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ISLANDING DETECTION FOR DISTRIBUTED GENERATION SYSTEM USING VARIOUS METHODS

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ABSTRACT

Customer demands better power quality and reliability. Distributed generation (DG) is widely used due to environmental worries to fulfill additional power requirement. Islanding detection is an important requirement for distributed generation. Several problems are caused, when DG fails to trip at islanding condition. It gives negative impact to the loads and generators. When islanding has occurred, distributed generator must be disconnected as soon as possible. Thus, distributed generator must be equipped with islanding detecting devices like over/under voltage relay, impedance relay, etc. They give trip signals to DGs when islanding is found. In this paper, one case study is analysed with different methods such as voltage measurement, impedance measurement, total harmonic distortion (THD), and negative sequence component. The case study is verified for detecting islanding under different loading condition such as normal condition, islanding situation, and isolation of other DG.

Keywords: *Distributed generator (DG), Islanding, Voltage, Impedance, Negative sequence component, Threshold, Total harmonic distortion (THD)*

INTRODUCTION

Small power generators, widely known as Distributed Generation (DG), becomes a popular as a distributed generation. DG helps effectively for supporting peak load. Thus, generation sources are constructed to meet the rising demands of power. Moreover, the whole distribution and transmission system also requires advancement to carry the additional load. So, creating extra power foundations and making changes in the transmission system will require large amount of cost and time, which may not be reachable. Recently, distributed generators are installed at low voltage buses near electrical consumers to reduce burden of transmission line.

Islanding is the situation in which a distribution system becomes electrically isolated from the remaining power system, yet continues to be energized by DG connected to it. Load and DG are separated from the grid when any contingency present in system. According to the figure 1, DG is separated from grid, but still load has continuous supply of power, this is known as islanding. Islanding may be intentional or unintentional. Intentional islanding occurs while maintenance, whereas some fault or disturbances present in the system causes unintentional islanding.

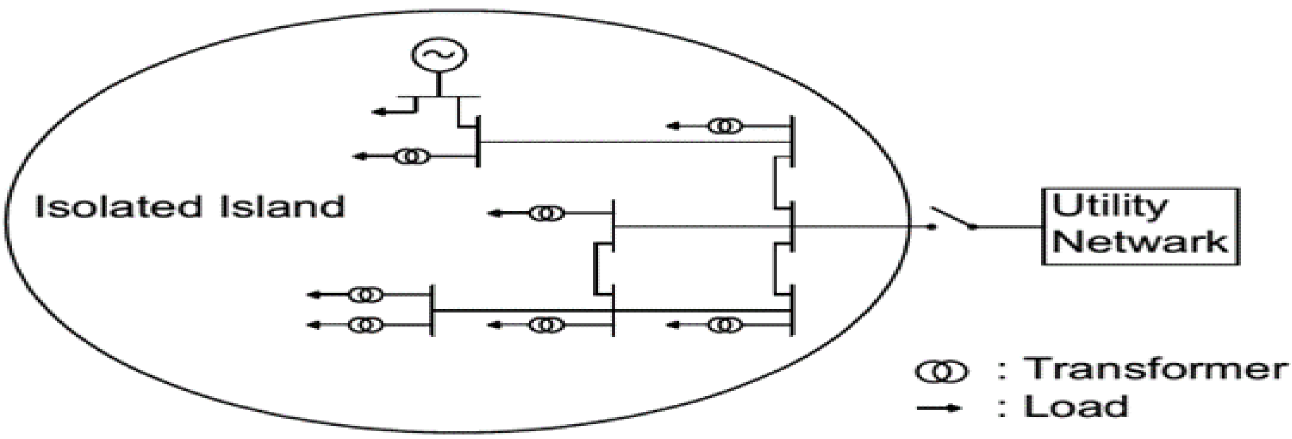

Figure 1. Islanding

Every method has its own detection zone in which it operates sensitively known as detection zone. Thus, non-detection zone (NDZ) can be defined as portion in which relay is not sensitive. The islanding detection method is developed to get fast and accurate detection with small NDZ. According to IEEE standard 1547-2003, maximum time for detection should be 2sec. Islanding detection is divided mainly into two techniques: (1) Remote and (2) local.

Local method is also divided into other three methods: (1) Active, (2) Passive and (3) Hybrid technique. Remote islanding detection techniques are based on communication between grid and DGs. Remote methods are expensive for small system, but this method is more reliable. These methods are more accurate than local techniques and also gives complexity. In local method, system parameters are measured such as voltage, power, current, frequency, etc. Active method detects even small difference between generation and load demand. It interacts with system directly, but detection is slow and NDZ is less. Passive method gives detection when there are large changes, but when small changes are present in system then active method is used. NDZ is large in passive method. Hybrid method has combination of active and passive method. In hybrid method, first passive detection is done then active method is applied. Detection time is larger than that in other methods.

This paper presents number of methods for islanding detection which provides the protection of distributed generator. Detection is tested at distributed generation bus at 575V.

SIMULATED SYSTEM MODEL

1. MODEL DESCRIPTION

System model is taken to investigate islanding and normal condition, as shown in figure 2. Grid voltage of 120kV, is stepped down to 25kV then it is given into two identical lines, it is again stepped down to 25kV/575V, which is given to load. Distributed generation is wind power plant which has 6 wind turbine, each wind turbine (WT) generates 1.5MW. So total 9MW generation is fed from DG to load. DG is connected to grid through 30km distribution line. Load is connected nearer to DG.

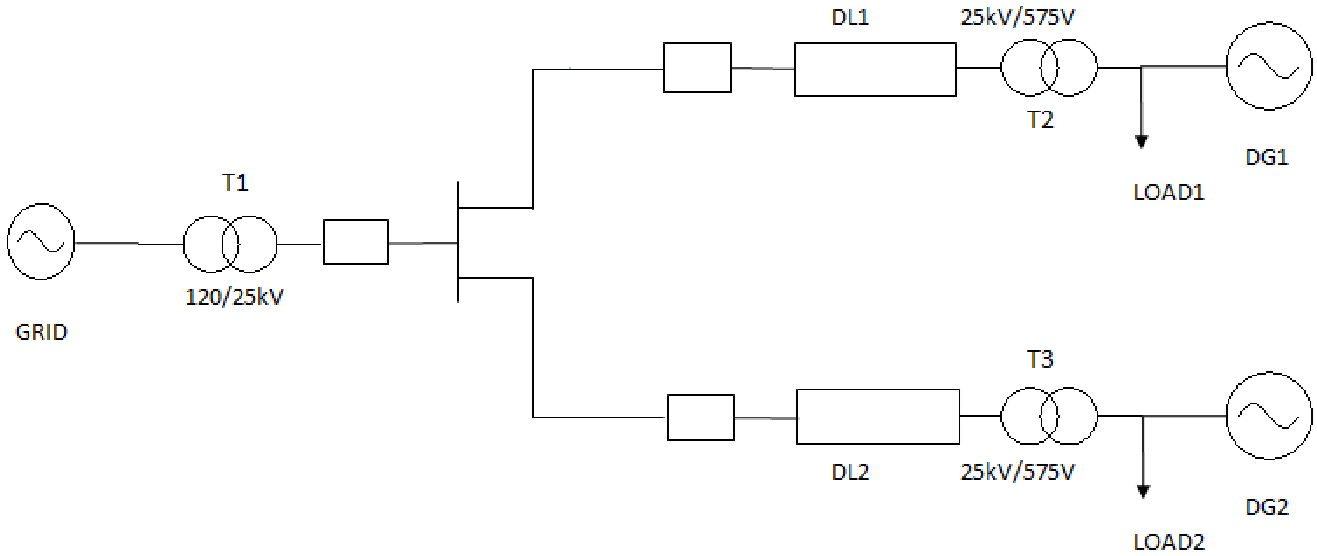

Figure 2. System model

Table 1. System data

Frequency	50Hz	Generator	Rated short circuit MVA = 2500, Rated kV = 120, Vbase = 120kV
Distributed generator	9MW with 6wind turbine (DFIG) each has generation of 1.5MW	Distribution lines DL1, DL2	PI section 30km, Rated MVA = 20, Rated kV=25, Vbsae = 25kV, L0 = 3.32e-3H/km, L1 = 1.05e-3H/km, C0 = 5.01e-009F/km,

			C1 = 11.33e-009F/km, R0 = 0.413Ω/km, R1 = 0.1153Ω/km
Transformer T1	Rated MVA = 25, Rated kV = 120/25kV, Rm = 500pu, Xm = 500pu, R1 = 0.00375pu, X = 0.1pu	Transformer T2, T3	Rated MVA = 12, Rated kV = 575V/25kV, Rm = 500pu, Xm = 500pu, R1 = 0.00375pu, X1 = 0.1pu, Vbase = 25kV
Load1	12MW	Load2	12MW

2. SIMULATION CONDITIONS

Simulation model is implemented over three conditions such as normal, islanding, and DG2 out with considering three different loading conditions which are low load (6MW), normal load (12MW), and high load (18MW). The model is simulated for 1sec for 50Hz. Sample time of model is 5 µs. Model is simulated for 1.6 kHz (base frequency = 50 Hz, sample = 32). Simulation is carried out in MATLAB software. Initial wind speed is constant at 11m/s. Three conditions are described as below.

1. Normal condition: All breakers are ON in this condition. Load is supplied by grid and DGs.

2. Islanding condition: Grid side breakers are OFF at islanding condition. Load is supplied by DGs.

3. DG2 out condition: Breaker of DG2 is opened. All other breakers are in closed condition.

SIMULATION OF MODEL

System model is run under different condition then voltage and current are measured at DG1 bus. Active power is calculated from measured voltage and current. By observing results, which are shown in figure 9, 10, and 11, power supplied by grid is zero in islanding condition and power flow from DG2 is zero in DG2 out condition. Large unbalance is introduced at low loading means 6 MW. Maximum voltage variation is present during islanding condition. So voltage measurement is useful for islanding detection, which is described in following section.

1. VOLTAGE MEASUREMENT

System voltage is almost 1pu (rated voltage) under the normal condition. When the DG is disconnected from the main grid, voltage variation is beyond its threshold value. Relay, which is based on voltage measurement compares voltage with set threshold and gives trip signal at islanding condition when voltage is beyond threshold value. Voltage measurement and trip signal are decided which are shown in figure 3 and figure 4. Here, C1 and C2 are threshold values which are decided according to the requirement of islanding detection. As per IEEE standard 1547, Allowable values are 1.1pu at maximum level and 0.88pu at minimum level in voltage relay. NDZ (Non detection zone) is large in detection using DG voltage. Algorithm for detection is shown in figure 5. In algorithm, RMS voltage at DG1 bus is measured after simulating model, then voltage is compared with threshold values, C1 (575V + 10% of 575V = 632.5V) and C2 (575V - 10% of 575V = 517.5V). If voltage is beyond these threshold values, then relay gives trip signal, otherwise it is non islanding condition.

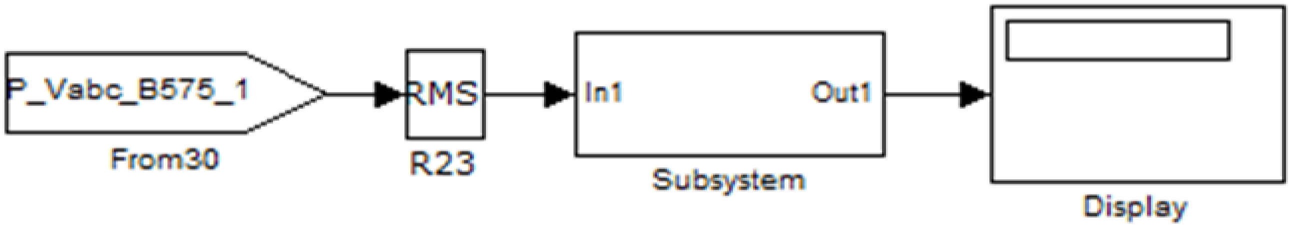

Figure 3. Voltage measurement

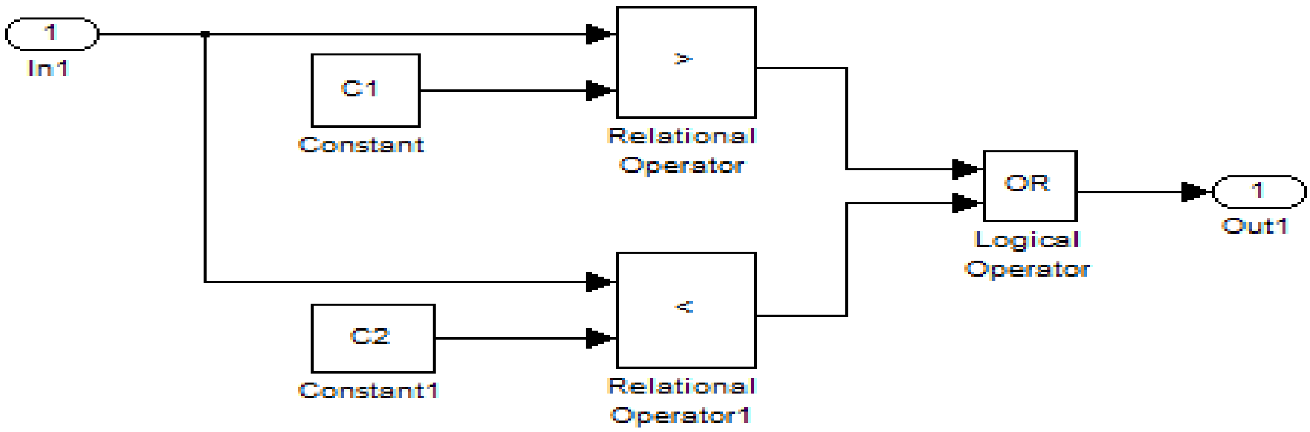

Figure 4. Subsystem of detection through DG1 voltage

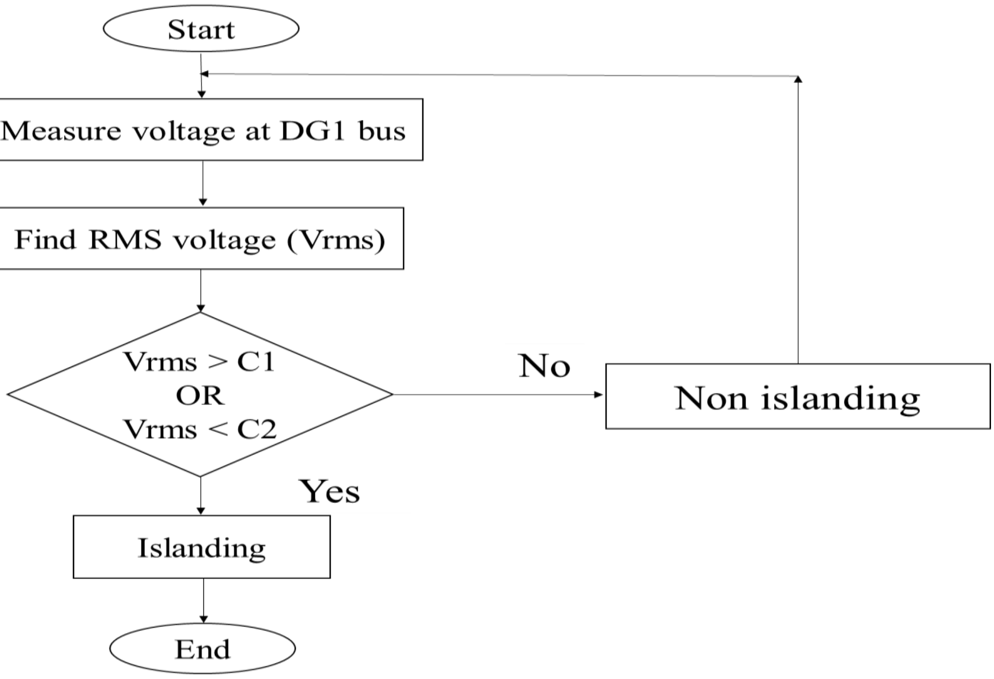

Figure 5. Algorithm for detection using voltage at DG1

2. IMPEDANCE MEASUREMENT

Impedance measurement is introduced as shown in figure 6. RMS voltage and current are sent to subsystem that is shown in figure 7 and impedance is measured. Non detection zone is smaller than voltage measurement.

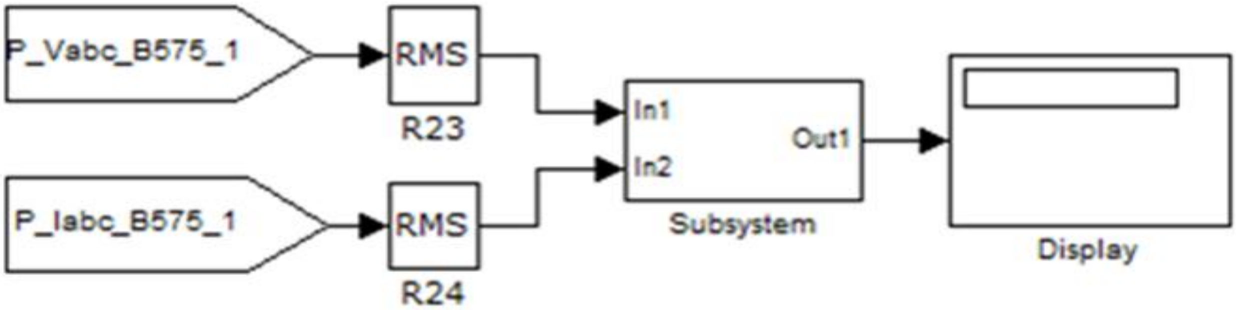

Figure 6. Impedance measurement using voltage and current signals

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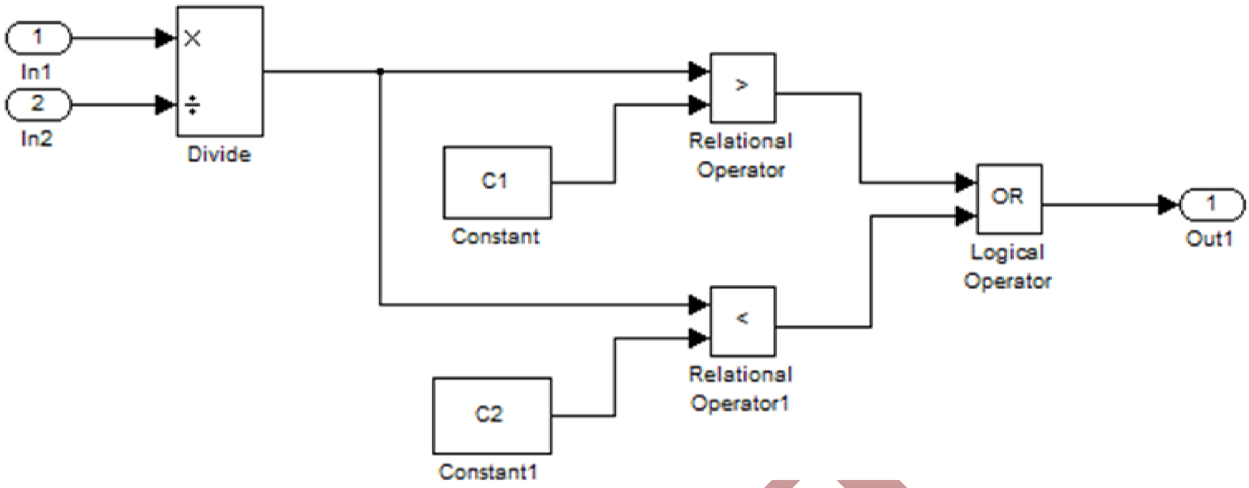

Figure 7. Subsystem of detection through impedance

Impedance is compared with constant threshold value. If impedance exceeds threshold, then relay gives tripping signal. It is difficult to set threshold which gives true trip signal during large load changes. Algorithm for impedance relay is almost the same as voltage detection method, which is shown in figure 8. In algorithm, RMS voltage and current are measured, which are sent in the subsystem (figure 7) to find impedance. After getting impedance, it is compared with threshold values, C1 (0.0735 + 10% of 0.0735 = 0.08085Ω) and C2 (0.0735 - 12% of 0.0735 = 0.06468Ω). If impedance is beyond these threshold values, then relay gives trip signals, otherwise it is non islanding condition. Large changes in impedance are present during islanding condition. If threshold is taken, which is 10% of the normal impedance for detection of islanding during 16 MW then relay trips for DG2 out condition though it is non-islanding. So threshold range is increased to get true detection of islanding.

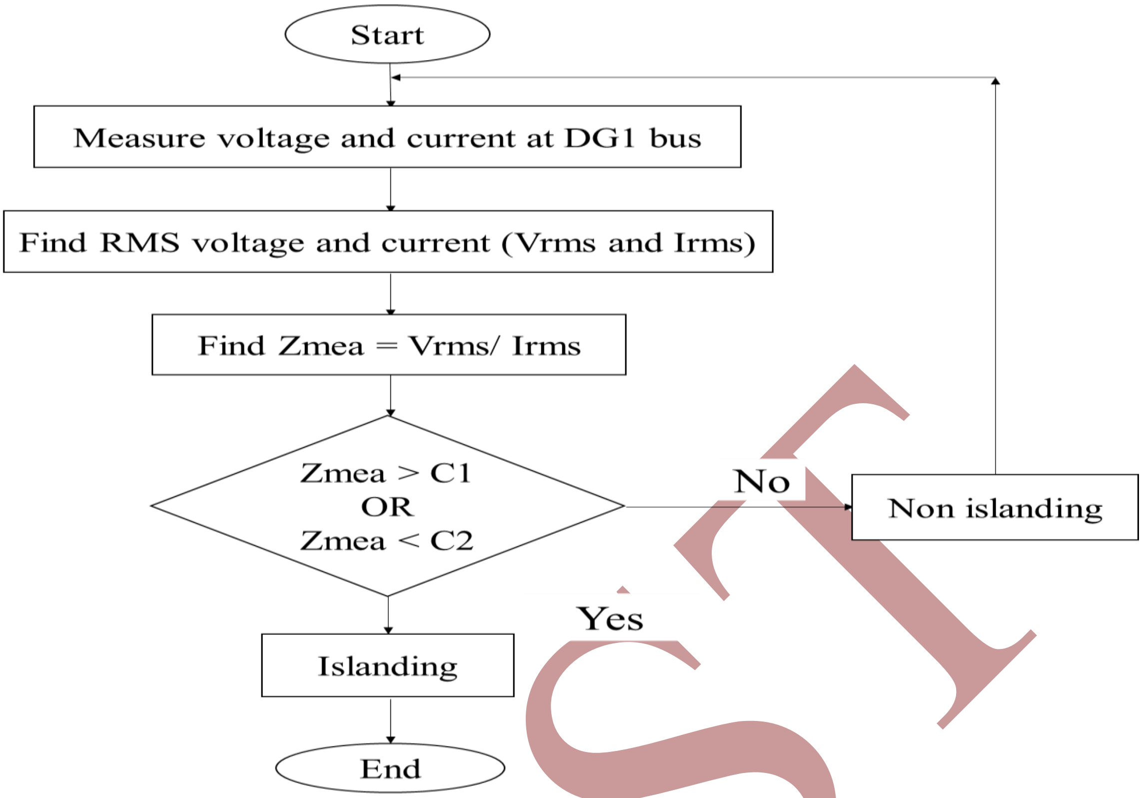

Figure 8. Algorithm for detection using impedance

3. TOTAL HARMONIC DEVIATION METHOD

FFT analysis is observed for investigating harmonic distortion. It is a very simple method to detect islanding. Total harmonic distortion of voltage at DG1 is measured by FFT analysis. Switching position is changed during 0.3sec to 0.5sec in this simulation. THD is less during the normal condition. But large harmonic distortion is observed after islanding than before islanding. In the proposed method, total harmonic distortion is observed during following cycles.

1. 0.35sec to 5 cycles
2. 0.1sec to 9 cycles
3. 0.35sec to 9cycles

4. NEGATIVE SEQUENCE COMPONENT

Negative sequence component of voltage and current is measured from negative sequence analyzer. Negative sequence component gives better detection for each condition. Thus, negative sequence component method is preferable. Negative sequence component of voltage and current change with disturbances. These changes are large during islanding condition. So, threshold can be decided easily. So it distinguishes islanding detection for any type of load.

TEST RESULTS AND DISCUSSION

Power flow is shown in figure 9, figure 10, and figure 11 for different loading conditions. Detection of islanding is done by observing power flow from grid (Pg), load (PL) and DGs (Pdg). Supplied power from grid is zero during islanding condition. In DG2 out condition, power supplied by DG2 is zero.

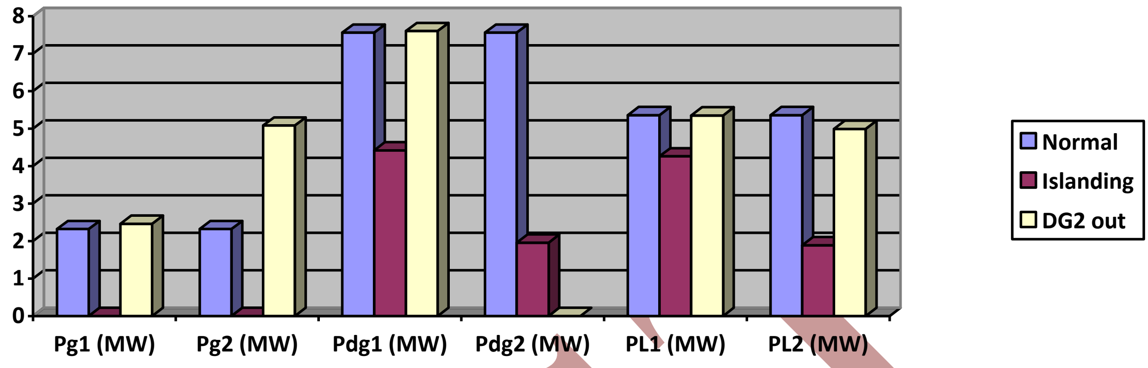

Figure 9. Power flow at 6MW load

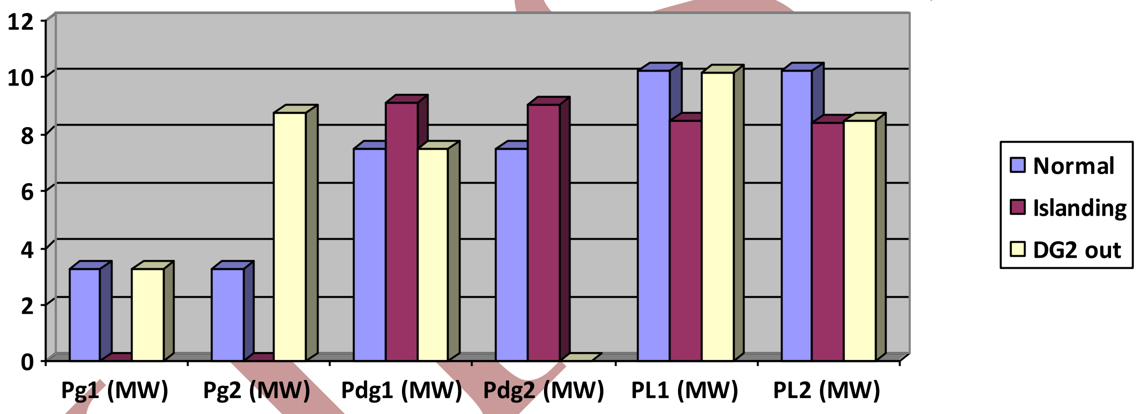

Figure 10. Power flow at 12MW load

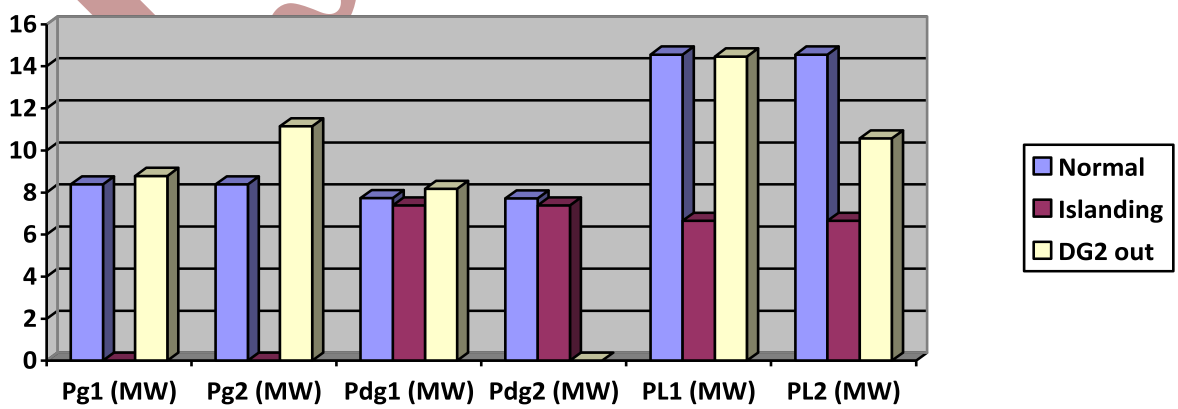

Figure 11. Power flow at 18MW load

1. VOLTAGE MEASUREMENT

Change in voltage is large during islanding condition with respect to that of in the normal condition. Voltage variation occurs at each bus in different condition, but detection is observed at DG1. So focus only must be on DG1 bus. Voltages at DG1 during islanding condition are 500.6V, 516.5V, and 391.3V under loading condition 6MW, 12MW, and 18MW respectively. These voltages are beyond threshold value so relay gives trip signal during islanding condition.

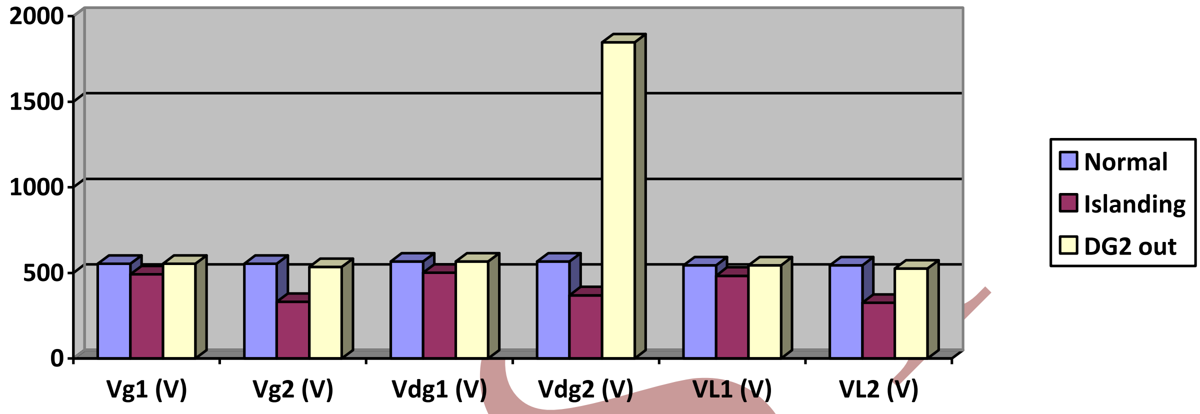

Figure 12. Voltage at 6MW load

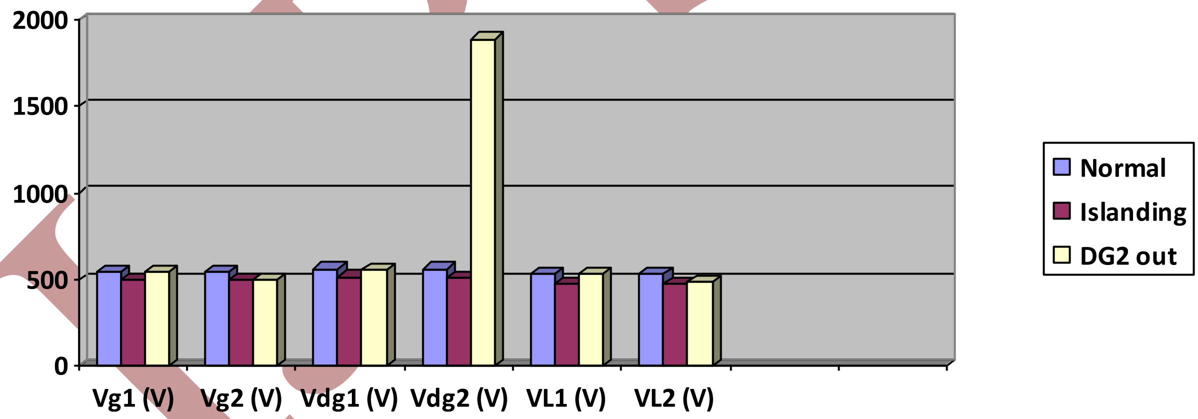

Figure 13. Voltage at 12MW load

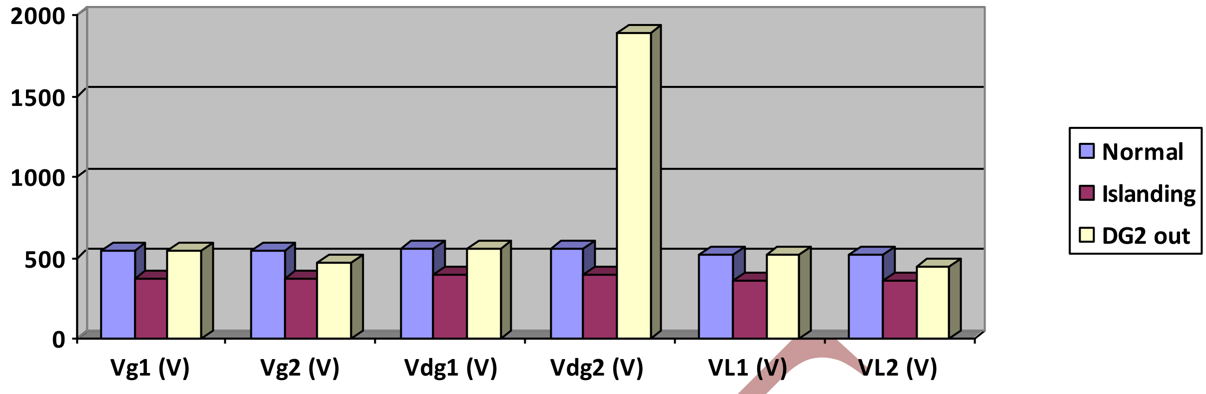

Figure 14. Voltage at 18MW load

2. IMPEDANCE MEASUREMENT AT DG1

Impedance is beyond threshold limit during islanding condition which has impedance values as 0.0981ohms, 0.0508 ohms, and 0.0358ohms respectively for the load 6MW, 12MW, and 18MW. So, relay gives trip signal under islanding condition only because impedance is within threshold limit during normal and DG2 out condition.

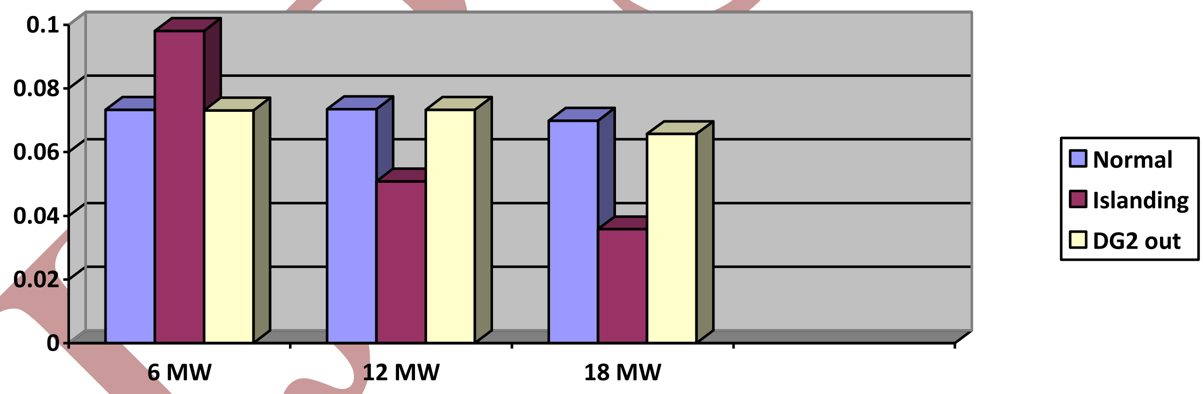

Figure 15. Impedance measurement at different loading condition

3. TOTAL HARMONICS DETECTION MEASUREMENT

THD of voltage at DG1 bus is shown in figure 16, 17, and 18. By observing results, THD after changes is very high as compared to that of in before the changes during islanding condition. THD is less than 1% in the normal condition. As per IEEE, THD must be less than 5% in the normal condition so the non-detection zone is very small as compare to voltage and impedance measurement. In DG2 out condition, THD is around 7% which is not a major variation in THD. THD variation is suddenly increased to high value during islanding condition.

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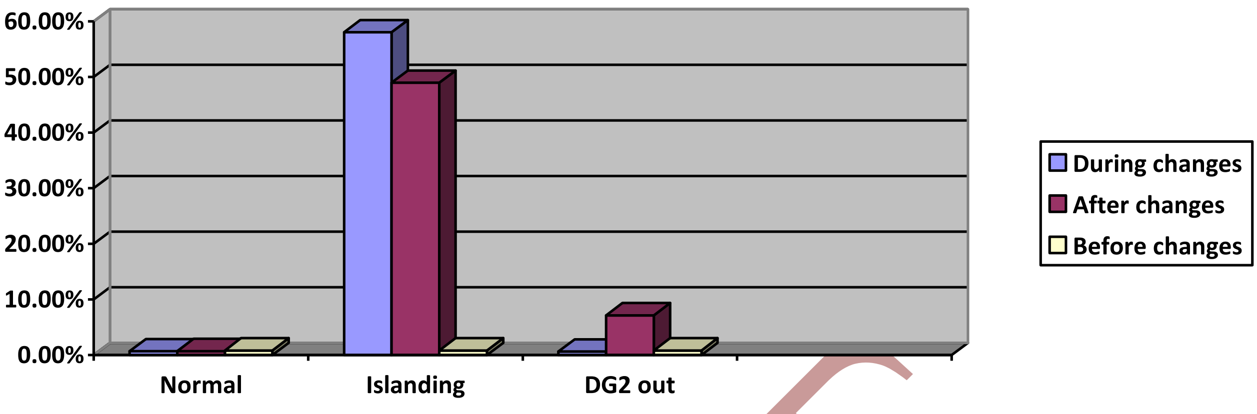

Figure 16. THD for Low Loading 6 MW

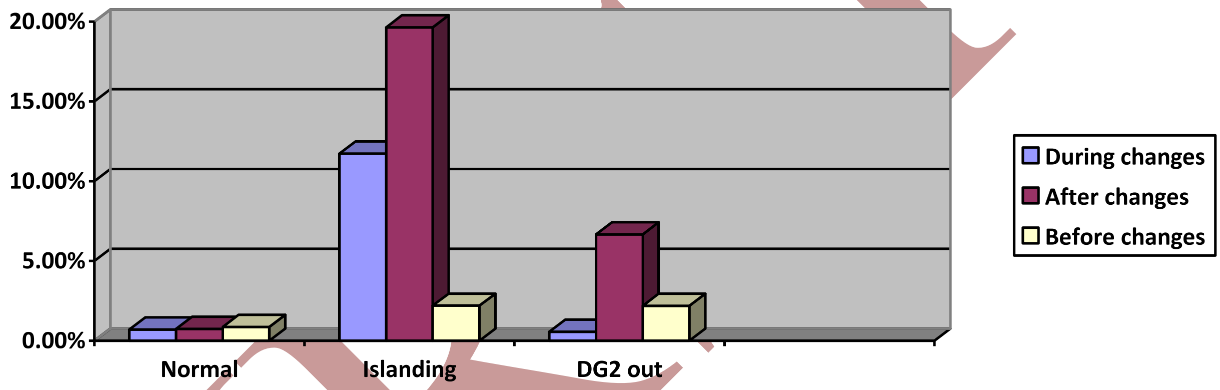

Figure 17. THD for Normal Loading 12 MW

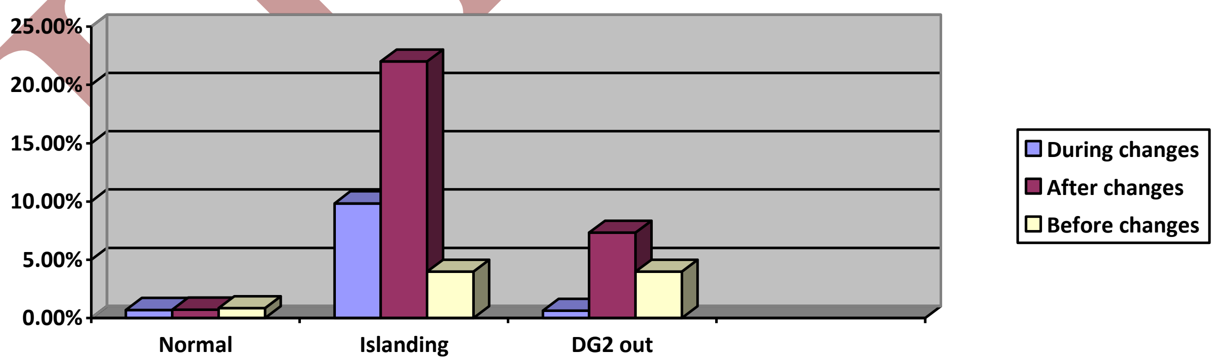

Figure 18. THD for High Loading 18 MW

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4. NEGATIVE SEQUENCE COMPONENT METHOD

Negative sequence voltage and current are shown in following results under different loading conditions. In all loading condition, negative sequence voltage and current are almost zero in the normal condition. Islanding and DG2 out conditions are applied during time period 0.3 to 0.5sec. During islanding condition, negative sequence component gets high peak during 0.3 to 0.5sec. In DG2 out condition, negative sequence components have less peak as compare to islanding condition peak. System takes some time to settle after breaker reclosing at 0.5sec so, negative sequence components are not totally zero after 0.5sec. Shown results are only for 12MW load, same results should be observed for 6MW and 12MW.

Voltage and current at DG1 under different conditions:

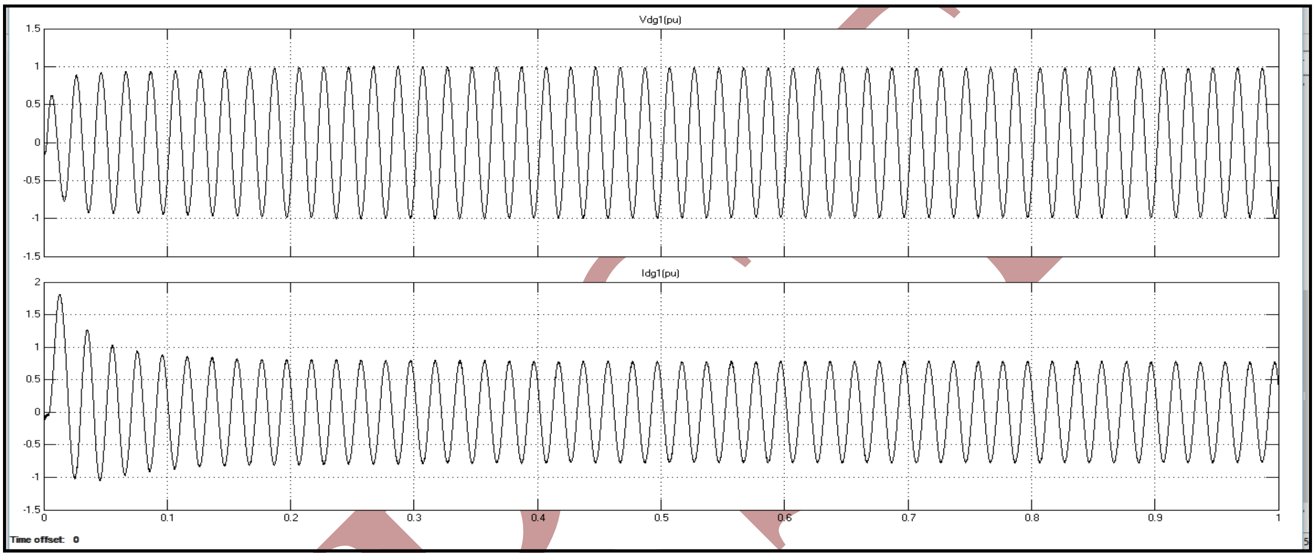

Figure 19. Voltage and current at DG1 with 12MW load in normal condition

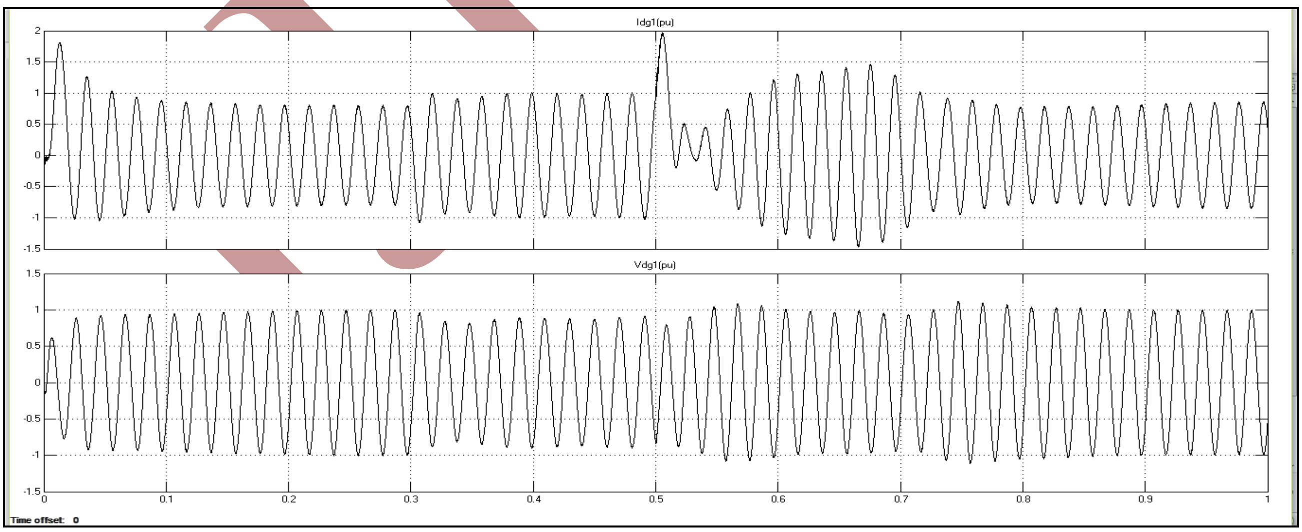

Figure 20. Voltage and current at DG1 with 12MW load in islanding condition

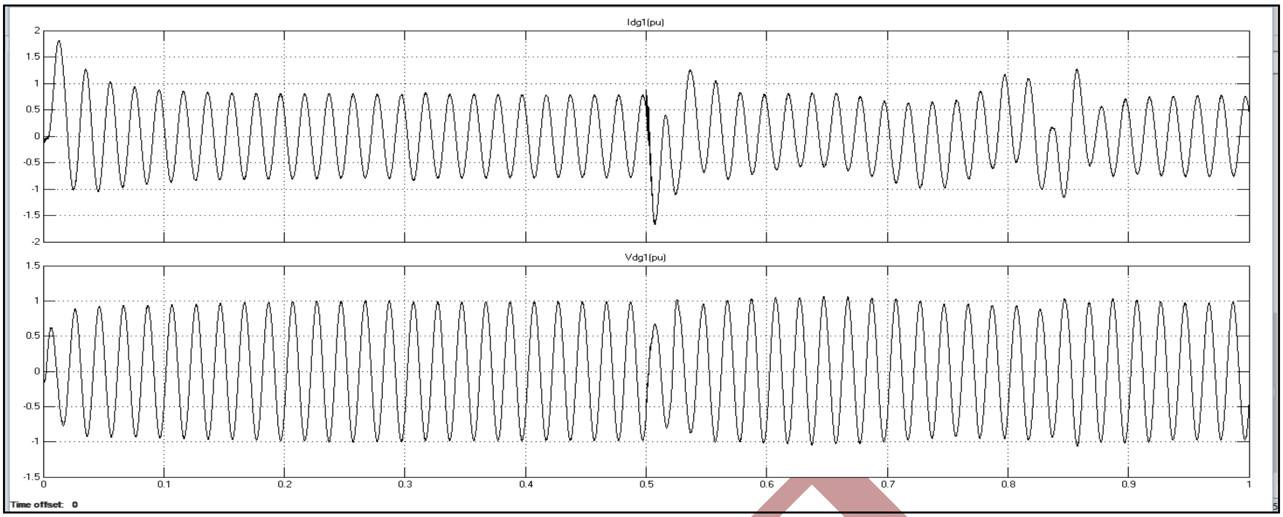

Figure 21. Voltage and current at DG1 with 12MW load in DG2 out condition

Negative sequence voltage and current under different conditions:

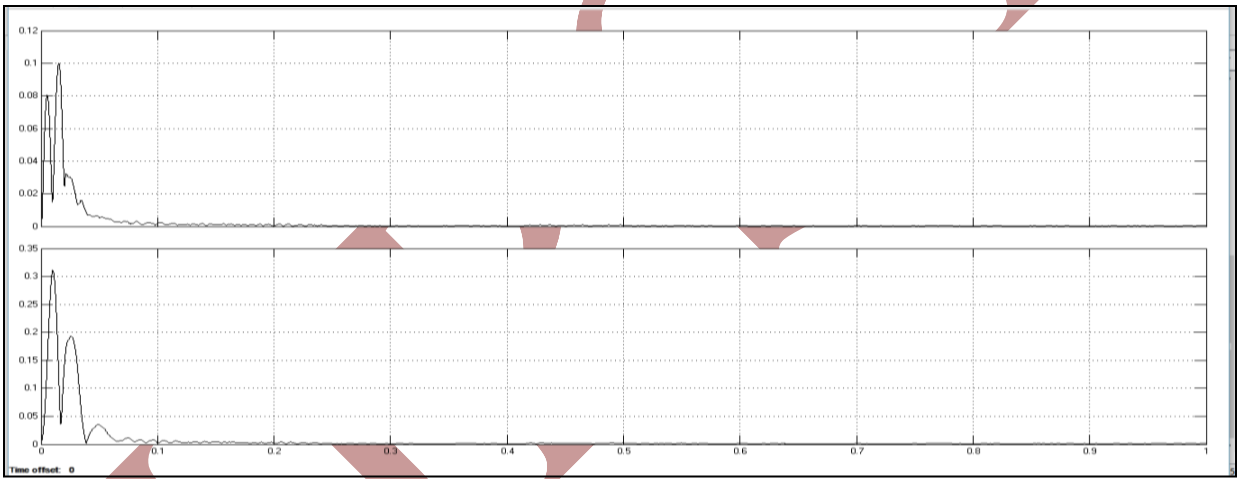

Figure 22. Negative sequence voltage and current at DG1 at 12MW in normal condition

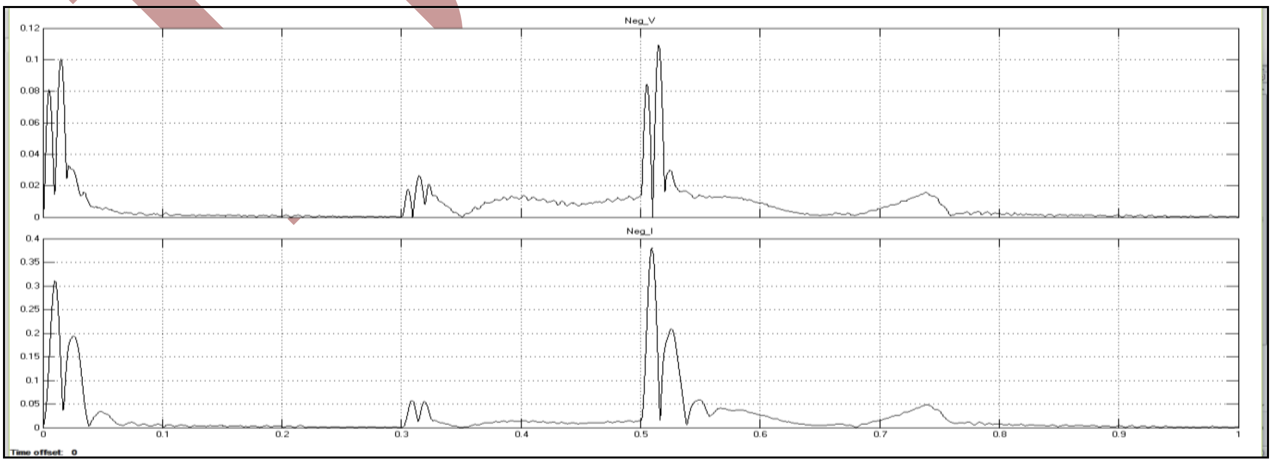

Figure 23. Negative sequence voltage and current at DG1 with 12MW in islanding condition

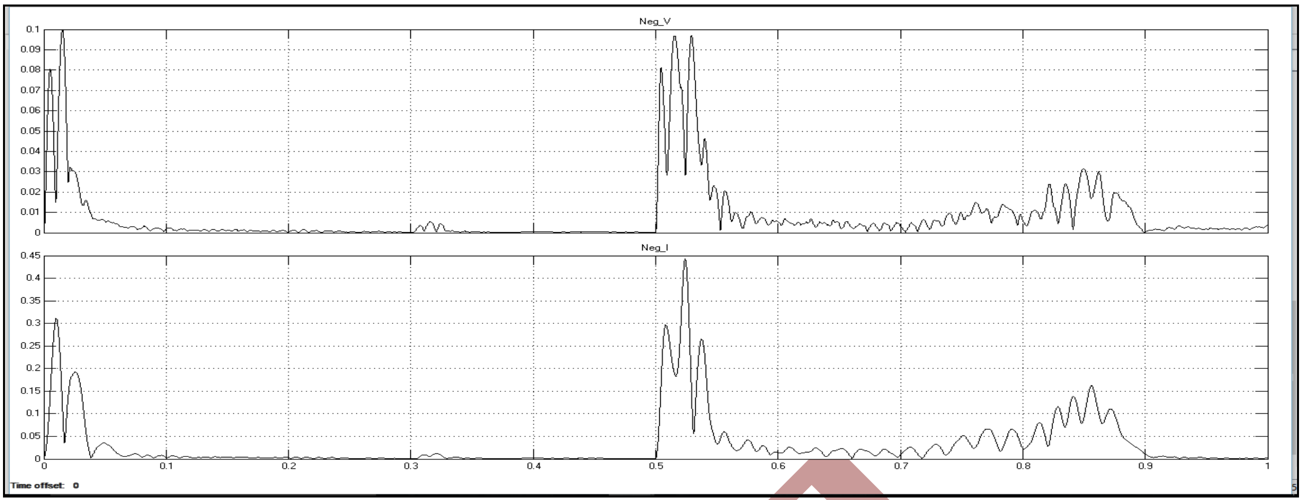

Figure 24. Negative sequence voltage and current at DG1 with 12MW in DG2 out condition

CONCLUSION

Different islanding detection techniques are described and compared in this paper. Detection technique requires proper threshold value, or else relay gives false detection though it is non-islanding condition. Detection of islanding is needed for protection of distributed generator.

Voltage measurement gives true islanding detection for different loading condition. Maximum voltage variation is observed under islanding condition. In impedance method, threshold range is increased to detect true islanding detection for all loading. Threshold can be reduced, but it gives false tripping at non islanding condition (DG2 out). Variation of impedance is large in islanding condition.

Total harmonic distortion is large during islanding condition for each loading condition. THD is the same for all load condition at the normal condition. Harmonics distortion is more after islanding condition than before islanding condition. Non detection zone is less as compared to that in voltage and impedance measurement. Negative sequence component methods are widely used as it gives better detection in all conditions giving good response with changes. Islanding condition can be distinguished by using negative sequence component method at all loading condition.

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