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Islanding Detection Analysis in Wind Turbine Units Based On Voltage, Frequency and Negative Sequence Components.

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Abstract: In this paper a new islanding detection method based on voltage, frequency and negative sequence components are used for the islanding detection analysis in wind turbine units. The proposed method is based on processing of the rate of change of q-axis component of voltage and accelerates of change of frequency and negative sequence component of the voltage and current signals are analyzed through wavelet transform. The proposed techniques are tested on islanding and possible non-islanding condition such as normal operation; sudden load change and tripping of other DG's etc. The studies reported in this paper are based on time-domain simulations using MATLAB/SIMULINK MODEL.

Keywords: Distributed Generation (DG), negativesequence voltage, negative sequence current, wavelettransform, accelerates of change of frequency (ACOF), ROCOQA-dq-component.

1. Introduction

DGs generally refer to Distributed Energy Resources (DERs), including photovoltaic, fuel cells, micro turbines, small wind turbines, and additional equipment. In recent years, the distributed resources in the electric utility system with ongoing technological, social, economical and environmental aspects shows high depth of penetration of distributed generations (DGs).Distributed energy resource units connected to the distributed network have the potential to reduce the demand for distribution and transmission network capacity, reduce losses, and increase the reliability of electricity supply to customers [1].

But there are many issues that need to be seriously considered with the DG connected to utility grid and one of the main issues is islanding detection. If DG feeds power to the local loads and utility grid supply gets isolated due to some emergency conditions, then it is called islanded operation which leads to several negative impacts on utility power system and the DG itself, such as the safety hazards to utility personnel and the public, the quality problems of electric service to the utility customers, and serious damage to the DG if utility power is wrongly restored [3,4].Therefore, during the interruptions of utility power, the connected DG must detect the loss of utility power and disconnect itself from the power grid as soon as possible. It is desired to know the sources of power system disturbances and find remedies to mitigate them.

According to the IEEE 1547-2003 standard [4], the DG disconnection is required within two seconds after the utility disconnection. Consequently, for safety DER integration, Anti-Islanding (AI) protection is a requirement. Remote and local techniques are used for islanding detection. Remote techniques such as Supervisory Control and Data Acquisition (SCADA), Trip (disconnect) Signal and Power Line Carrier Communication (PLCC) systems are centralized methods implemented on the utility side. They offer high performance and applicability on multi- source topologies. However, those centralized methods are expensive to implant [5]. On the other hand, local techniques include passive and active methods which are implemented on the DG side. Local passive methods have a large Non Detection Zone (NDZ), and hence are not useful for high DG penetration. A solution for the NDZ reduction is the utilisation of local active anti-islanding methods.

Those active methods are currently based on the injection of voltage, frequency or output power perturbations, and the subsequent monitoring for the detection of changes in electric parameters to confirm islanding condition. Those methods can detect the islanding condition, but one of their problems is that they can fail when multiple sources are connected at PCC, because the effect produced by one source may be interfered by another one if synchronization between the multiple converters is not possible. Another drawback of active methods is that they can cause power quality disturbances as Total Voltage Harmonic Distortion (TVHD) increase and voltage and frequency fluctuations or instability. These problems become bigger if the introduced perturbation is increased to make possible the islanding detection [6,7], especially in systems with high penetration.

In this paper new technique based on rate of change of q-axes component of voltage (ROCOQAC) and accelerates of change of frequency (ACOF) and a technique based on wavelet transform [12-14] has been found to be an effective tool in monitoring and analyzing power system disturbances by processing negative sequence component of voltage and current signals at the target DG location. The simulation test systems were simulated in MATLAB/SIMULINK using Sim Power system Block set.

2. DISTRIBUTION NETWORK

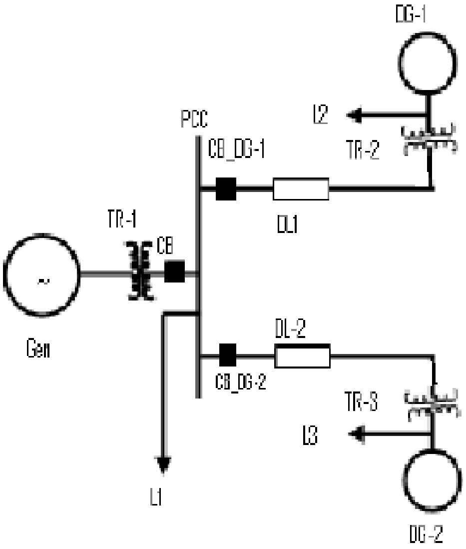


Fig-1: The studied power distribution network

The detailed studied system is shown in Fig. 1. The base power has been chosen as 10 MVA. The studied system consists of radial distribution system with 2 DG units (wind farms), connected to the main supply system through Point of Common Coupling (PCC). The DG units are placed at a distance of 30 km with distribution lines of pi-sections. The details of the generator, DGs, transformers, distribution lines and loads are mentioned as below.

- Generator: rated short-circuit MVA=1000, f=50 Hz, rated kV =120, Vbase = 120 kV.
- Distributed Generations (DGs): Wind farm (9 MW) consisting of six 1.5-MW wind turbines (Doubly Fed Induction Generator) is connected to a 25-kV distribution system exports power to a 120-kV grid through a 30-km 25-kV feeder.
- Transformer T1: rated MVA = 25, f = 50 Hz, rated kV = 120/25, Vbase = 25 kV, R1 = 0.00375 pu, X1= 0.1 pu, Rm= 500 pu, Xm= 500 pu .
- Transformer T2 and T3: rated MVA = 10, f = 50 Hz, rated kV = 575 V/ 25 kV, Vbase = 25 kV, R1 = 0.00375 pu, X1= 0.1 pu, Rm= 500 pu, Xm= 500 pu
- Distribution lines (DL): DL-1 and DL-2: PI-Section, 30 km each, Rated kV = 25, rated MVA = 20, Vbase = 25 kV, R1 = 0.1153 ohms/km, R0 = 0.413 ohms/km, L1 = $1.05e^{-3}$H/km, L0 = 3.32e-3 H/km, C1 = 11.33e-009 F/km, C0 = 5.01e-009 F/km,
- Normal Loading data:
  L1 = 10 MW, 5 kVAR.
  L2, L-3 = 12 MW, 0.9 MVAR

The voltage and current signals are retrieved at the target DG location for islanding conditions and non-islanding conditions (other disturbances). The possible situations of islanding and non-islanding conditions are given as follows

- Tripping of main circuit breaker (CB) for islanding conditions.
- Sudden load change at the target DG location.
- Opening of breaker between the power system and DG.
- Tripping of other DGs apart from the target one.
- Loss of power at PCC.

2.1 Proposed technique.

ROCOQAC algorithm uses synchronous transformation based phasor estimation of the retrieved instantaneous voltage signals.
The signal x (t) is represented as follows:

$$X(t)=\sum_{n=1}^{\infty} X_{\max}\cos(n\omega_0 t+\phi_n) \qquad (1)$$

Under balanced conditions, each three phasevariableX_{abc}(t) of equation (1)can be transferred to stationary αβ reference frame system by applying the following abc to αβ transformation

$$x_{\alpha\beta}=x_a e^{j0}+x_b e^{j2\pi/3}+x_c e^{-j2\pi/3} \qquad (2)$$

Where $x_{\alpha\beta}=x_\alpha+jx_\beta$, in order to calculating dq parameters can be used of equation(3):

$$x_d+jx_q=x_{\alpha\beta}e^{-j\theta} \qquad (3)$$

Where Ɵ calculated by:

$$\theta = \arctan\left(\frac{x_{\beta}^{ref}}{x_{\alpha}^{ref}}\right) \qquad (4)$$

One of the excising algorithms for detection of islanding is based on accelerates of change of frequency (ACOF).In this method frequency of DG unit is regularly measured and accelerates of change of frequency is calculated the ACOF,is calculated as:

$$ROCOF = \frac{d^2 f}{dt^2} \qquad (5)$$

Islanding condition can be detected by comparison of value of ACOF with a threshold. However, this method is not reliable. Islanding and some other events, such as switching of motors and capacitor banks, may have similar effect on ACOF, thus the algorithm may take incorrect decision and interrupt the production of DG in a wrong way. Here, we propose a new algorithm that employs both ACOF and ROCOQAC in order to detect the islanding event. Figure 2 shows algorithm of the proposed method. In the first step, the frequency of load voltage is measured for ten cycles (0.2s); ACOF is calculated afterwards. The accelerate of change of frequency is calculated by Equation(5). In next step, ACOF has been compared with its threshold values. If the value of ACOF in some portions of the measurement period (0.2 s) exceeds the threshold value then, ROCOQAC will be calculated and if its value exceeds from its threshold too, in this case islanding will be detected. In other cases when one of them doesn't exceed from their threshold, system will be continue to power production(Figure 2).In this study the threshold value of ACOF set to 75mHZ/S2 and ROCOQAC threshold value set to 250 V/sec.

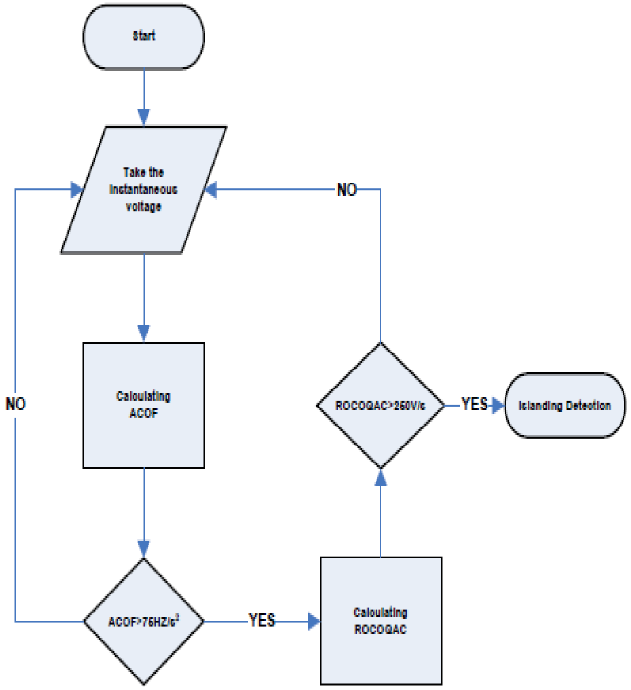


Figure 2.Proposed algorithm in order to islanding detection.

2.2Negative sequence component of voltage and current signals at DG location for islanding detection:

Negative sequence component is one of the key indicators which quantify the presence of any disturbances in the voltage and current signals retrieved at the target DG location. Thus, in this technique, the negative sequence component of the voltage and current signals retrieved at the target DG location is considered for analysis towards effective detection of islanding and non islanding events. The negative sequence component of voltage and current signals at the target DG location can be expressed by symmetrical component analysis as:

$$V_n = 1/3(V_a + \lambda^2 V_b + \lambda V_c) \qquad (1)$$

$$I_n = 1/3(I_a + \lambda^2 I_b + \lambda I_c) \qquad (2)$$

Where Va, Vb, Vc are three phase voltages , and Ia, Ib, Ic are three phase currents retrieved at the target DG location, and $\lambda = 1\angle 1200$, is the complex operator. The negative sequence component of the extracted voltage and current signals at the target DG location is obtained by passing it through the three-phase sequence analyser block in MATLAB/Simulink. Out of the three sequential components, it is only negative sequence component of the voltage signal, considered in this study because it reflects the information under disturbance condition. Quantification of the negative-sequence voltage at the target DG location is carried out which provides high degree of immunity to noise, for detection of islanding event and other disturbances due to sudden load change, DG line ct-off etc, thus enable better performance.

3. WAVELET TRANSFORM

The wavelet transform decomposes transients into a series of wavelet components, each of which corresponds to a time domain signal that covers a specific frequency band containing more detailed information.WT divides up data, functions into different frequency components, and then studies each component with a resolution matched to its scale. In this study, 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 demonstrated to perform well. The islanding of the study cases is detected through discrete wavelet transform (DWT). Both approximation and details information related fault voltages are extracted from the original signal. When the utility grid isolates, it can be seen that variations within the decomposition coefficient of the voltage and current signals contain useful signatures. Filters of different cut-off frequencies are used to analyse the signal at different scales. The signal is passed through a series of high pass filters to analyse the high frequencies, and it is passed through a series of low pass filters to analyse the low frequencies. Hence the signal (S) is decomposed into two types of components approximation (C) and detail (D). The approximation (C) is the high scale, low-frequency component of the signal. The detail (D) is the low-scale, high-frequency components. The decomposition process can be iterated, with successive approximations being decomposed in turn, so that one signal is divided into many lower resolution components which is called the wavelet decomposition tree and is shown in Fig. 3. As decompositions are done on higher levels, lower frequency components are filtered out progressively.

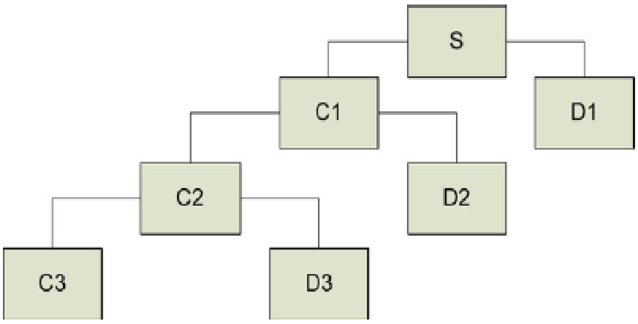


Fig-3: Wavelet decomposition tree.

4. Implementation and Simulation Results

The fig.2 model is simulated in MATLAB/SIMULINK.These paper based on time –domain simulation. Grid as open condition at 0.1s and closed condition at 0.15s.Generator 1 as open condition at 0.2s and close condition at 0.25s.Generator 2 as open condition at 0.3s and closed condition at 0.35s.Fault as open condition at 0.4s and closed condition at 0.45s.Load switching as open condition at o.5sand closed condition at 0.55s and capacitor as open condition at o.6s and closed condition at 0.65s.Islanding condition analysed with negative sequence components ,ACOF and ROCOQA.

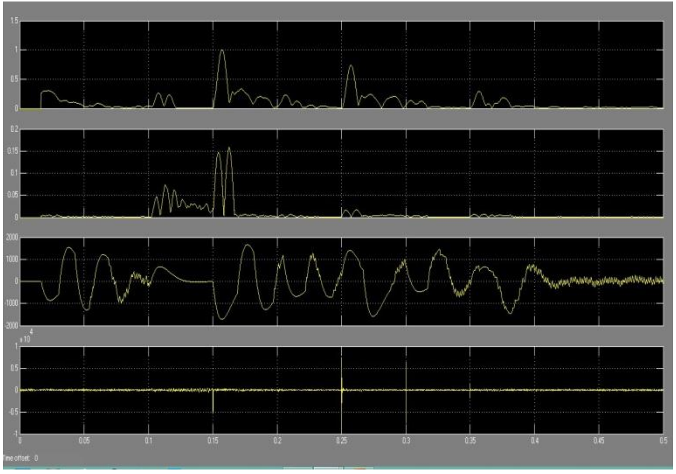


Fig.4 The negative sequence component of voltage and current, ACOF and ROCOQA for islanding condition.

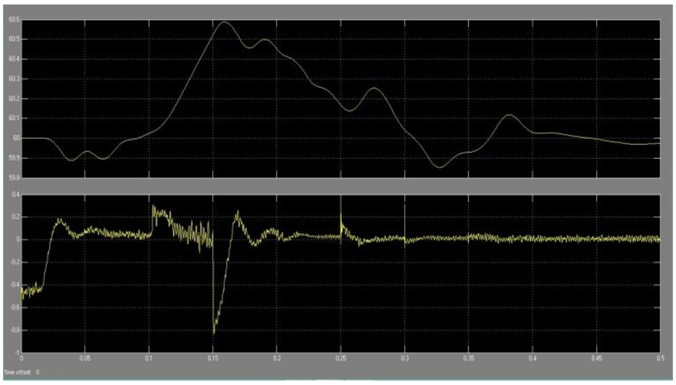


Fig.5 Frequency and q-component for islanding condition.

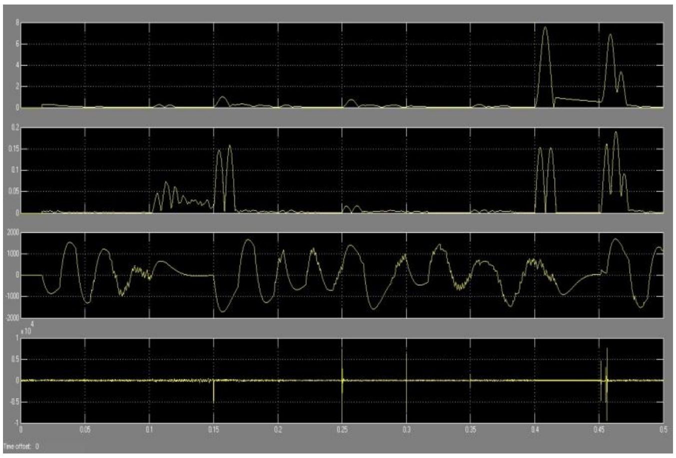


Fig.6 Islanding condition with three phase to ground fault.

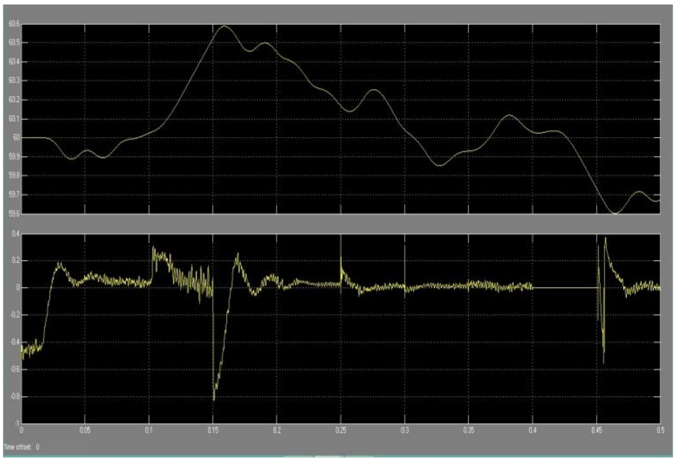


Fig.7 Frequency and q-component with three phase to ground fault.

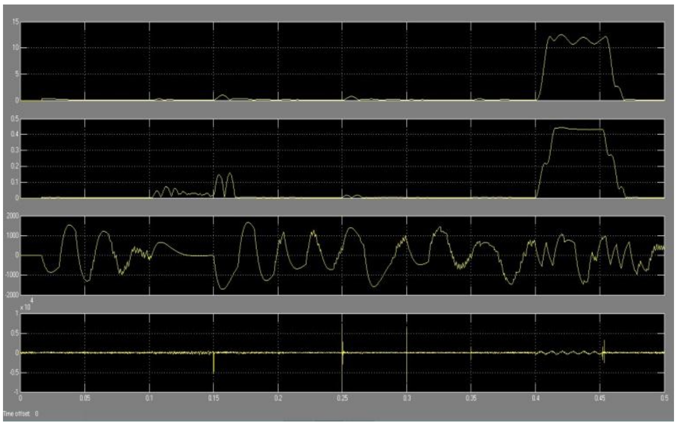


Fig.8 islanding condition with two phase to ground fault.

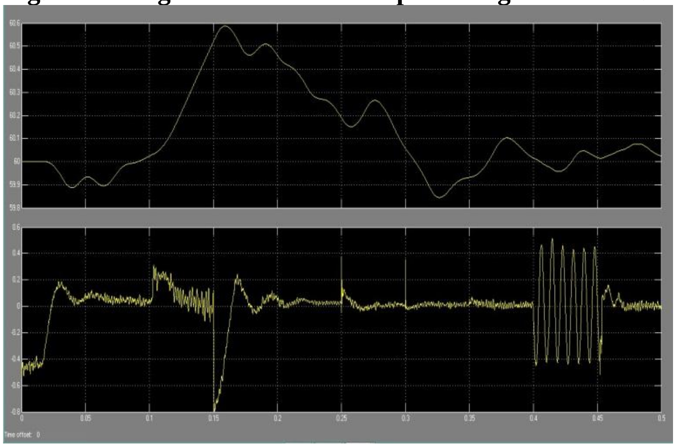


Fig.9Frequency and q-component with two phase to ground fault.

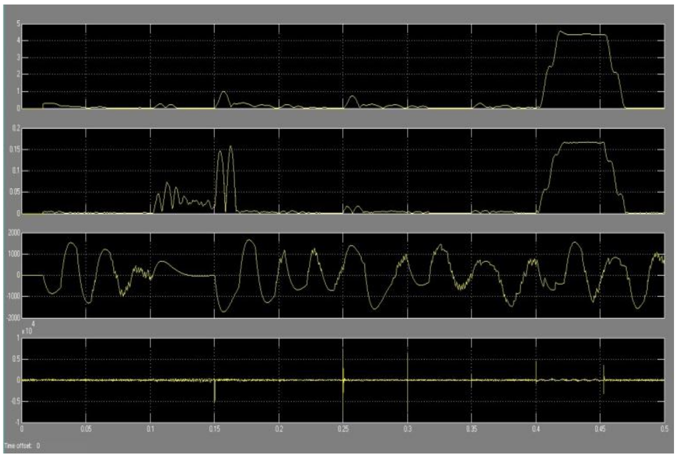


Fig.10 Islanding condition with single phase to ground fault.

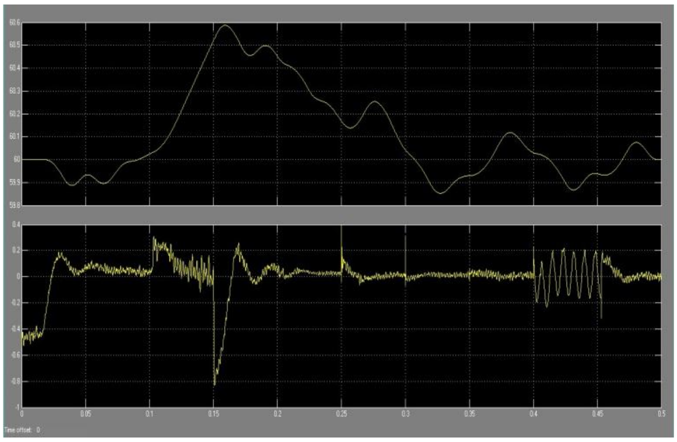


Fig.11 Frequency and q-component with single phase to ground fault.

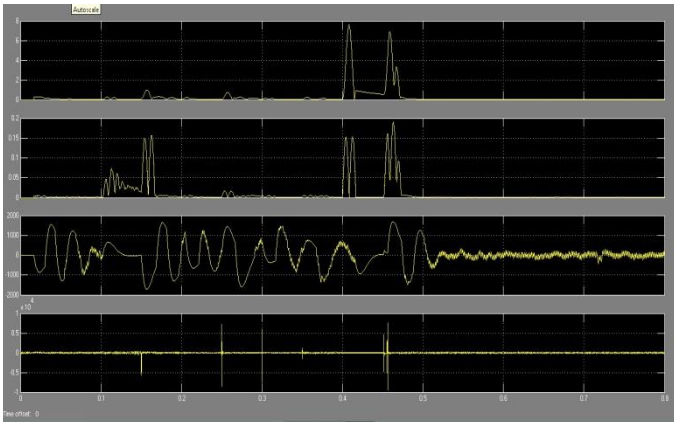


Fig.12 Islanding condition with load switching.

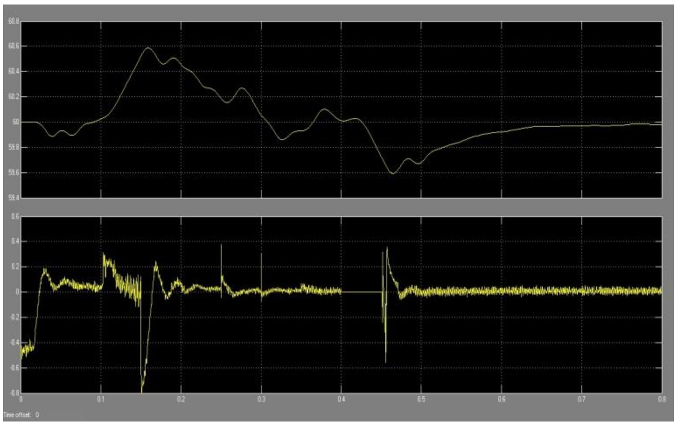


Fig.13 Frequency and q-component with load switching.

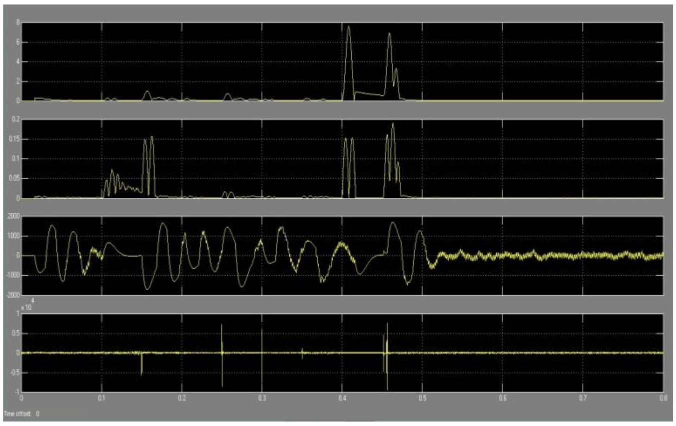


Fig.14 Islanding condition with capacitor switching.

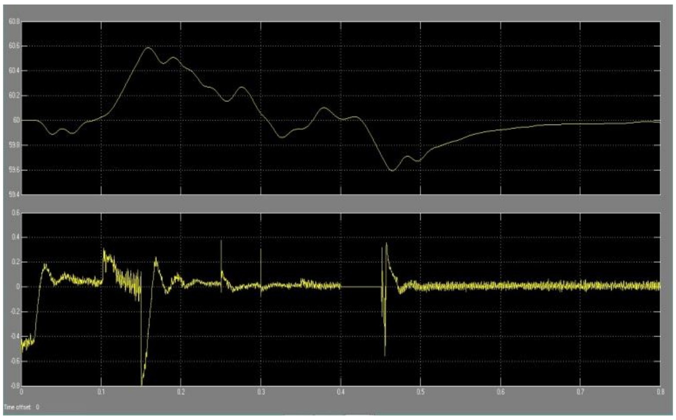


Fig.15 Frequency and q-component with capacitor switching.

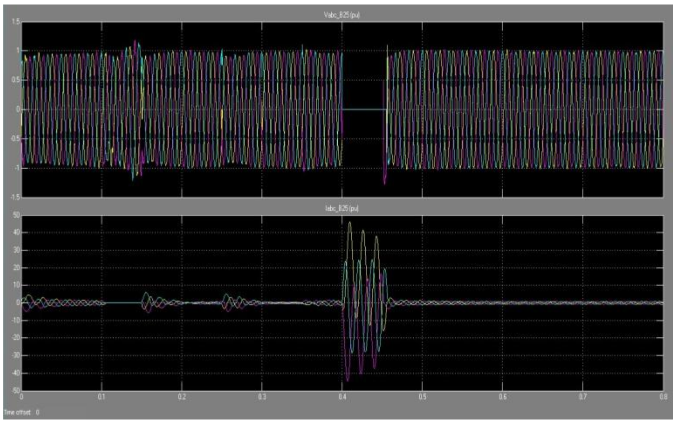


Fig.16.Voltage and Current at Grid bus.

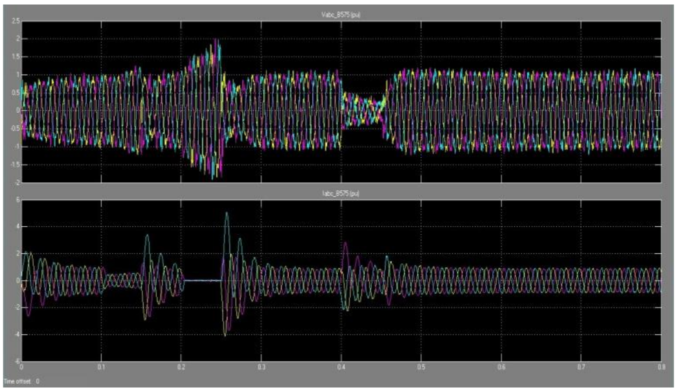


Fig.17 Voltage and Current at Generator 1 bus.

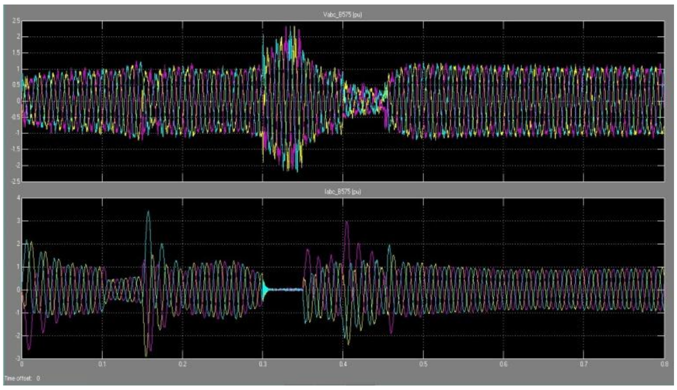
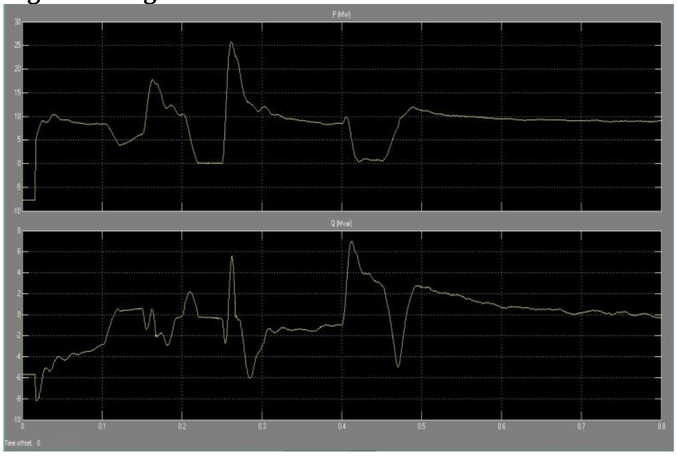


Fig.18 Voltage and Current at Generator 2 bus.



. **Fig.19 Real and Reactive power at Generator 1 bus.**

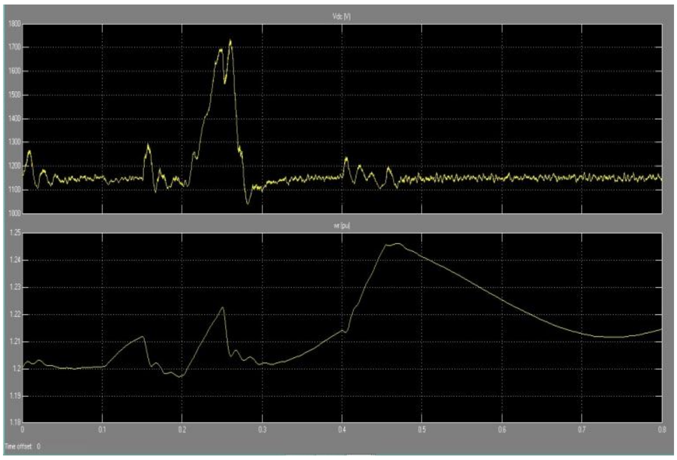


Fig.20 DC voltage and speed at Generator 1 bus.

6. Discussion

For different condition islanding condition has been analyzed with negative sequence components,ACOF and ROCOQA.Result shows that Negative sequence current will be more when grid has opened and at the time of grid re-closing. Frequency will raises to maximum value at the time of grid opening and it falls down as grid closed, During three phase to ground fault and two phase to ground fault and single phase to ground fault the negative sequence component will be more than the negative sequence component of grid re-closing. Real power also falls down at the time of grid opening and reactive power draws more power at this point. Finally the system will draws more DC voltage at the time of grid opening condition.

7. Conclusion

This paper presents a new method based on negative sequence component of voltage and current, and based on frequency and voltage analysis (ACOF and ROCOQA) for the islanding detection of wind turbines. The proposed method was simulated and implemented on a wind turbine simulator. The result show the suitable reliability of the proposed method under different load conditions, such as capacitor bank switching and load switching. Thus the proposed methods are highly effective for islanding.

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