International Journal of Power Electronics and Drive System (IJPEDS)
Vol. 11, No. 4, December 2020, pp. 2046~2054
ISSN: 2088-8694, DOI: 10.11591/ijpeds.v11.i4.pp2046-2054

Islanding detection of distributed generation systems using hybrid technique for multi-machine system

Sindhura S. Sirige, Sallena Choudhur, Jayalakshmi N. S.
Department of Electrical and Electronics Engineering, Manipal Institute of Technology, Manipal Academy of Higher Education, Manipal-576104, India

Article Info

Article history:

Received Jan 9, 2020
Revised Apr 26, 2020
Accepted May 30, 2020

Keywords:

Distributed generators
Practical voltage unbalance
Frequency perturbation
Islanding detection
IEEE test system

ABSTRACT

Due to depletion of conventional fuels and increase in power demand, many renewable energy sources are being integrated into the electrical grid. One of the major concerns with this integration of these renewable sources with utility grid is unintentional islanding. Many techniques have been proposed to detect unintentional islanding, all of them trying to comply with the IEEE standard 1547. This paper presents an analysis of the hybrid technique to detect the islanding condition of the power system with multi-machine systems. This work aims at analysing the technique against increasing size of the system with increasing number of distributed generators by including practical voltage unbalance formula. The validity of this detection technique is verified using IEEE standard test power systems in MATLAB platform. This method can be used to identify multiple islanding conditions effectively. The simulation results show the effectiveness of the technique to detect islanding condition for multi-machine systems.

This is an open access article under the CC BY-SA license.

Corresponding Author:

Jayalakshmi N. S.
Department of Electrical and Electronics Engineering
Manipal Institute of Technology,
MAHE, Manipal-576104, India.
Email: jayalakshmi.ns@manipal.edu

1. INTRODUCTION

The huge penetration of distributed generation (DG), renewable energy applications and the use of the microgrid concept have changed the shape of conventional electric power syste structure. Most of the new power system networks are transforming into the DG model integrated with renewable and non-renewable energy resources by forming a microgrid. A microgrid operates in the grid-connected or stand-alone mode. It is expected that there will be a great change in the power system configuration due to the interconnection of DGs at the distribution level. The integration of these DRs can improve the power quality, reduce peak loads and minimize the necessity of reserve margin. As defined in IEEE standard 1547-2003 [1] islanding is the condition when a part of an area electric power supply (EPS) is energized purely by the local supply units in its area, while it is disconnected from the rest of the area EPS. The standard states that unintentional islanding is nothing but an unplanned islanding condition. According to this standard, the islanding in which a distributed resource (DR) is a local supply should be detected and the DR should disconnect from the area EPS within two seconds of its occurrence. The islanding detection in DG systems is a challenging problem that causes several protection and security problems.

One of the most challenging issues in today's world is bridging the gap between generation and consumption rates of electricity. Integrating distributed generators (DGs) with the electrical grid is a major step being taken to rectify this situation. The DGs improve power quality, reduce the peak loads and so the need for a reserve margin is exterminated [2, 3]. But, unintentional islanding of the DG system from the utility grid is a serious obstacle in its usage. So, many techniques are continuously being introduced for the detection and disconnection of DG [4-9], that aim to meet the 1547 standard. Out of these, hybrid techniques are the most popular ones [10, 11] as they are a combination of active and passive techniques, where one technique overcomes the disadvantages of the other, thus strengthening the overall technique. One such technique of islanding detection is, a hybrid detection technique using voltage unbalance and frequency set point [11] that includes the two techniques mentioned in a sequential manner, first the passive technique, then the active technique. Thus, it reduces the instances of applying a perturbation. The hybrid islanding detection techniques [12-16] are employed to overcome the short comings of both active and passive techniques, to detect the islanding of a distribution system with renewable energy sources.

The application of this technique has been done on a system with two DGs. In this work, we have applied the technique to different systems with different number of buses and DGs to analyse its validity for bigger systems with increased number of machines. The validity of this detection technique is verified using IEEE standard test power systems in MATLAB platform. We can see how each of the parameters (voltage unbalance and frequency) varies as the system changes, if there is a pattern of change, thus proving if the change in parameter is related to the size of the system. We also check if the technique is valid or successful to all the systems in consideration. This method can be used to identify multiple islanding conditions successfully.

In the following sections, we have presented the implementation and results of the work under sections II and III. The simulation was done by MATLAB script coding. The results show that there is a relation between the number of DGs and voltage unbalance parameter. It is also seen that the technique is not valid for all the systems and fails to detect the islanding from a particular size (of the system) onwards. The observations from the results obtained are discussed under section IV of this paper, followed by section V which gives the conclusion of the work.

2. METHODOLOGY

This paper uses IEEE standard power systems to demonstrate the effectiveness of the hybrid islanding technique considered. These results ultimately show the validity of the technique for each of the standard test systems. The chosen hybrid technique involves observation of voltage unbalance at each of the DG terminals as the passive technique and frequency perturbation as the active technique. The schematic block diagram of the hybrid technique is depicted in Figure 1.

In this paper, instead of the standard formula for finding ideal voltage unbalance as given in the existing literature, this method utilizes the relation for determining the voltage unbalance for practical use as given in the standardization document IEC 61000-2-12 [17]. The practical values of the voltage unbalance of DG system is calculated using the expression,

$$VU = \sqrt{6 \times \left(\frac{{V_{ab}}^2+{V_{cb}}^2+{V_{ac}}^2}{V_{ab}+V_{cb}+V_{ac}}\right) - 2} \quad (1)$$

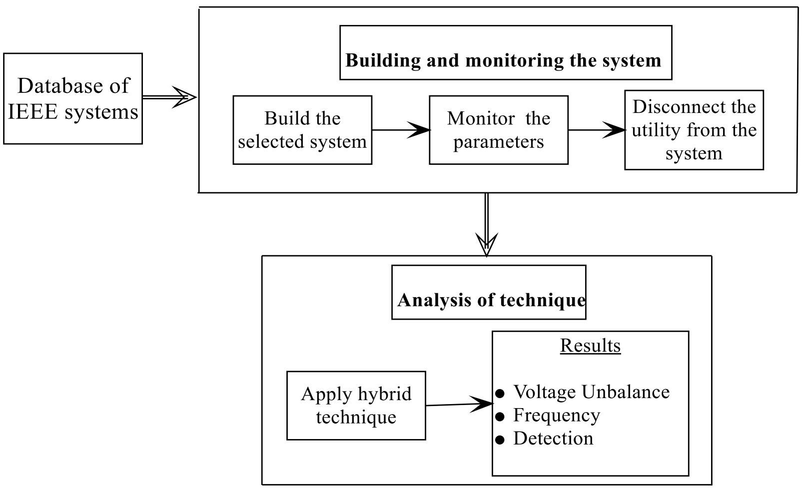


Figure 1. Schematic block diagram of the hybrid technique

2.1. Monitoring the parameters
The hybrid technique chosen is classified under the category of local detection techniques. This means that the observation and analysis of the parameters is done at the terminals of the DGs itself. Here, we must monitor the voltage unbalance and frequency at the terminals of all the DGs in the system.

2.2. Islanding operation
Islanding is induced by disconnecting the utility at a specified instant of time (say, t=10s). This means that, after occurrence of islanding [22, 24] the admittance matrix representing the system considered will be different. So, we must construct the new admittance matrix and then monitor the parameters using the following equations [18, 20].

$$I_G = YE_G \tag{2}$$
$$P_G = YI_G^* \tag{3}$$
$$V_t = E_G - XI_G \tag{4}$$
$$2H\frac{d(\Delta\omega)}{dt} = P_M - P_G \tag{5}$$
$$E_G = Ee^{i\Delta\delta} \tag{6}$$

Where, I_G is the current through the generator, Y is the reduced admittance matrix, E_G is the generator voltage, P_G is the generated active power, V_t is the terminal voltage of generator, X is the internal reactance of the generator, H is the inertia of the generator, ω is the rotor speed of the generator, P_M is the mechanical power of the generator, which is initialized as equal to active power and δ is the load angle [19].

2.3. Application of hybrid technique
This hybrid technique is a sequential grouping of two techniques. First, the passive technique is applied by measuring the voltage unbalance [21, 23] and if the VU exceeds the threshold, then the active technique that is frequency perturbation is applied. Then, if the frequency value goes below the frequency threshold then, it is predicted to be an islanding condition [25, 26].

The VU, at the terminals of all the DGs is monitored continuously using equation (1). Whenever the threshold condition [11] as expressed in equation (2) is met, then the frequency set point of the DGs is perturbed. The threshold value (*k*) for the frequency of the DGs considered is to be 49.2 Hz. Here, the frequency set point is lowered from 50 Hz (f_s) to 49 Hz (f_{min}) and the DG frequency is monitored for the next 1.5 seconds. If the frequency of the DG goes lower than the frequency threshold, it means that there is no utility to regulate the system and this state is considered as an islanding condition. In any case, the frequency set point is changed back to 50 Hz.

The voltage unbalance threshold value is given by the equation as

$$\zeta = \kappa \times VU_{avg} \tag{7}$$

Where ζ is the threshold for instantaneous voltage unbalance, κ =35 and VU_{avg} is the average voltage unbalance for the past one second duration. The sequence of the hybrid technique is shown in Figure 2.

3. SIMULATION RESULTS
The islanding detection technique was tested for different standard IEEE bus systems. The IEEE 3, 5 and 14 bus systems contain 2 DGs and IEEE 6 bus system has 3 DGs. The IEEE 30 bus and 118 bus system contain 6 and 19 DGs respectively. The simulation results for the above systems are reported in this section. Initially, the systems are under normal operation with the machines connected to the utility. All the machines operate at 50Hz when the system is connected to the utility grid.

3.1. Systems with 2 machines
The systems with 2 machines will have a 2×2 admittance matrix before the condition of islanding. But, at the instant of separation from the utility the admittance matrix of the system reduces to 1×1 matrix due to the loss of utility system. Figure 3 (a), shows the switching action in the 3-bus test system at t= 10 secs with VU spike of value 2.4%. The frequency plot depicted in Figure 3 (b) shows a dip in the frequency to 47.2 Hz which is below the threshold value. We can observe from Figure 3(c) that the islanding is detected from the detection plot. This confirms that this switching instant is due to an islanding condition.

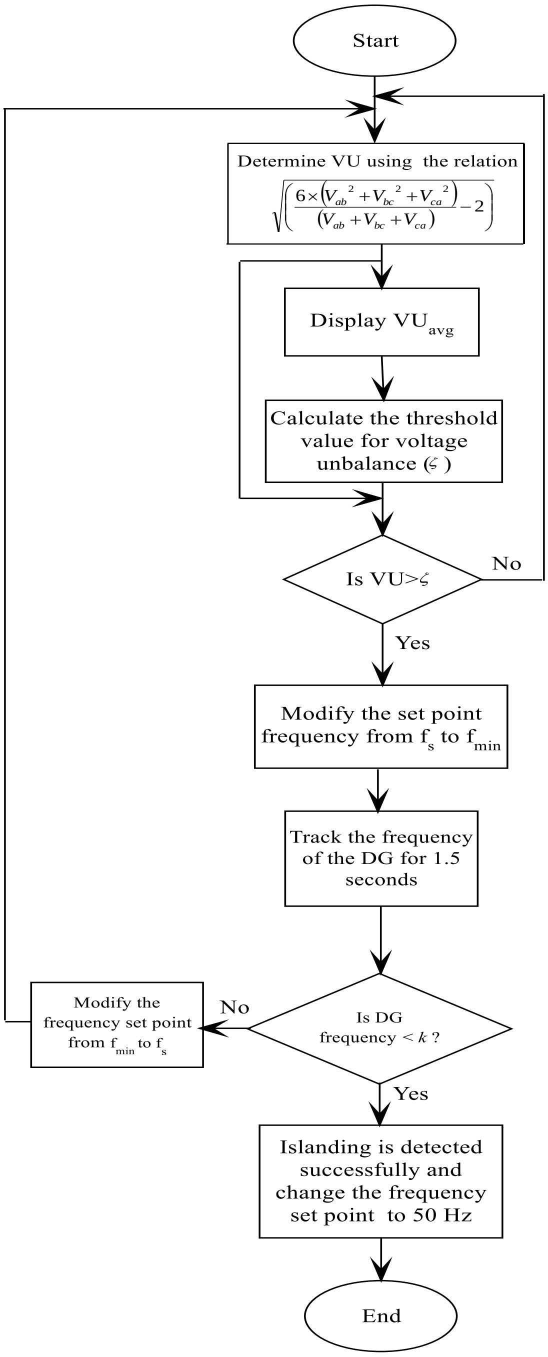


Figure 2. Flowchart for the hybrid islanding technique

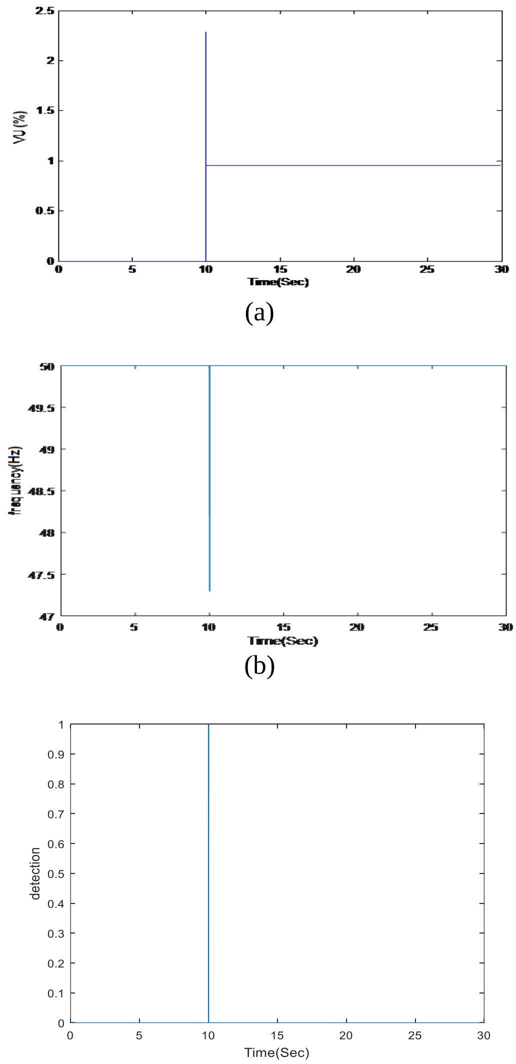
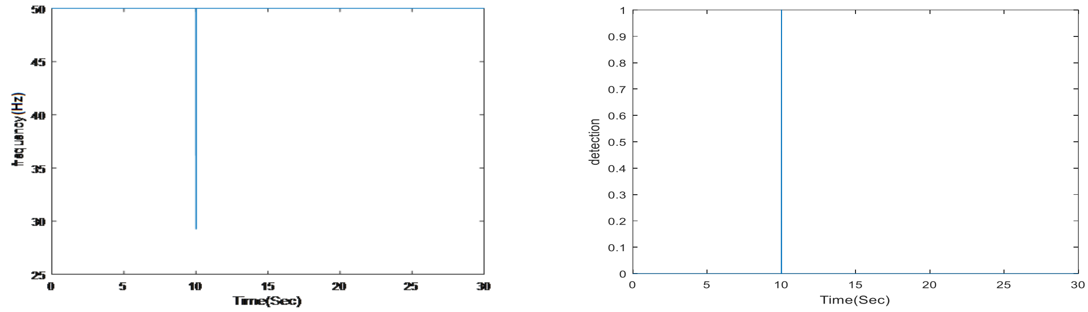


Figure 3. (a). Voltage unbalance at DG terminal, (b). Frequency of the DG, (c). Detection plot

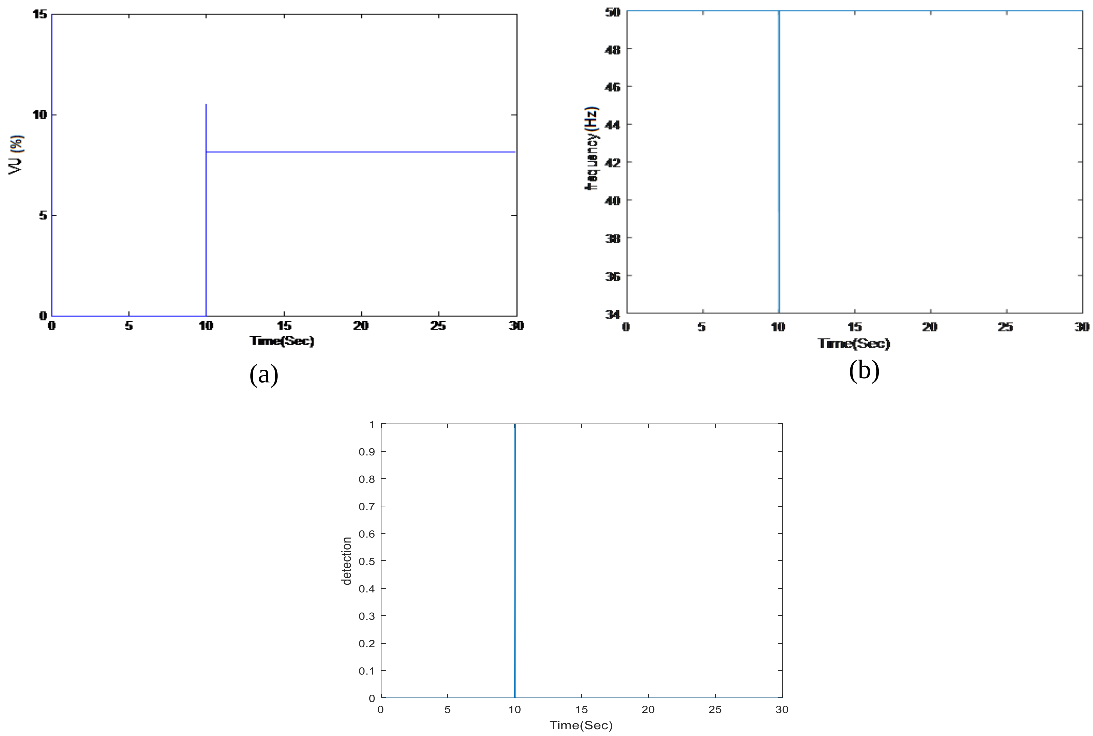
The switching action for the 5-bus test system at t= 10 secs and the corresponding frequency plot in Figure 4(a) shows that the frequency drops to 30 Hz which crosses the threshold value. We can see that the islanding is detected from the detection plot as in Figure 4(b). Since the conditions are met for detection, the islanding condition is confirmed.



(a) (b)

Figure 4. (a) Frequency of the DG, (b) Detection plot

Figures 5(a), 5(b) and 5(c) show the VU, frequency and detection plots for the IEEE 14 bus system. In Figure 5(a), the voltage unbalance shoots up to 11% which is lower than the 5-bus system and then drops to 8%. The frequency drops to 34 Hz as seen in Figure 5(b) and islanding condition is detected as in Figure 5(c).



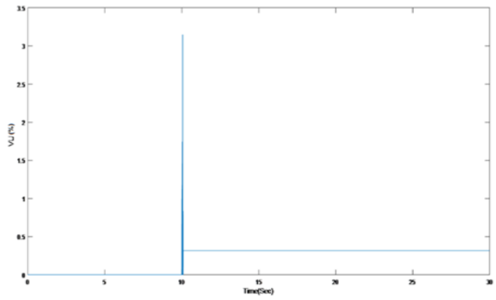
(a) (b)

(c)

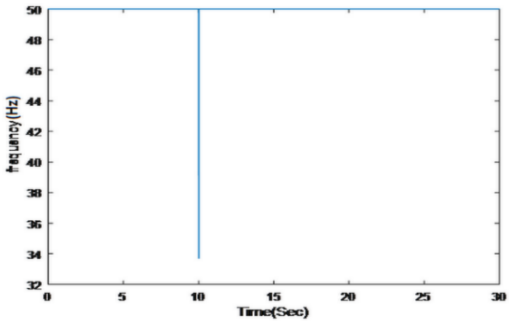
Figure 5. (a) Voltage unbalance at DG terminal, (b) Frequency of the DG
(c). Detection plot

3.2. System with 3 machines

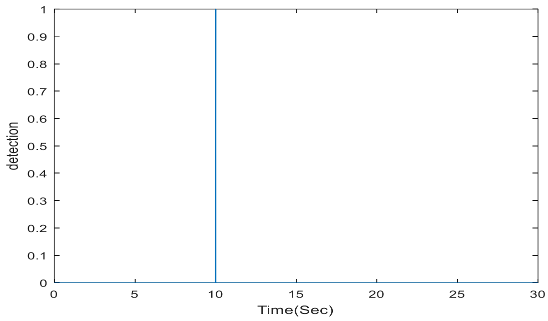
These systems initially have a 3×3 admittance matrix and after islanding, it reduces to 2×2 matrix. In this case, IEEE 6-bus system is considered. Figure 6(a) shows the VU plot and 6(b) shows the frequency variation of the system. As seen from Figure 6(c), the condition of islanding is detected.



(a)



(b)

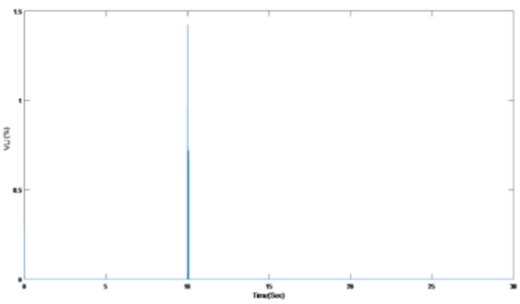


(c)

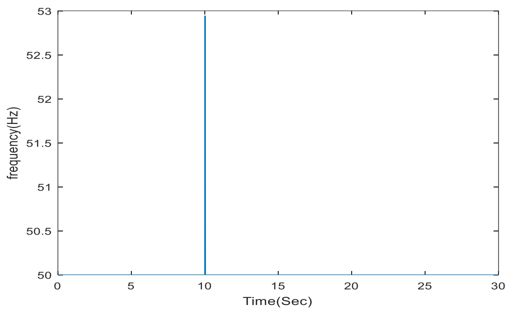
Figure 6. (a) Voltage unbalance at DG terminal, (b) Frequency of the DG, (c) Detection plot

3.3. System with 6 machines

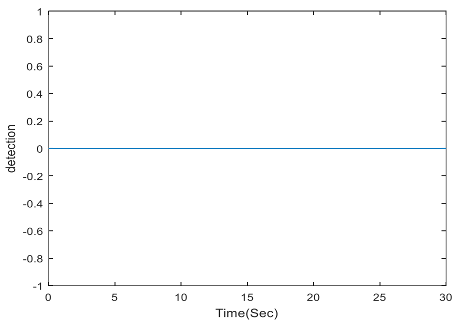
For this system, IEEE 30 bus system is considered for the analysis. Figure 7(a) shows the plot for VU of the DG terminal. In Figure 7(b), the frequency increases to 53 Hz which does not meet the criteria of frequency and the islanding is not detected as depicted in Figure 7(c).



(a)



(b)



(c)

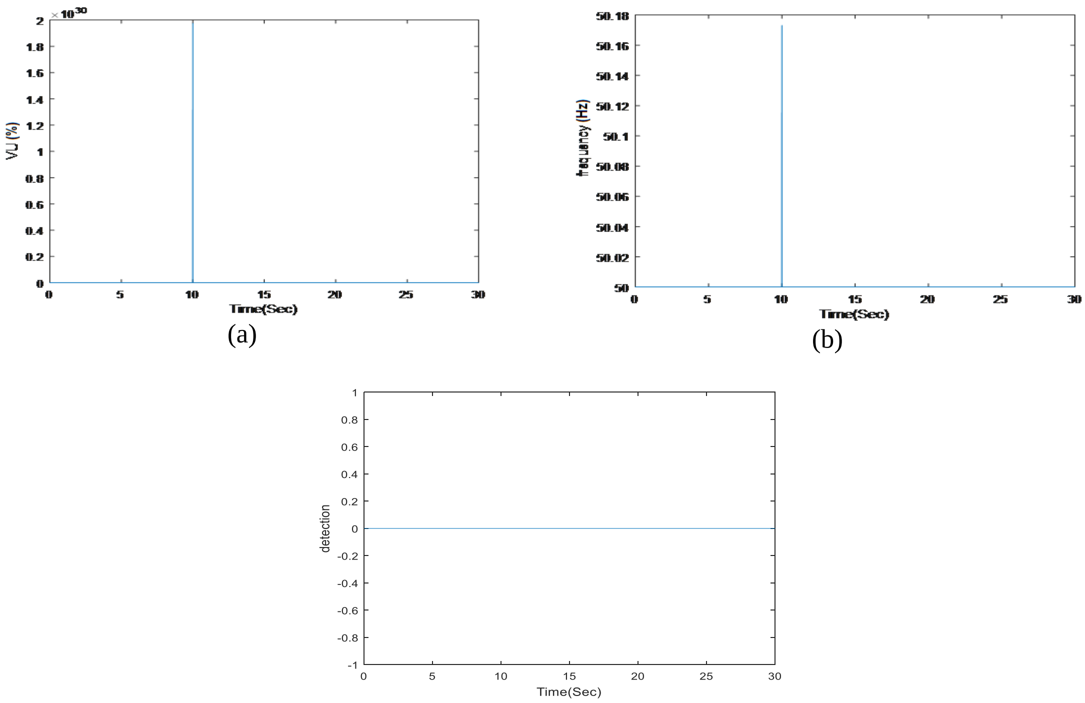
Figure 7 (a). Voltage unbalance at DG terminal Figure 7 (b). Frequency of the DG Figure 7(c). Detection plot

3.4. System with 19 machines

In this case, the technique is evaluated for IEEE 118 bus test system. Figure 8(a) shows the plot for VU of the DG terminal. In Figure 8(b), the frequency increases to 50.17 Hz and the islanding detection plot as depicted in Figure 7(c). We can observe from these plot that there is a spike in voltage unbalance at the instant of islanding, shoots up to a high value, making it an invalid case. The result of the frequency perturbation is a rise in the frequency of the DG at the instant of islanding. As per the algorithm, detection fails as the frequency does not dip lower than the threshold frequency.

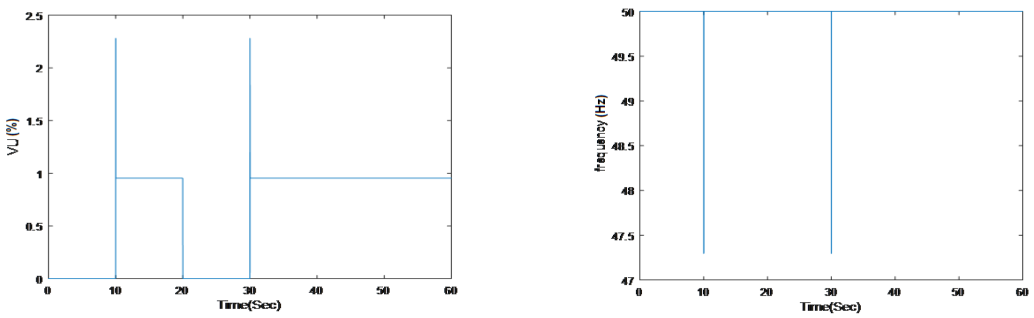
3.5. System with multiple islanding conditions

In this paper, multiple islanding conditions are also simulated to validate the effectiveness of the technique. Initially, the grid is disconnected from the system at t = 10 seconds and it is reconnected to the system at t = 20 seconds. The islanding is again applied at t = 30 seconds for IEEE 3 bus system with 2 machines. The plot in the Figure 9(a) depicts 2 spikes, one at t=10 seconds and at t=20 seconds. The result of the frequency perturbation is a dip in the frequency of the DG at both the instants of islanding as shown in Figure 9(b). The values of voltage unbalance and frequency dip are similar to that of the 3-bus system during single islanding condition. Both the islanding conditions are detected successfully as indicated in Figure 9(c).

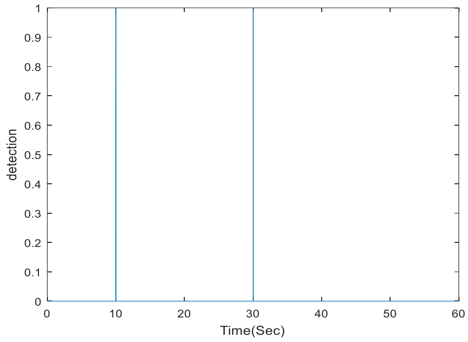


(a) (b) (c)

Figure 8. (a) Voltage unbalance at DG terminal, (b) Frequency of the DG, (c) Detection plot



(a) (b)



(c)

Figure 9. (a) Voltage unbalance at DG terminal (b) Frequency of the DG (c) Detection plot

4. DISCUSSIONS

From simulation results we can observe that this hybrid islanding detection technique for DGs is efficiently applicable for multi-machine system. The effectiveness of the technique is validated for different standard IEEE test systems. This method can be used to identify multiple islanding conditions successfully.

Once the islanding occurs, the frequency changes depend on factors like inertia of the machine, mechanical and electrical power. This can be observed in the swing equation and the change in frequency may be negative or positive. So, the technique fails, as it only utilizes the lower threshold value for frequency. If the frequency change is positive, it does not have a threshold value for comparison. This can be observed in IEEE 30-bus and 118-bus system, where the islanding detection fails.

5. CONCLUSION

This paper details an analysis of the hybrid islanding detection technique of DG system for different multi-machine systems. Different standard IEEE test systems are used to validate the effectiveness of the technique in MATLAB environment. This hybrid technique is superior to the voltage unbalance or frequency perturbation technique when applied individually. The frequency perturbation technique is applied only when the voltage unbalance threshold is met, thus preventing continuous perturbations. Also, we observe that the technique utilizes the lower threshold value for frequency and if the frequency change is positive this technique fails to detect the islanding condition. The multiple islanding conditions can be detected effectively using this hybrid technique.

REFERENCES

[1] IEEE 1547 Standard for Interconnecting Distributed Resources with Electric Power Systems, Std. 1547, 2003.Electric Power Systems, Std. 1547, 2003.

[2] P. P. Barker and R. W. de Mello, "Determining the impact of distributed generation on power systems: part-1 radial distribution systems," *Proc., IEEE Power Eng. Soc. Transmission Distribution conf.*, Vol. 3, 2000.

[3] T. Ackermann, G. Andersson, and L. Solder, "Electricity market regulations and their impact ondistributed generation," in *Proc. Int. Conf. DRPT*, 2000.

[4] H. Laaksonen, "Advanced Islanding Detection Functionality for Future Electricity Distribution Networks," *IEEE Trans. Power Del.*, Vol. 28, No. 4, 2013.

[5] Basanta kumar Panigrahi, Ria Nandi, Bibhusmita Mahanta and Kumaresh Pal, "Islanding Detection in Distributed Generation," *International Conference on Circuit, Power and Computing Technologies [ICCPCT]*, pp, 1-5, 2016.

[6] Soumya R. Mohanty, Nand Kishor, Prakash K. Ray and João P. S. Catalão, "Comparative Study of Advanced Signal Processing Techniques for Islanding Detection in a Hybrid Distributed Generation System," *IEEE Trans. on Sustainable Energy,* Vol. 6, No. 1, 2015.

[7] Ku Nurul Edhura Ku Ahmadn, Jeyraj Selvaraj and N. Abd Rahim, "A review of the islanding detection methods in grid-connected PV inverters," *Renewable and Sustainable Energy Reviews*, Vol. 21, pp. 756–766, 2013.

[8] Aziah Khamis, Hussain Shareef, Erdal Bizkevelci and Tamer Khatib, "A review of islanding detection techniques for renewable distributed generation systems," *Renewable and Sustainable Energy Reviews* 28, 483–493, 2013.

[9] Canbing Li, Chi Cao, Yijia Cao, Yonghong Kuang, Long Zeng and Baling Fang, "A review of islanding detection methods for microgrid," *Renewable and Sustainable Energy Reviews,* Vol. 35, pp. 211–220, 2014.

[10] Pukar Mahat, Zhe Chen and Birgitte Bak-Jensen, "A Hybrid Islanding Detection Technique Using Average Rate of Voltage Change and Real Power Shift," *IEEE Trans. Power Del*., vol. 24, no. 2, 2009.

[11] Vivek Menon and M Hashem Nehrir. "A hybrid islanding detection technique using voltage unbalance and frequency set point," *IEEE Tran.s on Power Systems*, Vol. 22, No. 1, pp. 442-448, 2007.

[12] Arguence, O.; Raison, B.; Cadoux, F., "Comments on "impact of load frequency dependence on the NDZ and performance of the SFS islanding detection method"," *IEEE Transactions on Industrial Electronics*. Vol. 64, No. 9, pp. 7277–7279, 2017.

[13] Murugesan, S.; Murali, V.; Daniel, S.A. "Hybrid analyzing technique for active islanding detection based on d-axis current injection," *IEEE Systems Journal*, vol. 12, no. 4, pp. 3608-3617, 2017.

[14] Khodaparastan, M.; Vahedi, H.; Khazaeli, F.; Oraee, H. "A novel hybrid islanding detection method for inverter-based DGs using SFS and ROCOF," *IEEE Trans. Power Deliv*. Vol. 32, pp. 2162–2170, 2017.

[15] Dhar, S.; Dash, P.K. "Harmonic profile injection-based hybrid active islanding detection technique for PV-VSC-based microgrid system," *IEEE Trans. Sustain. Energy*, vol. 7, pp. 1473–1481, 2016.

[16] N. Kothari and B. G. Fernandes, "A hybrid active islanding detection technique for single-phase inverter-based distributed generation system," *2015 IEEE International Conference on Industrial Technology (ICIT)*, pp. 2828-2834, 2015.

[17] Angelo Baggini. Handbook of power quality. John Wiley & Sons, 2008.

[18] K Uma Rao. Computer Techniques and Models in Power Systems. IK International Pvt Ltd, 2010.

[19] AY Hatata, El-H and Abd-Raboh and Bishoy E Sedhom. "A review of anti-islanding protection methods for renewable distributed generation systems," *Journal of Electrical Engineering*, Vol. 16, No. 1, pp 1-12, 2016.

[20] Olle Elgerd and Patrick van der Puije, "Electric power engineering," Springer Science & Business Media, 2012.

[21] S.-I. Jang and K.-H. Kim, "An islanding detection method for distributed generations using voltage unbalance and total harmonic distortion of current," *IEEE Trans. Power Delivery*., vol. 19, no. 2, pp. 745–752, 2004.

[22] F. Katiraei, M. R. Iravani, and P. W. Lehn, "Microgrid autonomous operation during and subsequent to islanding process," *IEEE Trans.Power Delivey*., vol. 20, no. 1, pp. 248–257, 2005.

[23] Aref Pouryekta and Vigna K. Ramachandaramurthy. "A Hybrid Islanding Detection Method for Distribution Systems," *Distributed Generation & Alternative Energy Journal*, Vol. 33, Issue 4, pp 44-67, 2018.

[24] Mishra, M., Rout, P.K., "Fast discrete s-transform and extreme learning machine-based approach to islanding detection in grid-connected distributed generation," *Energy Syst*, vol. 10, pp. 757–789, 2019.

[25] Mishra, M., Sahani, M., Rout, P.K., "An islanding detection algorithm for distributed generation based on Hilbert-Huang transform and extreme learning machine," *Sustain. Energy, Grids Netw.* Vol. 9, pp. 13–26, 2017.

[26] Fatemeh Ghalavand, Behzad Asle Mohammadi Alizade, Hossam Gaber and Hadis Karimipour, "Microgrid Islanding Detection Based on Mathematical Morphology," *Energies*, Vol. 11, pp. 2–18, 2018.