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A NOVEL DETECTION OF ISLANDING IN DISTRIBUTION NETWORKS WITH MULTIPLE DISTRIBUTED GENERATIONS

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ABSTRACT

As the demand for electrical energy increases, traditional power generation will no longer be a sustainable source. Distributed generation is emerging technology in which the generation sources are placed near to load centers. Performance and security of the new distributed generation systems needs special attention therefore, a specialized analysis is required to detect different conditions. For safe operation of distributed generation, one of the main requirements is the detection of islands. In this paper for detection of islands a novel method is proposed for highly penetrated wind power distributed power system. Wavelet transform is selected as an appropriate tool to discriminate islanding condition from other disturbances. Energy and standard deviation has been calculated for islanding and other disturbance conditions like normal operation, other DG's tripping and instant load change etc. The proposed approach is capable of differentiate islanding condition from non-islanding conditions and is very effective and vigorous for different operating conditions.

Keywords: *Distributed generation, multiple DGs, wavelet transform, negative sequence components, islanding*

1. INTRODUCTION

Due to the fast growing demand for electricity, huge revenue is being financed in establishing power generation and distribution systems. New supply generation systems such as wind turbine, photovoltaic, diesel generators and fuel cell are tie up to the main grid in order to meet rising demand. These Distributed generations (DGs) can meet the load requirement and provide surplus power to the existing grid.

When a microgrid is disconnected and separated from the remaining system due to a fault but remains energized, the condition is called islanding condition. A large amount of power can be taken from the micro grid when there is some fault in the utility grid, which causes power loss and damage to some parts of the system. So this state of isolation of microgrid is called islanding. The intentional islanding is done for maintenance purposes.

Within 2 seconds any incident that accidentally causes an island should be detected and prevented according to IEEE std. 1547[1]. The following are the problems due to Accidental Island of distribution system

- Security issues for utility workers as they may not know the distribution system still energized even the grid is not supplying electricity
- During islanding situation common power quality issues may occur in the system which may include unable to control parameters like current and voltage and also there is chance to damage some loads.

- The main problem is with auto- recloser, when a temporary fault may occur in the system then an auto-recloser trips and after two seconds again the circuit is closed by auto-recloser. But within these two seconds the DG starts supplying power to the lines. So there may be a phase difference between load side voltage and grid side voltage. If auto-recloser closes at this time which causes large current which may damage the apparatus on both load side and grid side.

Therefore, the detection of islanding is compulsory and it is prevented within two seconds. So, there is a need to monitor islanding situations.

The detection of islanding techniques can be divided into four groups. Active Techniques, passive techniques, Communication based techniques and hybrid techniques [2]. In communication based techniques the islanding can be detected based on the information of circuit breaker tripping and this information is transmitted to DG through communication channel [3]. These methods have zero non detection zone and less detection time. In active islanding detection technique some disturbance may inject into the system and check the stability of a system. If the system is stable, there is no island, and if the system is unstable, there is an island state [4] [5]. Actually the grid connected system can be able to with stand small disturbances due to inertia of grid. But an islanding system with DG becomes unstable even for a small disturbance also due to low inertia. This technique is a rapid detection technique and undetected region is also small [4] [6]. But execution cost is high. Passive island detection methods analyze parameters such as current, voltage, and frequency at a common connection point and distinguish between island and non-islanding events [7]-[8]. Compared to other methods passive islanding detection techniques have a large non detection zone [9]. Some of passive islanding detection techniques are ROCOV [10], ROCOF [11], ROCPAD [12], voltage and current harmonics [13]-[14]. Hybrid island detection methods combine the advantages of active and passive identification methods [15] - [17]. In [18] Islanding detection is done using Rate of Change of Reactive Power (ROCORP), in [19] islanding operation is determined based on system configurations, by checking the connection between main source and DG's using Graph Search Method. In [20] islanding detection is based on slip frequency, and this technique is least affected by variations in load quality factor and active power discrepancy conditions and the islanding is detected with a minimum NDZ. In [21] detection of islanding is depends on parallel inductive impedance switching at distributed generation location, and at DG output the rate of change of voltage is continuously monitored. Information communication technology (ICT) is crucial for efficient detection of island. Cloud based ANN is used for island detection [22].

2. CONTRIBUTION AND PAPER ORGANIZATION

In this paper, Negative sequence voltage and current signals are used to detect the island condition of power distribution system. Wavelet transforms is a tool for analyzing the extracted negative sequence voltage and current signals. To detect islanding situation the data of time-frequency, obtained from level-1 decomposition (d1) are used. The discrete wavelet decomposition method separates the test signal into approximate and detailed coefficients (Level 1). The approximate coefficients are obtained by passing the test signal through a low pass filter (LPF) and detailed coefficients are obtained from a high pass filter with input test signal. The obtained approximate coefficients can be further passed through the filters to obtain the level 2 decomposition coefficients. The detailed coefficients extracted are used to detect the island condition in this paper. The standard deviation and change in energy of 1evel-1 decomposition coefficients for one cycle, gives insight island and non-island situation of electrical distribution system.

The rest of the paper is arranged as follows. Section-III explains in detail about basic formulation and description of proposed methodology. Sections IV briefs about various conditions studied for islanding and non-islanding events. Simulation results are represented in section V and final conclusions are summarized in section VI.

3. PROPOSED MODEL

In this paper, the effect of wind power plants in microgrid during islanding is studied. This proposed test system consists of three 9MW wind farms each having a wind turbine driven by doubly-fed Induction generator. Detailed model of DFIG is considered for simulation study. The model fits well to detect harmonics and to study dynamic performance of a system for relatively short time. Figure 1 shows the studied distribution network with three DGs.

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The test system comprises of a main distribution system and a radial distribution system with 3 DG units. Both are attached via Point of Common Coupling. DG sections are located at 30 kilometers distance with distribution lines. At target DG the voltage and current signals are taken for both islanding and non-islanding situations. Other than islanding, the possible non-islanding situations studied here are

- Normal condition
- 50% instant load changes at target DG.
- DGs tripping other than target DG.

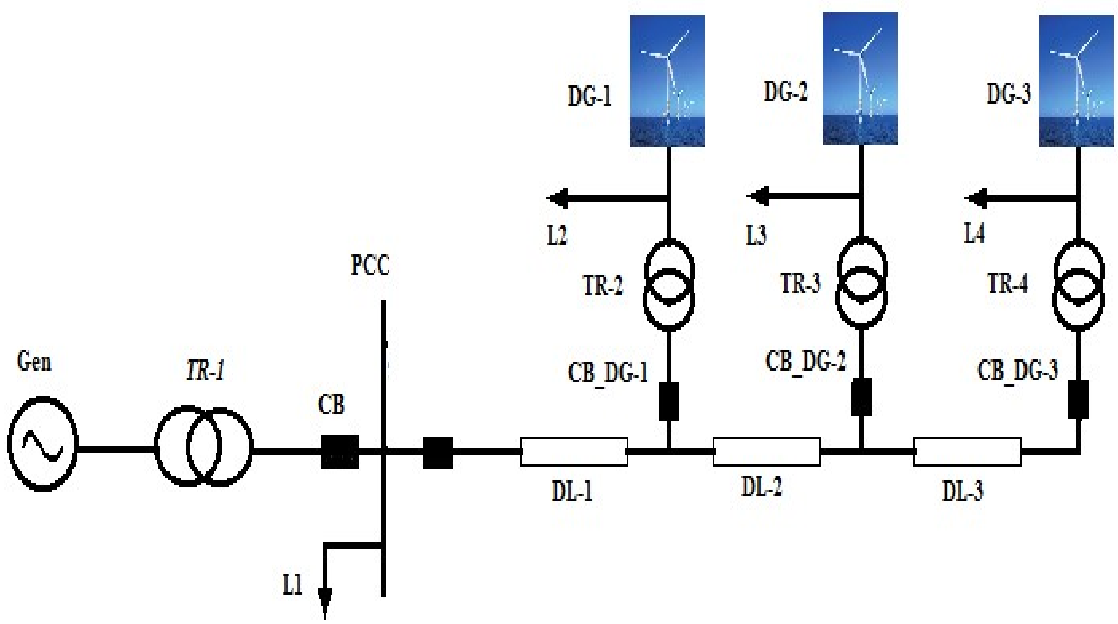

Figure.1: The Proposed Power Distribution Network With Three Dgs

4. ISLANDING AND NON ISLANDING SITUATIONS

Situation-1:

The main circuit breaker and the remaining circuit breakers 1, 2 and 3 are in closed state. The condition is called normal state. In this situation, three phase voltage & current waveforms are purely sinusoidal at the end of any DG.

Situation-2:

The main breaker is closed initially and it is opened at time t = 0.4 seconds. But the circuit breakers 1, 2 and 3 are permanently closed. Once the main circuit breaker is opened, the total distribution system is separated from the remaining system. The situation is called an islanding.

Situation-3:

In this case load is instantly changed to 50% at the target DG location. This condition is called instant load change condition.

Situation-4:

In this case the main circuit breaker is permanently closed. But the circuit breakers 2 and 3 are opened at time t = 0.4 seconds.

The above four cases are simulated in MATLAB-SIMULINK and clearly identifies the islanding event by using wavelet transform.

5. SIMULATION RESULTS

This model is simulated with a sample rate of 1.6 KHz and the number of Samples per cycle is 32. The conditions (islanding, normal, load change and other DGs tripping) discussed above are simulated using MATLAB software. By closing of main circuit breaker the voltage and current wave forms are studied. The voltage and current components at target DG for islanding condition are shown in figure 2. From the figure it clearly identifies the islanding event, which starts at time t = 0.4 seconds.

For three wind system the negative sequence components are obtained at the target DG location by passing 3 - φ voltage and current waveforms through sequence analyzer. These negative sequence components are processed through

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Wavelet Transform (db1) for detecting the islanding event from non-islanding events such as normal, 50% load change (instantly) and DGs tripping other than target DG.

The negative sequence voltage and its d1 coefficients for islanding and other situations such as normal, 50% load change and tripping of DGs other than target DG are studied. Figure 3 and Figure 4 shows negative sequence voltage and its d1 coefficients for islanding condition. The d1 coefficients clearly indicating the islanding event.

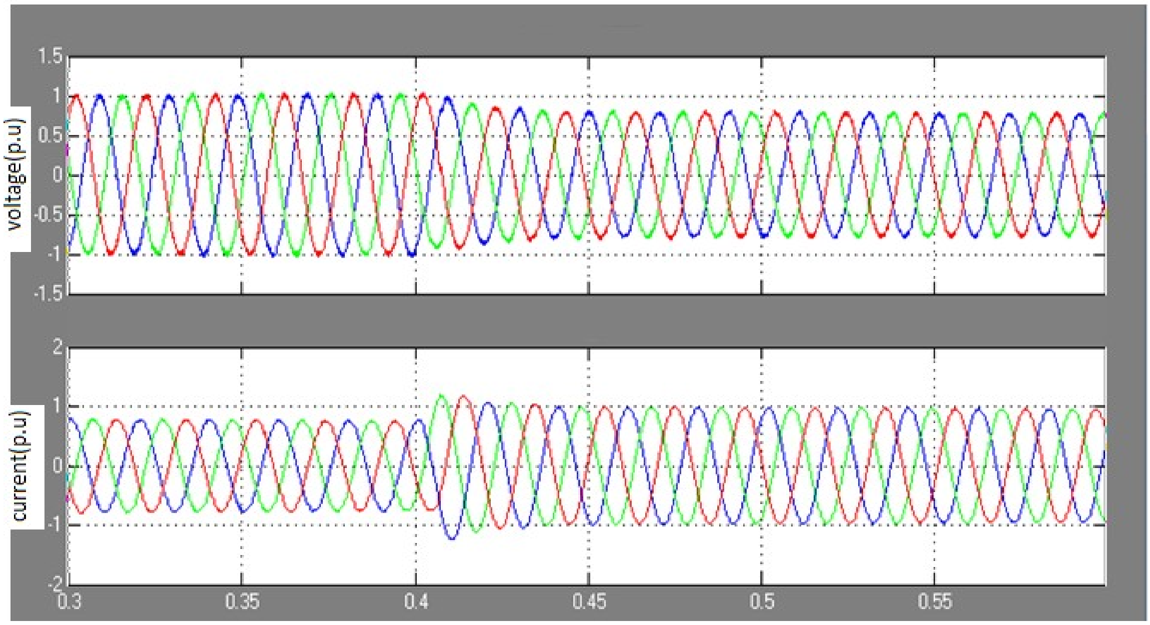

Figure 2: Voltage And Current Signals At Islanding Condition (Starts At 0.4 Sec)

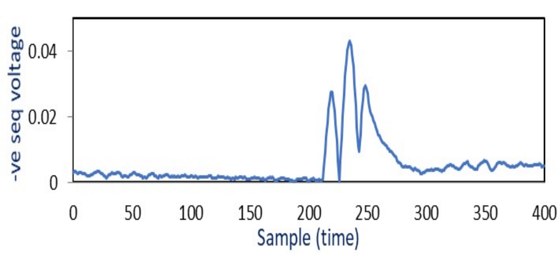

Figure 3: Islanding Negative Sequence Voltage

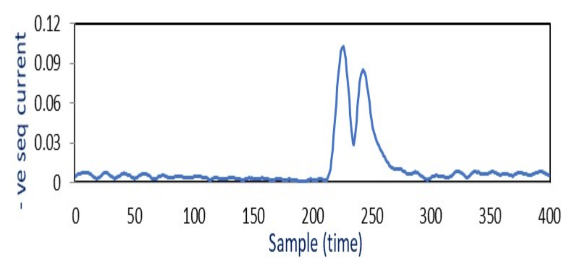

Figure 5: Islanding Negative Sequence Current

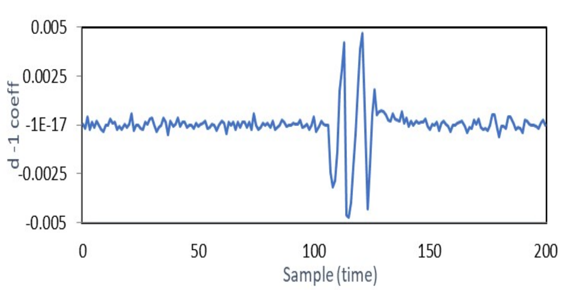

Figure 4: Islanding Condition D-1 Coefficient

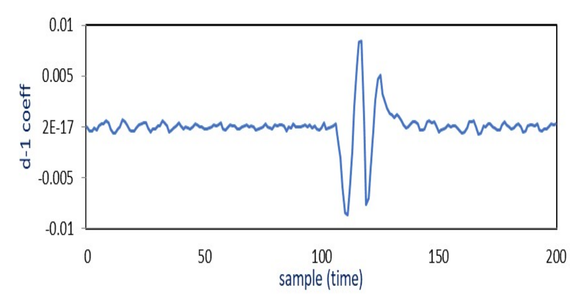

Figure 6: Islanding Condition D-1 Coefficient

Figure 5 and Figure 6 shows negative sequence current and corresponding d1 coefficients for islanding condition.

The juxtaposition of islanding and normal operation based upon negative sequence voltage d1 coefficients is given in Figure 7. Similar

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juxtaposition between islanding and other non-islanding situations for instant load change and other DGs tripping apart from the target DG are shown in Figure 8 and 9 respectively. It can be seen that the d1 coefficients are more visible in the case of the island compared to the non-island situations. The d1 coefficients of instant load change is also higher compared to other non-islanding situations, still the islanding event is clearly distinguish by this technique.

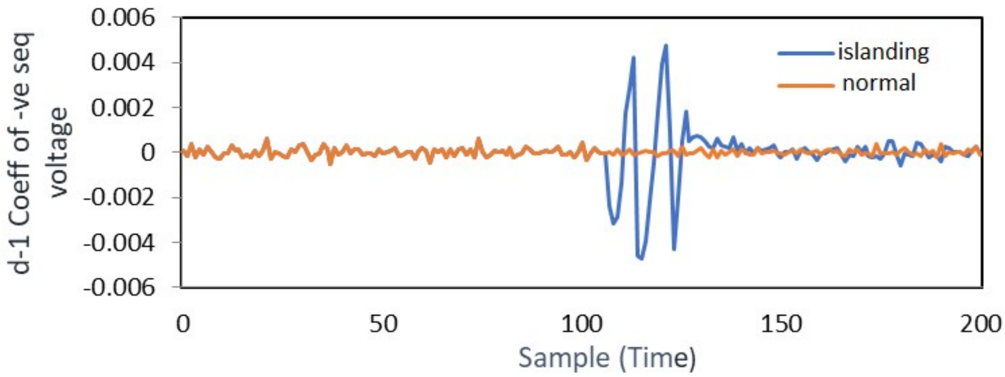

Figure 7: Analogy Between D1 Coefficients For Normal And Islanding Operation (Negative Seq. Voltage)

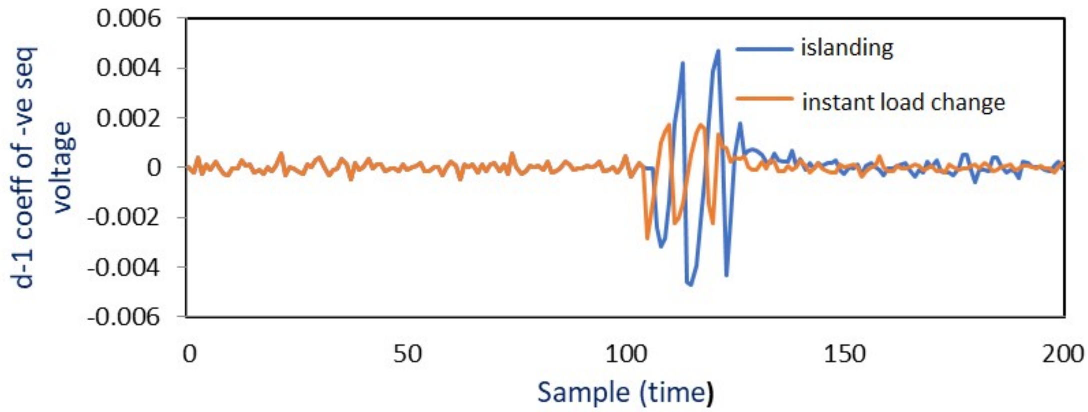

Figure 8: Analogy Between D1 Coefficients For Instant Load Change (50%) And Islanding Operation (Negative Seq. voltage)

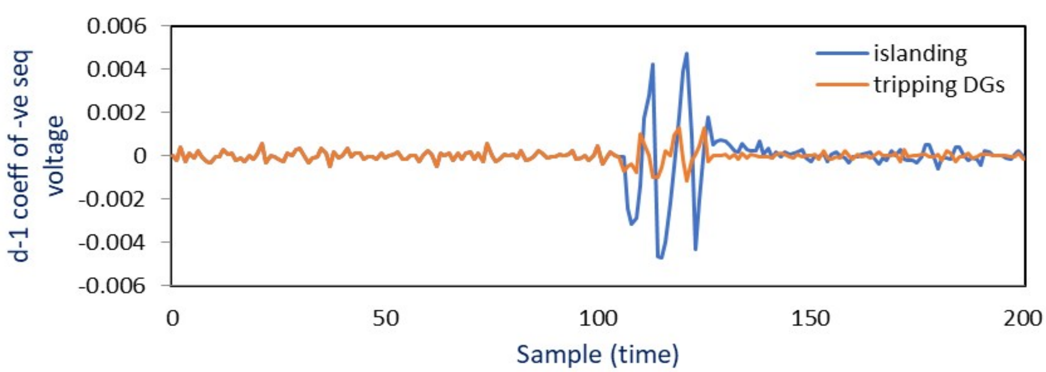

Figure 9: Analogy Between D1 Coefficients For Other Dgs Tripping And Islanding Operation (Negative Seq. Voltage)

Similar studies are made for different islanding and non islanding conditions such as normal, instant load change and other DGs tripping apart from the target based upon the negative sequence current d1 coefficients. The results are narrated in figure 10, 11 and 12.

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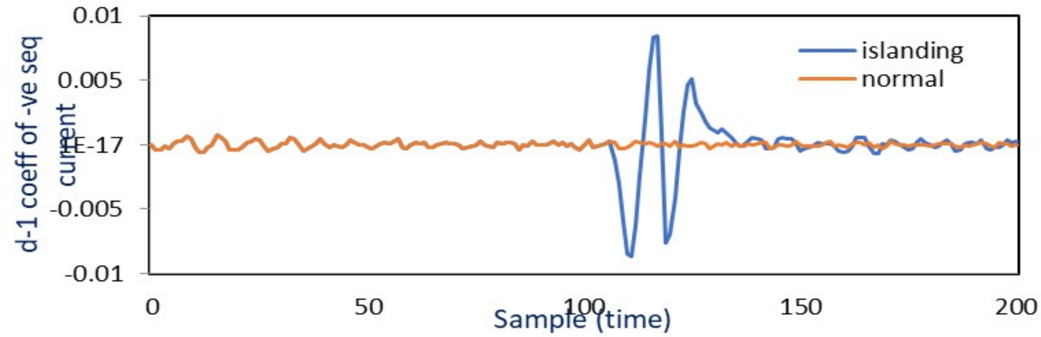

Figure 10: Analogy between d1 coefficients for normal and islanding operation (negative seq. current)

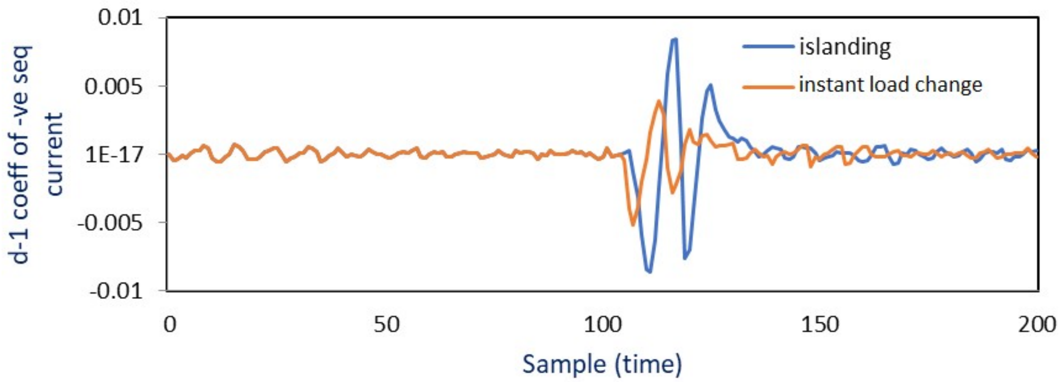

Figure 11: Analogy Between D1 Coefficients For Instant Load Change (50%) And Islanding Operation (Negative Seq. Current)

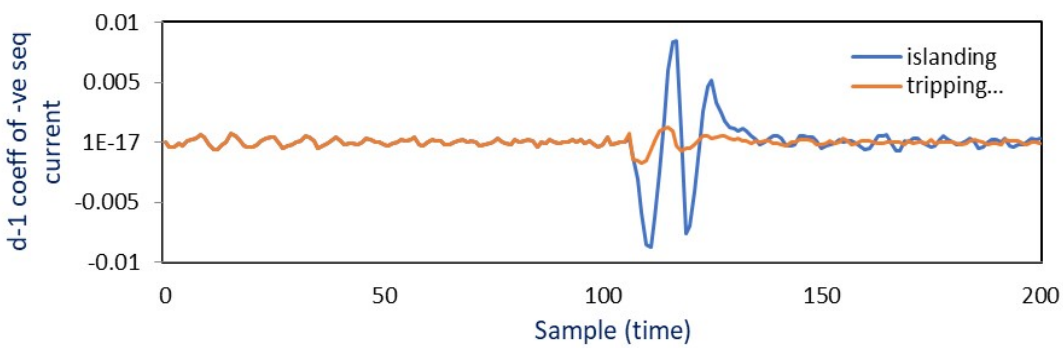

Figure 12: Analogy Between D1 Coefficient For Other Dgs Tripping And Islanding Operation (Negative Seq. Current).

The standard deviations & change in energy at target DG (DG1) is calculated for negative sequence voltage d-1 coefficients and they are tabulated. It is found from the Table-1, the change in standard deviation is 0.0324 for islanding operation compared to 2.8472e-04, 0.0086 and 0.0025 for normal, instant load change and other DGs tripping apart from target respectively. Similar observations are made for change in energy and those values are 0.0721 for islanding condition, 0.2438e-4 for normal condition, 0.0097 for instant load change and 0.00084 for other DGs tripping apart from target.

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Table- 1: Change In Standard Deviations And Energy Of Negative Sequence Voltage D-1 Coefficients For Islanding And Other Conditions

Events	Change in standard deviation	Change in energy
Islanding	0.0324	0.0721
Normal	2.8472e-04	0.2438e-4
instant load change	0.0086	0.0097
Other DGs tripping	0.0025	0.00084

Table 2: Change In Standard Deviations And Energy Of Negative Sequence Current D-1 Coefficients For Islanding And Other Conditions

Events	Change in standard deviation	Change in energy
Islanding	0.0832	0.2720
Normal	1.0213e-04	1.02e-04
instant load change	0.0223	0.0423
Other DGs tripping	0.0053	0.0022

Similar examination is made for negative sequence current d1 coefficients fetch at same target DG location, and is illustrated in Table-2. From Table-2 the change in standard deviation is 0.0832 for islanding operation compared to 1.0213e-04, 0.0086 and 0.0223 for normal, instant load change and other DGs tripping apart from target respectively. Similar observations are also made for change in energy and those values are 0.2720 for islanding condition, 1.02e-04 for normal condition, 0.0423 for instant load change and 0.0022 for other DGs tripping apart from target. From the above results it is observed that the change in standard deviation and energy are high valued in case of islanding compared to non-islanding situations and thus it can clearly distinguish islanding from non-islanding operations. Daubechies wavelets are orthogonal wavelets that preserve energy of the signals while Haaar wavelets involves in averaging and differencing. The proposed system is used for detection of island further the nature of the fault or actions is not examined in this paper.

6. CONCLUSION

Detection of an island in electrical distribution systems is effective with wavelet transform. The signals extracted using ICT are used as test signals. In this paper wavelet transform (db1) is applied to perceive the island. To execute the proposed concept, negative sequence components of voltage and currents are analyzed in time-frequency domain through wavelet transform. The obtained detailed coefficients clearly identify the condition of island. Further, standard deviation and change in energy are calculated to fix the boundaries in order to discriminate islanding from other possible non-islanding situations. Results show that wavelet transform is an accurate method to detect islanding event in a power distribution system with multi-DG systems.

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