Islanding Detection in Hybrid DG based IEEE 14 Bus System using Negative Sequence Component Analysis

Bhupendra Paliwal[1], C.S. Rajeshwari[2] ,Anjali Potnis[3]
[1](PG Scholar, Department of Electronics and Electrical Engg., NITTTR, Bhopal, India)
[2](Professor, Department of Electronics and Electrical Engg., NITTTR, Bhopal, India)
[3](Assistant Professor, Department of Electronics and Electrical Engg., NITTTR, Bhopal, India)

Abstract : The paper investigates islanding detection using recently developed negative sequence components based islanding detection technique on IEEE 14 bus system with Wind–solar PV based hybrid Distributed Generations with a brief review of existing islanding detection techniques.The negative sequence components of voltage and current at various buses were retrieved for different islanding and non-islanding cases.The per unit voltages of negative sequence voltages after islanding clearly detects the islanding and standard deviations of the cases differentiates between islanding and non-islanding conditions such as normal operation,sudden load change and tripping of other DGs etc. and the technique is found to be effective.

Keywords – Hybrid Distributed Generation,Islanding Detection,Negative Sequence Components

I. Introduction

The demand for clean and green energy is increasing day by day,hence becoming a prime requirement for both utilities and customers. After a century with power stations getting bigger and transmission grids need to transmit wider with increasing environmental issues, the need of distributed or local generation (DG) for local consumption has arisen upto a great extent. A DG system consists of small-scale power generation resources like wind mills, photovoltaic arrays, fuel cells, etc.,which are generally located near loads. The primary advantages of DG systems are that consumers can generate electric power with or without grid backup and the surplus power generated, can be sold back to the grid under low load-demand conditions. The gradual shift from centralized to distributed generation means changes, not only in the kinds of power plants used, but in the way electricity is transported from the point of production to the point of consumption i.e. one way power transmission to two way power transmission.

As more DG systems become part of the power grid, there is an increased grid protection interference issues, safety hazard for personnel, and an increased risk of damage to the power system equipments[1-6]. Despite the favourable aspects grid-connected DGs can provide to the distribution system, a critical demanding concern is islanding detection and prevention[7]. Islanded operation or islanding can be defined as a situation when the loads are fed power only from the distributed generations even after the power supply is suspended from the power utility or main grid[8]. The 1989–2014 conferences and journals present two types of anti-islanding methods: local, or remote. The local methods are passive, active and hybrid. Passive islanding detection relies on changes to electrical parameters to determine whether islanding had occurred like Under/over voltage and under/over frequency, Voltage phase jump detection, Harmonics measurement, Voltage unbalance etc.. As technology progressed, active methods were introduced like Impedance measurement and Slip-mode frequency shift techniques, whose development aimed to overcome the limits of passive methods[9]. Active techniques are applied by introducing a small disturbance to grids, which is the response of the intern with the grid and deciding if the grid is in the islanding condition.

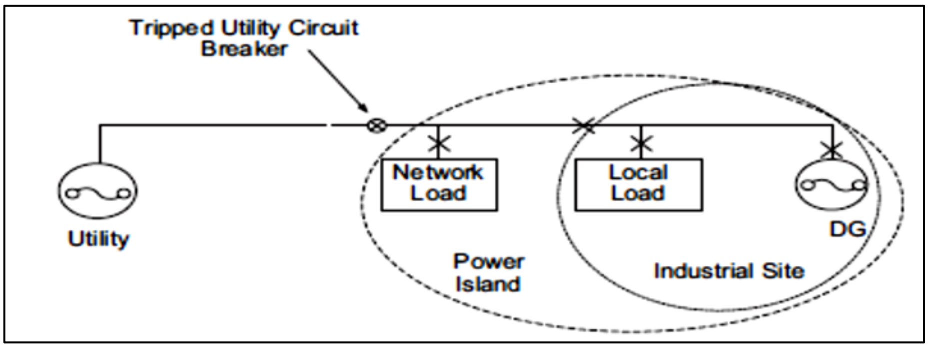

Fig.1 Islanding Operation

The hybrid technique is a combination of the active and passive techniques, in which active technique is applied only if islanding is detected based on the passive technique, for example Voltage unbalance and frequency set point method, technique based on Voltage and Real power shift and Voltage fluctuation injection technique.

Remote methods are more reliable but are neither more cost-effective nor simpler to implement than passive or active methods. These include System state monitoring, Switch state monitoring and Inter-tripping. Signal processing methods are also used for identification of island mode operation like Wavlet Transform, S-Transform etc. Signal processing techniques have aided researchers in understanding the existence of an island mode operation regardless if the location of control is local or central. The implementation of the signal processing technique allows for the extraction of the hidden features of the measured signals to detect the islanding condition. These extracted features can then serve as inputs to the artificial intelligent (AI)classifier to perform the classification of the islanding and non-islanding detection. Common AI classifiers used in islanding detection include the decision tree (DT),rule- based techniques, artificial neural network (ANN),probabilistic neural network (PNN),fuzzy logic (FL),and support vector machines (SVM). The drawback of S-transform is the need for more computation time and memory to process the signal than other techniques[10]. The data mining technique using Decision Tree (DT) may find limitations as the thresholds depend on the splitting criteria of the corresponding DT. Commonly used ROCOF relays, however, may become ineffective if the power imbalance in the islanded system is less than 15%, resulting in a high risk of false detection[11].

As negative sequence components provide vital information in case of unbalanced conditions in power system, thus same has been considered for the proposed islanding detection technique which is subjected to disturbance during islanding process such as deviations in frequency, voltage and active power etc. The negative sequence component of the voltage and current signals are extracted from the derived voltage and current signal at the target DG locations.

II. IEEE 14 Bus system with Hybrid DGs

The simulation model of IEEE-14 Bus system was developed using MATLAB/Simulink Software.The simulation block diagram of the system has been shown in fig.2.The studied system consist of ring main type distribution system with 2 DG units of hybrid type i.e. one DFIG wind farm through 30km. short transmission line and the other one is a Solar PV array,connected to the main supply system through Point of Common Coupling (PCC).The transmission lines between the buses are assumed to be short transmission lines. The details of the generators,transformers,distribution lines and loads are mentioned as follows:

- *Generator(G_1,G_2,G_3) :* Rated short circuit MVA=1000,f=50Hz,rated kV=11.
- *Distributed Generation (DGs):* DFIG based Wind farm (45 MW) consisting of thirty 1.5 MW wind turbines (Doubly fed induction generator) is connected to a 11kV bus of IEEE14 Bus system and a solar PV array of 440V,2.2 MW,connected to a 11kV bus of the system.
- *Transformer (T_1,T_2,T_3):* Rated MVA=100, f=50Hz, Rated kV=11/11, $R_1=10^{-6}$ pu, X_1=0.1 pu, R_m=500 pu, X_m=500 pu
- *Transformer (T_4):* Rated MVA=100, f=50Hz, Rated kV=575V/11kV, $R_1=10^{-6}$ pu, X_1=0.1 pu, R_m=500 pu, X_m=500 pu
- *Transformer (T_5):* Rated MVA=100, f=50Hz, Rated kV=440V/11kV, $R_1=10^{-6}$ pu, X_1=0.1 pu, R_m=500 pu, X_m=500 pu
- *Normal Loading data:* L1=21.7MW, 12.7MVAR, L2=94.2MW,19MVAR, L3=45MW, L4=7.6MW,1.6MVAR, L5=11.2MW, 7.5MVAR, L6=29.5MW, 16.6MVAR, L7=9MW, 5.8MVAR, L8=3.5MW,1.8MVAR, L9=6.5MW,1.6MVAR, L10=13.5MW,5.8MVAR, L11=14.9MW,5 MVAR.

The voltage and current signals are extracted at point of common coupling of DGs at the respective buses,at which they are connected for the analysis of islanding case and non-islanding cases.The circuit breakers for each DG units are installed at the DG ends.The possible cases of islanding and non-islanding conditions studied are as follows:

- Tripping of main circuit breaker(CB) at generator bus for islanding conditions.
- Opening of any breaker between power system and DG (PV array and Wind turbine).
- Loss of power on the PCC bus.
- Sudden load change at the PCC bus.
- Tripping of the other DG apart from the target one.

The above cases are simulated under possible variations in operating loading at normal, minimum and maximum loading conditions. The loads are varied at the PCC bus. The model is simulated at 1.6kHz.The voltage and current signals are extracted at the PCC bus of DGs and at another PCC bus of load.The islanding starts at 0.5 sec. as shown in the fig.3.The complete simulation study and analysis is performed using MATLAB-Simulink software package.

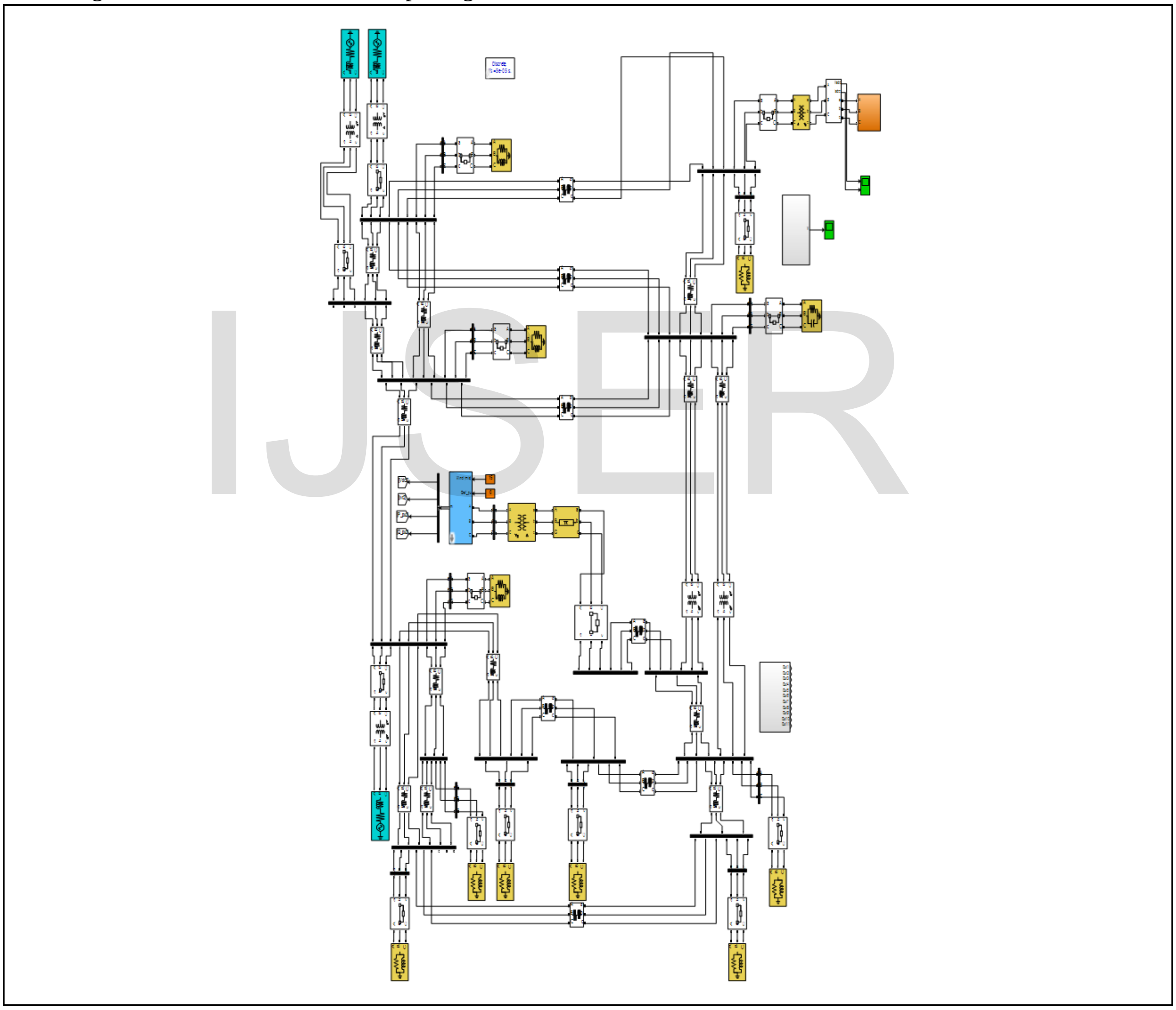

Fig.2: IEEE-14 Bus System (MATLAB/SIMULINK) Model for Islanding Detection with DGs

III. Negative Sequence Component Method

Negative sequence component is one of the key indicator s which qualify the presence of any disturbances in the voltage and current signals retrieved at the PCC location. Thus, in this technique, the negative sequence component of the voltage and current signals retrieved at the PCC bus is considered for analysis towards effective detection of islanding and non-islanding events.The negative sequence component of voltage of voltage and current signals at the point of common coupling (PCC) location in IEEE 14 Bus system can be expressed by symmetrical component analysis as follows:

$$V_n = \frac{1}{3}(V_a + \lambda^2 V_b + \lambda V_c) \ldots\ldots\ldots\ldots\ldots (1)$$

$$I_n = \frac{1}{3}(I_a + \lambda^2 I_b + \lambda I_c) \ldots\ldots\ldots\ldots\ldots (2)$$

Where Va,Vb,Vc are three phase voltages and Ia,Ib,Ic are three phase currents extracted at the bus of PCC of IEEE-14 Bus system,and λ=1<120º is the complex operator.The negative sequence component of the extracted voltage and current signals at the PCC or any bus is obtained by passing it through the three phase sequence analyzer block in Matlab/Simulink. From the three sequential components, it is only negative sequence component of the voltage signal, considered in this study as it gives the information about disturbances.Quantification of negative sequence voltage at the target bus of IEEE 14 bus system which provides high degree of immunity to noise,for detection of islanding event and other disturbances due to sudden load changes, DG line cut-off as well as abovementioned non-islanding cases, hence enabling better performance and simplicity.

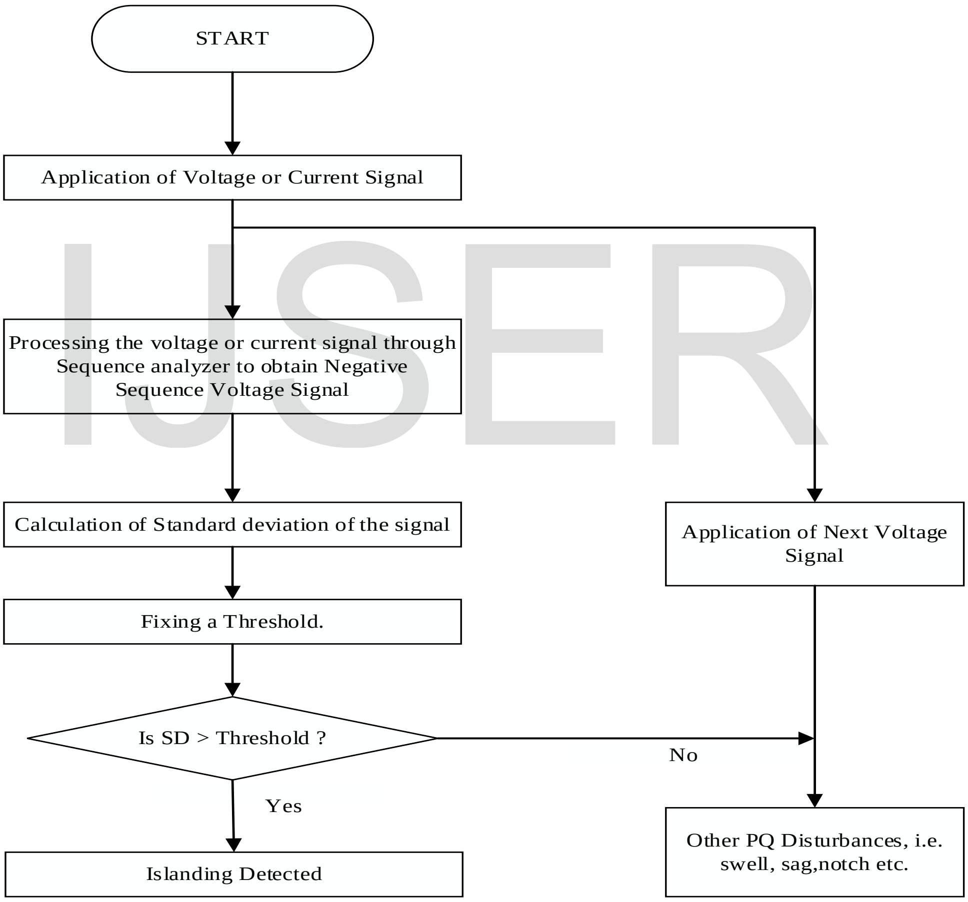

Fig.3: Flowchart for Islanding and PQ disturbance detection using Negative Sequence Components

IV. Simulation Results

The model is simulated at 1.6kHz (32 Samples on 50Hz base frequency).The voltages and currents as well as their negative sequences in per unit are retrieved at specified buses to detect islanding conditions.

ISSN 2229-5518

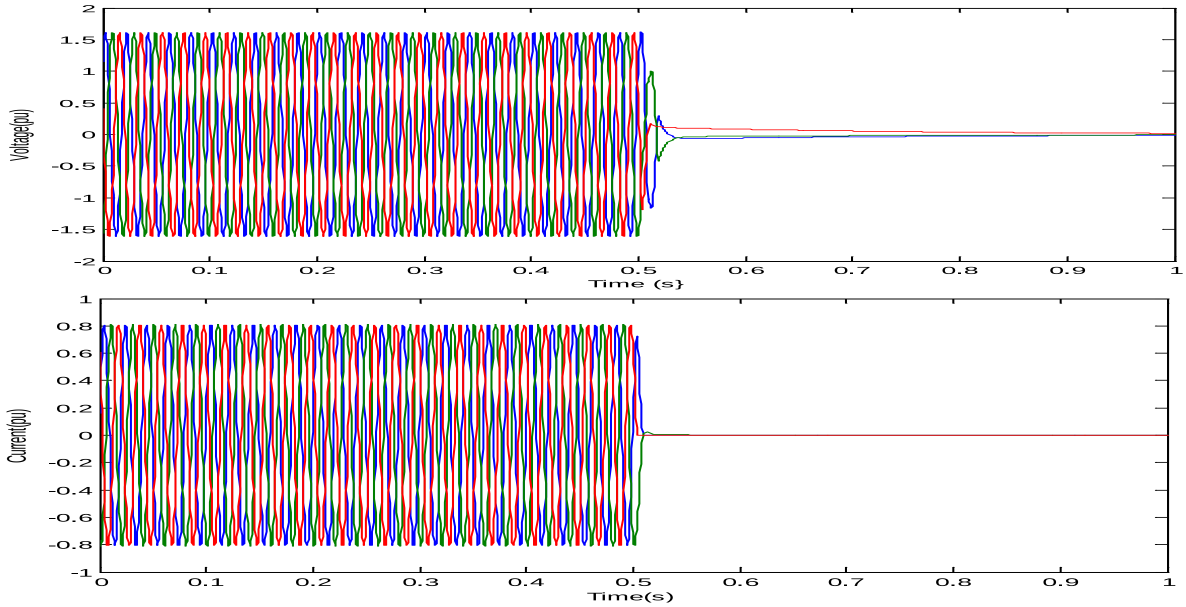

Fig.4: Three Phase voltage and current signals under islanding condition retrieved at Bus B4 (starts at 0.5 sec.)

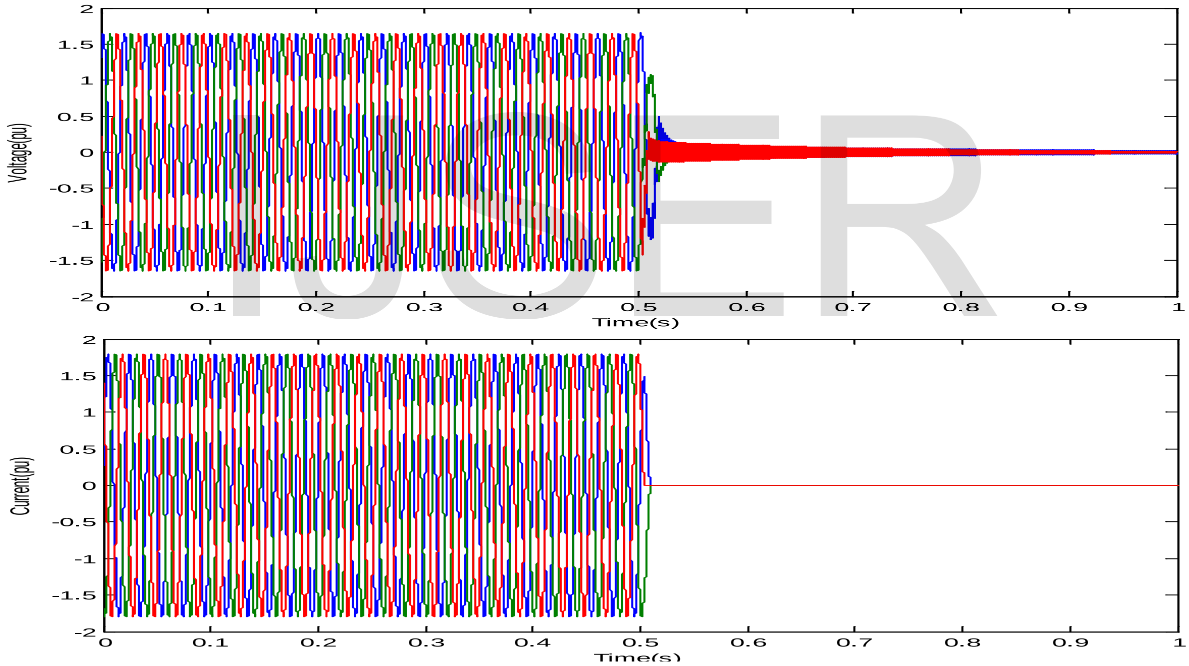

Fig.5:Phase voltage and current signals under islanding condition retrieved at Bus B2 (starts at 0.5sec.)

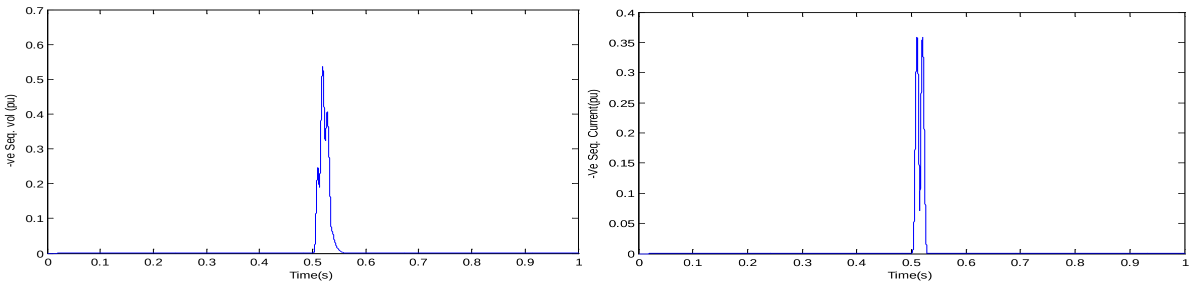

Fig.6: Negative Sequence Component of Voltage and Current at Bus B2 for islanding condition

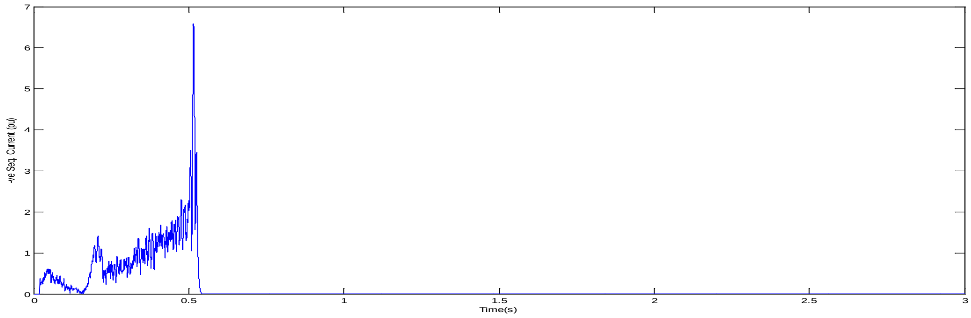

Fig.7:Negative Sequence Component of Voltage at Bus B4 for DG line Cut-off (Non-islanding)

Table I

Change in per unit voltage of each bus before islanding and after islanding situations of each bus during full load conditions

Condition	Standard Deviation(std)
Islanding	0.0174
Normal	0.0043
Sudden Load Change	0.0037
Tripping of other DG	0.0214

Table II

Standard deviations of the Negative sequence voltages : A comparison between Islanding Vs Non-Islanding conditions retrieved at each bus

Buses	Before Islanding (Per Unit Voltage)	After Islanding (Per Unit Voltage)
B1	0.9999	0.005262
B2	0.9998	0.005262
B3	0.9997	0.005262
B4	0.9996	0.005261
B5	0.9997	0.005261
B6	0.9994	0.005261
B7	0.9992	0.005262
B8	0.9992	0.005265
B9	0.9992	0.005261
B10	0.9993	0.005261
B11	0.9994	0.005261
B12	0.9994	0.005261
B13	0.9994	0.005261
B14	0.9993	0.005261

V. Conclusion

The Negative Sequence Component based technique investigates the negative sequence component of voltage and current for islanding detection in distributed generations on IEEE 14 bus system.The negative sequence per unit voltages and current values with standard deviations is used to detect islanding and non-islanding cases.It is found that the per unit voltages retrieved at each bus after islanding is quite low than before islanding.Further,standard deviation of negative sequence voltages at specified bus is calculated,which clearly detects the islanding conditions.It is observed that the standard deviation of the negative sequence voltage for clearly differentiates the islanding and non-islanding cases.

VI. References

[1] Mahat, P,Bak-Jensen,B. Review of islanding detection methods for distributed generation, *Third International conference on electric utility deregulation and restructuring and power technologies*,2008,2743–2748.

[2] Mahat, P, Chen,Z, Bak-jensen,B.,Review on islanding operation of distribution system with distributed generation,*Power and energy society general meeting*; 2011,1–8.

[3] Kunte,R,Gao,W. Comparison and review of islanding detection techniques for distributed energy resources,*40th North American power symposium,*2008,1–8.

[4] Fayyad,Y., Neuro-wavelet based islanding detection technique, *IEEE electrical power & energy conference*;2010,1–6.

[5] Timbus, A,Oudalov,A,Ho,C. Islanding detection in smart grids, *Energy conversion congress and exposition (ECCE)*,2010,3631–637.

[6] Abarrategui,D, Zamora, I. Comparative analysis of islanding detection methods in networks with DG,*19th International conference on electricity distribution Vienna*,2007,21–24.

[7] Samantray S.R.,Pujhari T.M.,Subudhi B.D.,A new approach to islanding detection in distributed generations,*Third International conference on power systems,Kharagpur,India*,2009

[8] Funabashi T., Koyanagi K., and Yokoyama R.,A Review of Islanding Detection Methods for Distributed Resources, *IEEE Bologna PowerTech Conference, Bologna, Italy,* June 23-26,2003

[9] Ku Nurul Edhura Ku Ahmad, Jeyraj Selvaraj, Nasrudin Abd Rahim,A review of the islanding detection methods in grid-connected PV inverters, *Elsevier Journal on Renewable and Sustainable Energy Reviews 21* ,2013,756–766Khamis A.,Shareef H.,Bizkevelci E.,Khatib T., A review of islanding detection techniques for renewable distributed generation systems, *Elsevier Journal on Renewable and Sustainable Energy Reviews 28*,2013,483–493

[10] W. Freitas, W. Xu, C. M. Affonso, and Z. Huang,Comparative analysis between ROCOF and vector surge relays for distributed generation applications, *IEEE Trans. Power Del., vol. 20, no. 2, pt. 2,* Apr. 2005, ,1315—1324.