A Hybrid Islanding Detection Technique for Synchronous Generator Based Microgrids

Santosh Kumar Singh, Mayank Rawal, Mahiraj Singh Rawat, and Tripurari Nath Gupta

Abstract Recently, microgrid has been emerged with an optimum solution for control and operation of distributed generations (DGs) in large power system. The islanding detection is one of the critical issues in grid connected microgrid. The hybrid islanding detection technique (IDT) uses the advantages of both passive and active techniques. Among passive techniques, the voltage unbalance (VU) IDT is the most effective technique and can be implemented comfortably for systems with load fluctuations. In this paper, a novel hybrid IDT has been developed using VU and rate of change of frequency (ROCOF) for synchronous generators based microgrid system. The proposed hybrid technique is compared with existing hybrid technique based on VU and frequency set point (FSP). In contrast to the current hybrid technique (0.21 s), the proposed technique detects the islanding in 22 ms, according to simulation results. Moreover, the proposed hybrid IDT can be applied for Inverter based DGs such as Solar Photovoltaic, wind energy, etc. in microgrid. The simulation results are obtained using MATLAB/Simulink 2019b.

Keywords Voltage unbalance · ROCOF · Islanding detection technique · Frequency set point · Hybrid technique

1 Introduction

As per IEEE 1547 standard [1], "An island is defined as a condition in which a portion of an area electric power system (EPS) is energized solely by one or more local EPSs through the associated PCCs while that portion of the area EPS is electrically separated from the rest of the area EPS". The islanding phenomenon can be categorized into unintentional and intentional islanding. Unintentional islanding can be hazardous to construction personnel operating on the main grid and can also result in utility equipment destruction. In literature, various IDTs have been proposed and implemented to detect unintentional islanding. The IDTs are generally classified into

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remote and local techniques. The implementation of local techniques is performed on distributed generation (DG) side. Further, the local IDTs are categorized into active, passive, and hybrid. The hybrid IDTs merge the advantages of active and passive IDTs or two passive/active IDTs and hence more efficient. A detail review of IDTs has been presented in [2–4]. In [5–7], the phase locked loop (PLL) is used to calculate ROCOF at point of common coupling (PCC). The ROCOF based IDT is sensitive to load fluctuations and hence the setting of threshold becomes difficult. For islanding detection, the VU based passive IDT utilizes the measurement of negative (NSV) and positive (PSV) sequence of voltage. This passive technique suffers from the disadvantages such as difficult to set threshold, unresponsive to network disturbances, and undesired harmonics in negative sequence component [8]. Recently, the hybridization of two IDTs has been utilized to improve islanding detection time, NDZ, etc. [9]. The hybrid technique using ROCOF over reactive power and d-axis current injection has been utilized to improve islanding detection time. This hybrid technique is best suited for mixed DG environment [10]. The hybrid techniques i.e., Q-f droop and reactive power variations (RPV) [11]; power control loop and signal processing [12]; VU and voltage phase angle (VPA) [13]; wavelet transform and artificial neural network (ANN) [14]; voltage and real power shift [15]; Sandia frequency shift and ROCOF [16]; "wavelet packet transform and probabilistic neural network" [17]; "adaptive neuro-fuzzy inference system" [18]; Voltage unbalance factor [20]; "rate of change of reactive power and Rate of change of active power" [21]; Pattern-recognition method [22]; VU/THD and bilateral reactive power variation [23]; Discrete fractional Fourier transform [24] have been proposed and implemented by various researchers.

The passive technique has several disadvantages such as large NDZ, failed to detect balance islanding and difficult to implement in multiple DG systems. Moreover, the active techniques have also several disadvantages such as degradation in power quality, long detection time, and synchronization issues. In this Paper, an improved hybrid IDT is proposed using VU and ROCOF. The two passive methods are combined together due to easy implementation and have negligible influence on power quality and having fast detection time. The following is how the remainder of the paper is organized: The second section delves further into the passive and active strategies employed. The proposed hybrid technique using VU and ROCOF is explained in Sect. 3. Section 4 is on focused simulation results and analysis. At last, the paper is concluded in Sect. 5.

2 Passive Methods

In this section, the passive methods i.e., VU and ROCOF for islanding detection have been reviewed.

2.1 Voltage Unbalance

The DGs mounted in the microgrid can match the load demands if the power grid is isolated. The voltage unbalance can be observed at terminals of DGs. This passive technique identifies the islanding dependent on the VU of three-phase voltages at PCC. In this method, the ratio of NSV to PSV is utilized to identify islanding event. The voltage unbalance at any time *t* can be determined from the expression given below:

$$VU_t = \frac{V_{NS_t}}{V_{PS_t}}, \tag{1}$$

where V_{NS} and V_{PS} represent the NSV and PSV component of voltages at the DG's output terminal. The detection time is 53 ms. The disadvantage of this technique is that it is influenced by undesirable harmonics when removing the negative sequence portion of voltage, difficult to set the threshold value.

2.2 Rate of Change of Frequency (ROCOF)

In this passive ID, ROCOF i.e., *df/dt* over a limited cycle at PCC is observed. If the value of df/dt is larger than threshold value, the inverter should cutoff the power output. The islanding detection time is around 24 ms. From the literature, the optimum threshold value for ROCOF technique is found to be 0.3 Hz/sec with 0.7 s islanding detection time. This technique may lead to erroneous results due to load fluctuations and switching. The *df/dt* can be determined by Eq. (2).

$$\frac{df}{dt} = \frac{f(t_k) - f(t_k - \Delta t)}{\Delta t}, \tag{2}$$

where $f(t_k)$ represents the frequency at time of the kth sample, $f(t_k - \Delta t)$ represents the value of determined frequency before the time of the kth segment, i.e., $t_k - \Delta t$. This method fails to recognize balanced islands. The setting of threshold values is very critical in this technique to distinguish islanding and switching events.

3 Proposed Hybrid IDT

The proposed hybrid IDT consists of the advantages of VU and ROCOF. Figure 1 displays the flow chart for the proposed algorithm. The voltage and frequency at PCC are monitored using this technique. ROCOF (*df/dt*) and voltage unbalance is determined for each DG. For any disturbance such as switching of loads or

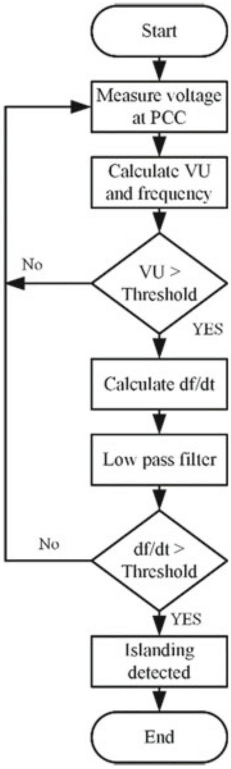

Fig. 1 Flow chart of proposed hybrid islanding method

islanding, a spike can be observed in VU. Whenever VU spike crosses the threshold value, the *df/dt* value at PCC is observed for 2 to 50 cycles and sent to the low pass filter (LPF). The aim to use LPF is to remove high frequency transients generated by components of the power system. The islanding case is observed if the ROCOF value still exceeds the threshold value. The maximum permissible VU spike value can be determine from [19].

4 Results and Analysis

The proposed hybrid method has been verified on test system as shown in Fig. 2. A diesel generator of 3 MVA is connected through the main grid via 25 kV/2.4 kV, Y-Δ transformer. Moreover, a 5 MW load is connected at main grid. The short circuit capacity (SCC) of main grid is 1000 MVA. The 1 MW load is connected near diesel generator. The Simulink model of test system is shown in Fig. 3.

The voltage and current profile at PCC before islanding and load changing is shown in Fig. 4. The following disturbances were simulated to study the islanding event. First, at 0.25 s, 0.8 MW load is inserted at PCC (near DG) and 0.9 MW load

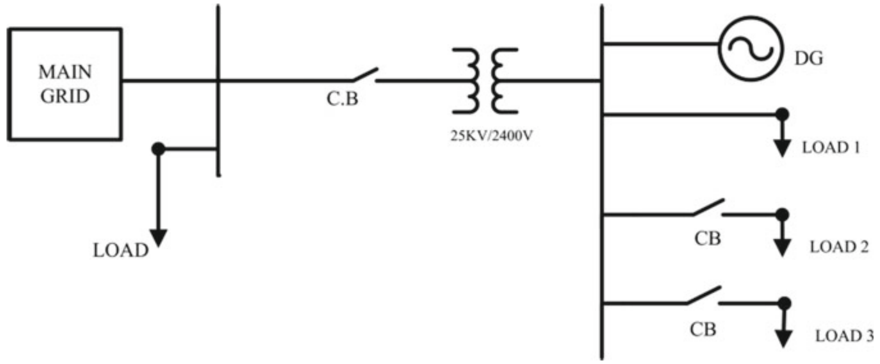

Fig. 2 Single line diagram of test system

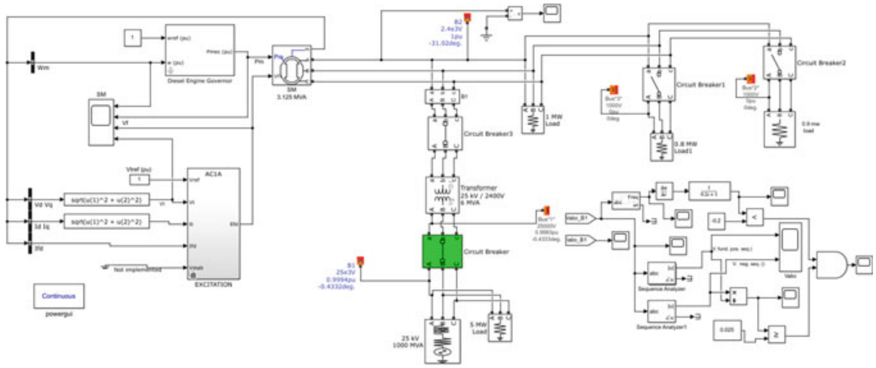

Fig. 3 Simulink model of test system

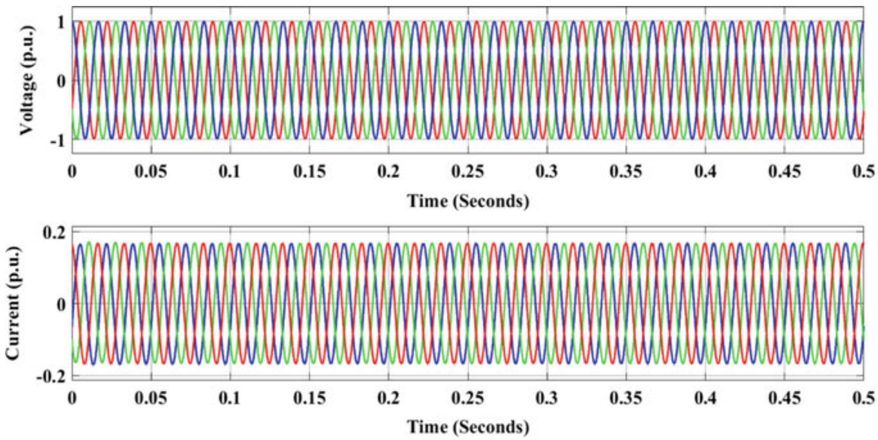

Fig. 4 Voltage and current profile at PCC before islanding

is inserted at 0.5 s. Further, at t = 1.0 s, main grid is disconnected through circuit breaker. The NSV and PSV at PCC is shown in Fig. 5. The VU spikes are observed at the terminal of DG at load switching and main grid isolation. From Fig. 6, it is observed that VU spikes are low in magnitude during load switching; however at main grid failure, the VU value is 0.04 pu. The frequency and ROCOF variation with respect to time can be observed from Figs. 7 and 8 respectively. It is observed that ROCOF is higher at the event of islanding compared to load switching event. From Fig. 9, it is observed that when VU spikes and *df/dt* both crosses the set threshold, to disconnect the main grid, a trip signal is sent to the circuit breaker. The islanding detection time is 22 ms, according to the simulation data. However, for the same test system, the islanding detection time for hybrid method using VU and frequency set point was found to be 0.21 s.

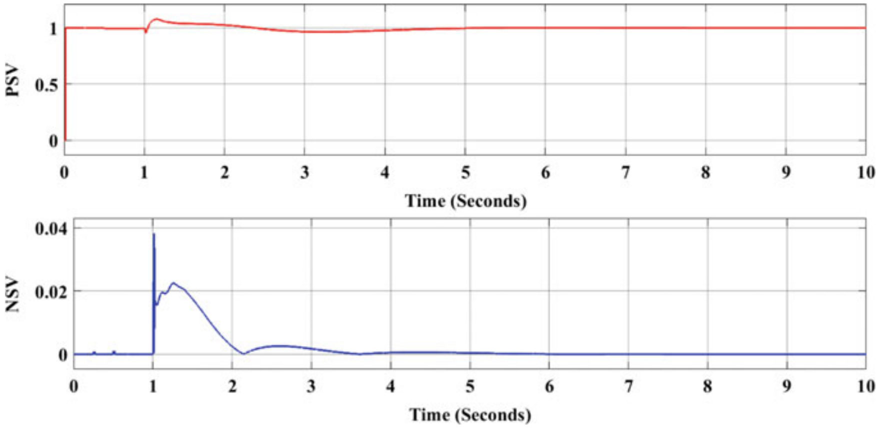

Fig. 5 Positive and Negative sequence voltages

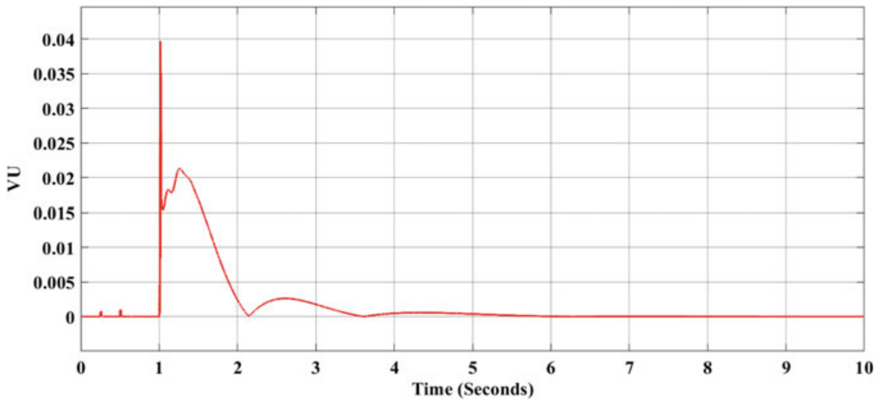

Fig. 6 Voltage unbalance at DG terminal

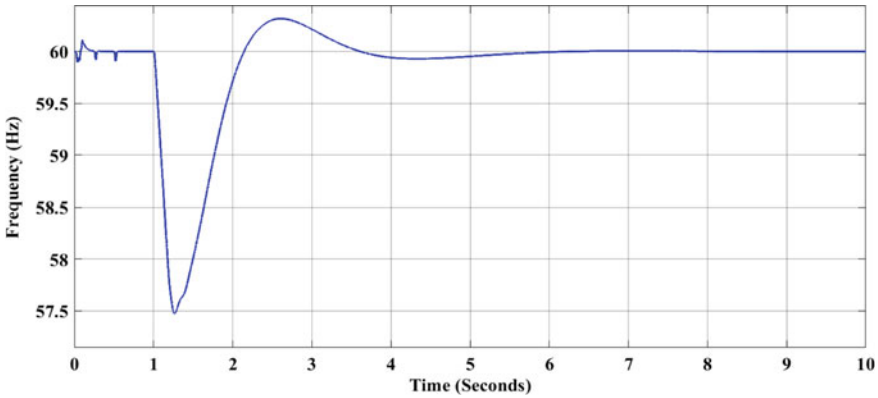

Fig. 7 Frequency variation at PCC

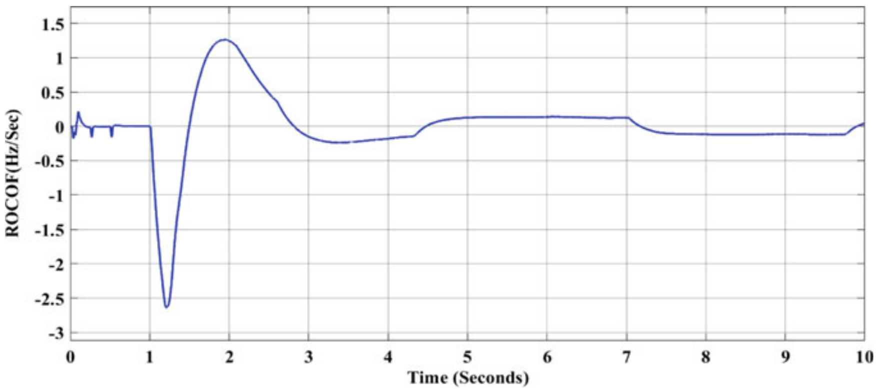

Fig. 8 ROCOF at PCC

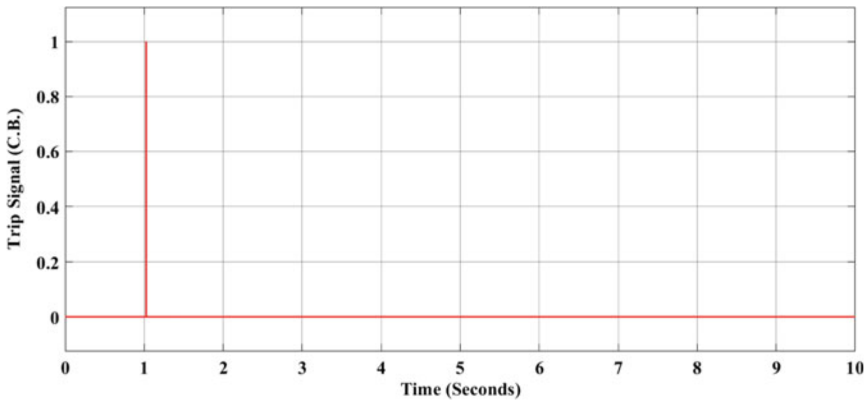

Fig. 9 Trip Signal input to circuit breaker at PCC

The voltage variation at DG terminal and current at PCC are shown in Figs. 10 and 11 respectively. A comparison between discussed IDTs is shown in Table 1. It is observed from Table 1 that the proposed method has lowest islanding detection time compared to other techniques.

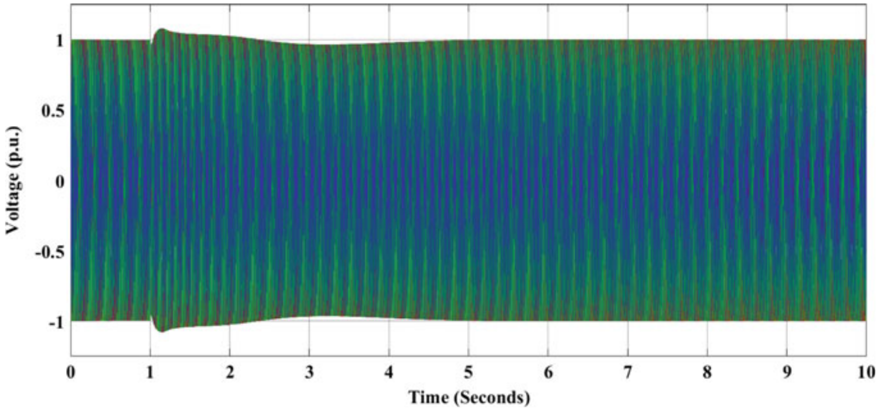

Fig. 10 Voltage during load switching and main grid isolation at DG terminal

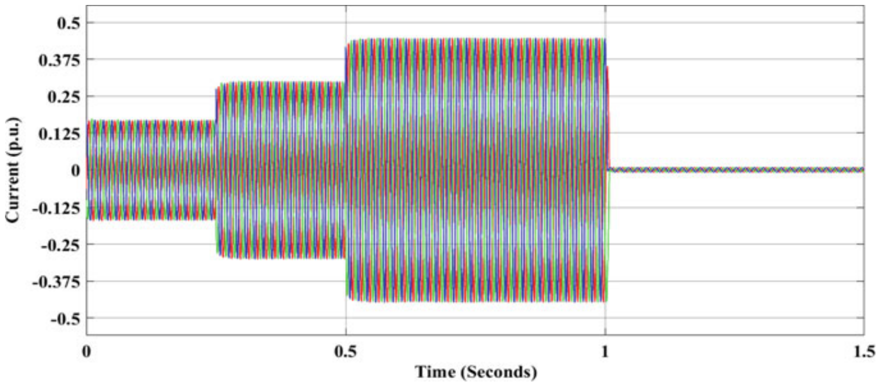

Fig. 11 Current during load switching and main grid isolation at PCC

Table 1 Evaluation of various IDTs

Methods	Detection time	NDZ	Power quality
VU	53 ms	Large	No impact
ROCOF	24 ms	Small	No impact
VU and FSP	0.21 s	Small	Degrade
VU and ROCOF	22 ms	No information	No impact

5 Conclusion

In this paper, a novel hybrid IDT using VU and ROCOF is presented for diesel generators based microgrid system. The proposed hybrid technique is compared with hybrid IDT based on VU and frequency set point (FSP) given in literature. The suggested hybrid system detects islanding in 22 ms, according to simulation results. Moreover, the islanding detection time for hybrid method using VU and frequency set point was found 0.21 s. This proposed method can also be applied on the inverter based DG systems. The simulation results are obtained using MATLAB/Simulink. In future, the proposed method can be investigated for hybrid microgrid system.

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