occurred. In Fig 9(c) at threshold level the color is light paste at the starting of DG line trip event. Lastly, at the starting of sudden load change condition Fig 9(d) at threshold level the color is light blue. Therefore, all four conditions show four colors which indicate the four different range of value of d1 coefficients.



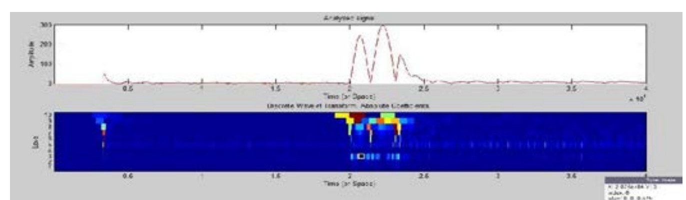
(a)



(b)



(c)



(d)

Fig 9: (a) DWT to Negative Sequence Voltage Component at Normal condition.

Fig 9: (b) DWT to Negative Sequence Voltage Component at islanding condition.

Fig 9: (c) DWT to Negative Sequence Voltage Component at DG line trip condition.

Fig 9: (d) DWT to Negative Sequence Voltage Component at Sudden load change condition

4.3 Differences among Islanding Conditions:

Differences among four conditions are clearly viewed by color code.

Events	Time, x (10^4)	Scale	Specified color range
Normal Condition	2.113	3	0 (Dark blue)
Islanding Condition	2.259	3	50-60 (Light Red)
DG Line Condition	2.191	3	20-30(Light Paste)
Sudden Load Change Condition	2.078	3	10-20(Light Blue)

All the negative sequence current quantities for each condition show four different colors which indicate four different values of coefficients like the voltage components. So, by using DWT to analyze negative sequence current components, we have been able to differentiate different conditions as well.

5 Conclusion

In our paper we introduce many islanding detection techniques, verifying the differences among them and the advantages of each one. Simulations using MATLAB and SIMULINK have been performed. We have used Passive islanding detection technique to detect islanding. To eradicate the problem of NDZ we have applied Wavelet Transform and processed the negative sequence voltage and current signals and d1 coefficients clearly detect the islanding events from non-islanding ones. The performance of the proposed schemes is to be studied on IEEE standard power distribution network with multiple DG interface. We are highly persuaded that further work on this model and implementation can give birth to a safe and more protected grid system.

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Appendix

Wavelet Transform of sampled waveforms can be obtained by implementing the discrete Wavelet Transform, which is given by,

$$DWT(f,x,y)=\sqrt{\frac{1}{x_0{}^m}}\sum_k f(k)\psi^*\left(\frac{n-kxo^m}{x0^m}\right)$$

$$DWT(f,x,y)=\sqrt{\frac{1}{x_0{}^m}}\sum_k f(k)\psi^*\left(\frac{n-kxo^m}{x0^m}\right)$$

$$\varphi(t)=\sum_{n=-\infty}^{n} \mathrm{h(n)}\sqrt{2}\varphi(2t-n)$$

$$h_1(k)=(-1)^k h\,(1-k)$$

$$y(t)=\sum_{n=-\infty}^{\infty} c_{j0}(k)2^{\frac{j0}{2}}\phi(2^{j0}t-k)+\sum_{k=-\infty}^{\infty}\sum_{j=j0}^{\infty} d_j(k)2^{\frac{j}{2}}\psi(2^jt-k))$$