

A Novel Passive Method for Islanding Detection in Microgrids

F. Namdari^{*(C.A.)}, M. Parvizi* and E. Rokrok*

Abstract: Integration of Distributed Generations (DGs) in power grids is expected to play an essential role in the infrastructure and market of electrical power systems. Microgrids are small energy systems, capable of balancing captive supply and requesting resources to retain stable service within a specific boundary. Microgrids can operate in grid-connected or islanding modes. Effective islanding detection methods are essential for realizing the optimal operation of microgrids. In this paper, a new passive islanding detection method is presented according to the change rate of DG's voltage over active power index. This technique has been applied on inverter-based and synchronous-based microgrids. The efficiency of the proposed method is verified through a comprehensive set of simulation studies carried out in Matlab/Simulink.

Keywords: Islanding Detection, Microgrids, Non-Detection Zone, Passive Method.

1 Introduction

The integration of Distributed Energy Resources (DERs) into distribution networks has been increasing due to the advantages such as high efficiency, modified power quality, and less greenhouse gas emission [1]. Therefore, it has been proposed to demarcate areas of a distribution network (with sufficient generation) as a microgrid in order to help the network operation as a provisional island when the need arises.

According to IEEE1547 standard, islanding mode of operation happens when one or many resources continue to feed power to a part of the grid that is disconnected from the main utility [2]. Unplanned Islanding situations can damage the grid itself or equipment connected to the grid and can even compromise the security of the maintenance personnel. There are three main methods of islanding detection for microgrids; active, passive, and Communication-based methods [3]. Active detection methods intentionally introduce perturbations into the system and detect islanding according to the response of the system. The downside of active methods is that they are not as fast as passive methods and they degrade the power quality with the injected perturbations [4-6]. There are communication-based approaches which are based on direct communication between the utility and DGs in a microgrid. The only set-back is the additional cost of communication systems and their reliability [7].

Passive detection methods measure some local parameters such as voltage, frequency, total harmonic distortion, etc. By comparing these values with the predetermined thresholds, islanding is detected [8-12].

Passive detection methods detect islanding very fast and without disturbing the system. The challenge of setting suitable thresholds and the large non-detection zone are the major drawbacks of passive methods.

One of the most common passive approaches is ROCOV index. This method that measures voltage change rate over time has been investigated and implemented in [13-15].

This paper presents a new passive islanding detection approach on the foundation of DG's voltage change rate over active power. The proposed approach is based on ROCOV method that is not affected by power mismatch.

The paper is organized in four sections. The proposed approach is presented in Section 2. Performance of the proposed method is evaluated in Section 3 on the two case study systems, and conclusions are drawn in Section 4.

2 The Proposed Method

As was mentioned, non-desired islanding situations for microgrids and distributed generations can damage the grid or equipment connected to the grid. The common methods used for islanding detection recently are the adapted and modified forms of the under/over voltage and under/over frequency relays. Among these methods, those which are based on voltage variations are the most reliable devices by the industry so far. Change rate of voltage relay (ROCOVR) and vector surge relay (VSR) are common examples of such relays [15].

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ROCOV index is one of the most common islanding detection methods for DGs in the distribution networks. Although the execution of this method is very simple, in small power mismatches operates poorly.

In this paper, active power imbalances are used to distinguish islanding conditions. In fact, change rate of DG's voltage over its active power (ROCOVOP) is used as a new detection index. From Fig. 1, as the overall scheme of grid connected microgrid, the DG's active power generation is:

$$P_D = V_D I_D \cos \varphi \quad (1)$$

In Fig. 1, N, D, and L represent main network, distributed generator, and local load, respectively.

In the islanding mode from Eq. (1), the following relations can be obtained:

$$P_D = V_D V_L Y_L \cos \varphi \quad (2)$$

Derivative of P_L can be attained, according to (3):

$$\frac{\partial P_D}{\partial V_L} = V_D Y_L \cos \varphi \quad (3)$$

For any deflection in V_L , Eq. (4) can be obtained:

$$\frac{\Delta P_D}{|V_D|} = \Delta |V_L| \times G_L \quad (4)$$

Change rate of voltage (ROCOV) is determined, as in Eq. (5):

$$\frac{\Delta V_L}{\Delta t} = \frac{1}{|V_D| \times G_L} \times \frac{\Delta P_D}{\Delta t} \quad (5)$$

where V_D and I_D are voltage and current of DG, Y_L and V_L are the amplitude of the local load admittance and voltage, and G_L is the real part of Y_L .

Eq. (5) shows that ROCOV index directly relies on the power imbalance. So, in small power mismatches, this method does not reach the preset threshold and cannot detect the islanding condition in microgrids.

To obtain a more effective method based on the aforementioned index, using Eq. (2), the change rate of DG's active power over its voltage is obtained, as follows.

$$\frac{\Delta P_D}{\Delta V_D} = \frac{V_L \times \cos \varphi}{Z_L} \quad (6)$$

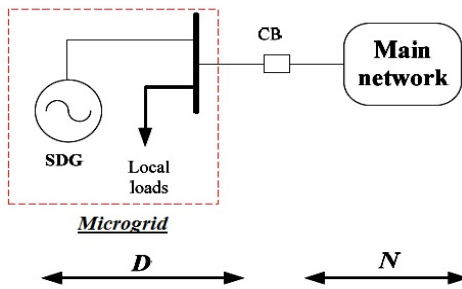


Fig. 1 Scheme of main network and distributed generating unit.

For any deviation in P_D , Eq. (6) is expressed as the following relation:

$$\frac{\Delta V_D}{\Delta P_D} = \frac{Z_L}{|V_L| \cos \varphi} \quad (7)$$

Eq. (7) shows that the proposed index is independent from the active power imbalance.

In the last step, performance of the proposed index should be evaluated for islanding and grid connected conditions. To obtain the proposed index in the grid connected mode, Eq. (8) can be expressed:

$$P_N + P_D = P_L \quad (8)$$

Change rate of Eq. (8) over voltage of distributed generator can be expressed as follows:

$$\frac{\partial P_N}{\partial V_D} + \frac{\partial P_D}{\partial V_D} = \frac{\partial P_L}{\partial V_D} \quad (9)$$

In the grid connected mode, if load change of P_L is found in D side, the following relation is obtained:

$$\partial V_N = k \partial V_D \quad (10)$$

From Eq. (10), Eq. (9) can be expressed as Eq. (11), which applies the relation of the proposed index for grid connected situation:

$$\frac{\partial P_D}{\partial V_D} = \frac{\partial P_L}{\partial V_D} - k \frac{\partial P_N}{\partial V_N} \quad (11)$$

In the islanding mode of operation, Eq. (11) can be expressed as follows:

$$\frac{\partial P_D}{\partial V_D} = \frac{\partial P_L}{\partial V_D} \quad (12)$$

Now, by considering $\frac{\partial P_L}{\partial V_D} = \frac{1}{k_1}$ and $\frac{\partial P_N}{\partial V_N} = \frac{1}{k_2}$, the proposed index for grid connected and islanding mode can be expressed as Eqs. (13) and (14), respectively.

$$\frac{\partial P_D}{\partial V_D} = \frac{k_2 - k k_1}{k_1 k_2} \quad (13)$$

$$\frac{\partial P_D}{\partial V_D} = \frac{1}{k_1} \quad (14)$$

By comparing Eqs. (13) and (14), it can be concluded that the proposed index (change rate of voltage to active power) has different values for islanding and non-islanding situations.

To achieve the proposed detection index, the whole studied signals should be converted into discrete signals. To attain the mentioned purpose, in this paper, Zero-Order-Hold (ZOH) filter is used [16]. Obtaining the threshold value of the proposed index (D_{th}) is similar to the procedure proposed in [16]. Another form of (7) is expressed, as follows:

$$\frac{\partial V_D}{\partial P_D} = \frac{S_b \times \cos \theta}{P_L \times V_L \times \cos \varphi} = D \quad (15)$$

where S_b and θ are apparent power rate of DG and phase angle of loads, respectively.

In Fig. 2, the variations of detection index versus active power of loads are demonstrated. As shown in Fig. 2, for DGs with active power from 0 to 30 MVar, the value of the proposed index is larger than 1. So, in this paper, the threshold of detection index (D_{th}) is set to 1.

Fig. 3 demonstrates the flowchart of the proposed method. In the first step, voltage and current are measured and discretized. After discretization, index (D) is calculated. When the amplitude of detection index (D) is larger than the obtained threshold value, the number of counter (K) is increased by one. Otherwise, counter will be reset and K will be equal to zero. The islanding condition is declared when the value of K exceeds K_{th} .

To determine threshold of K, the worst non-islanding which may occurs is considered. So, in this study $K_{th} = 6$ is obtained.

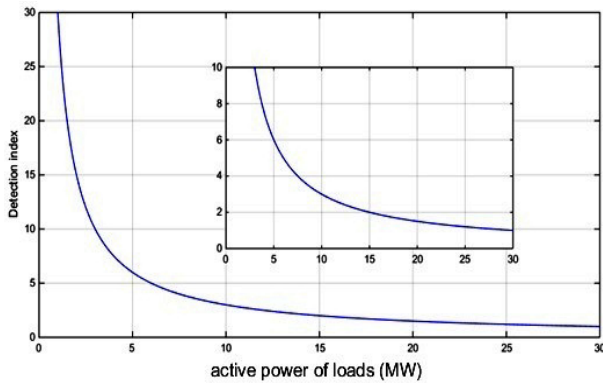


Fig. 2 Variations of detection index versus active power of local loads.

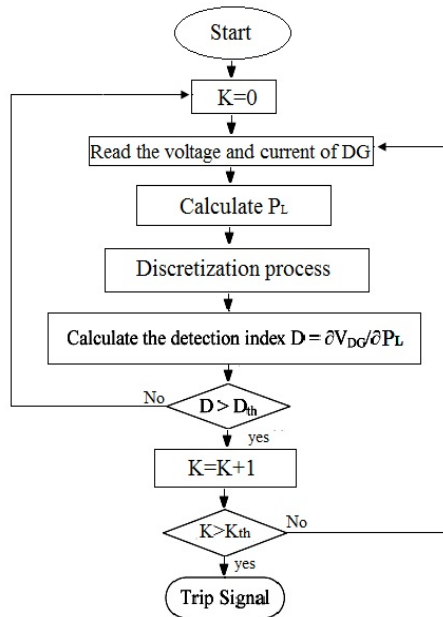


Fig. 3 Flowchart of the proposed method.

3 Simulation Results

To show the effectiveness of the proposed method, various events (islanding and non-islanding occurrences) are simulated in the case study systems. The case study systems are shown in Figs. 4, 5. In [16] and [17], all the information about the first and second case study systems was presented.

3.1 Different Active and Reactive Power Mismatches

In this section performance of the proposed method is evaluated for different active and reactive power mismatches in order to determine the NDZ of the proposed method and ROCOV method in case study systems in different loading conditions. It should be noted that threshold value of ROCOV relay has been adjusted to 2 pu/s and islanding occurs in 2 sec.

Detection trip demonstrates the operation mode of microgrid which has been distinguished by ROCOVOP method. When microgrid operates in the grid connected mode, the value of detection trip is 0; otherwise it sets 1. The simulation results demonstrated in Figs. 6-11. As illustrated in Figs. 6 and 9, both ROCOV and ROCOVOP methods can detect islanding for 22% and 17% active power mismatches in first and second case study systems respectively.

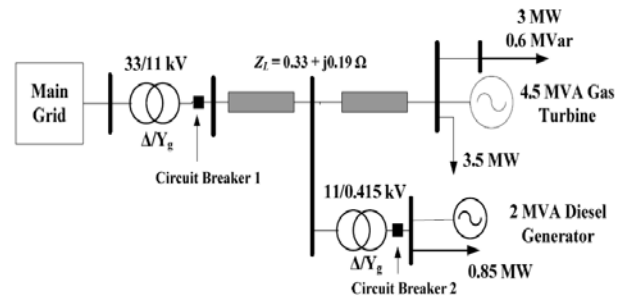


Fig. 4 Single line diagram of the first case study system.

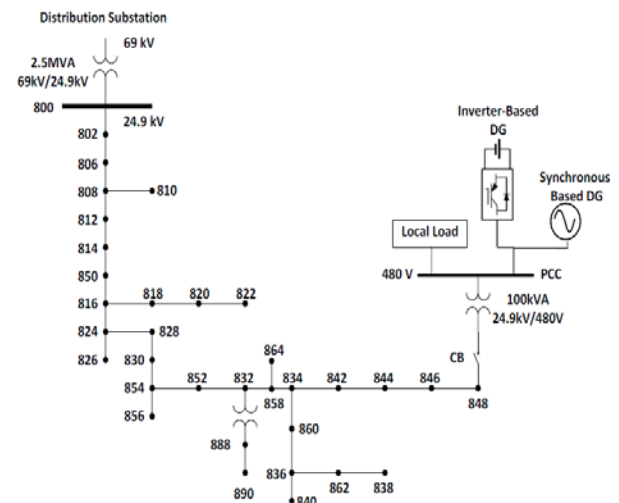


Fig. 5 Single line diagram of the second case study system.

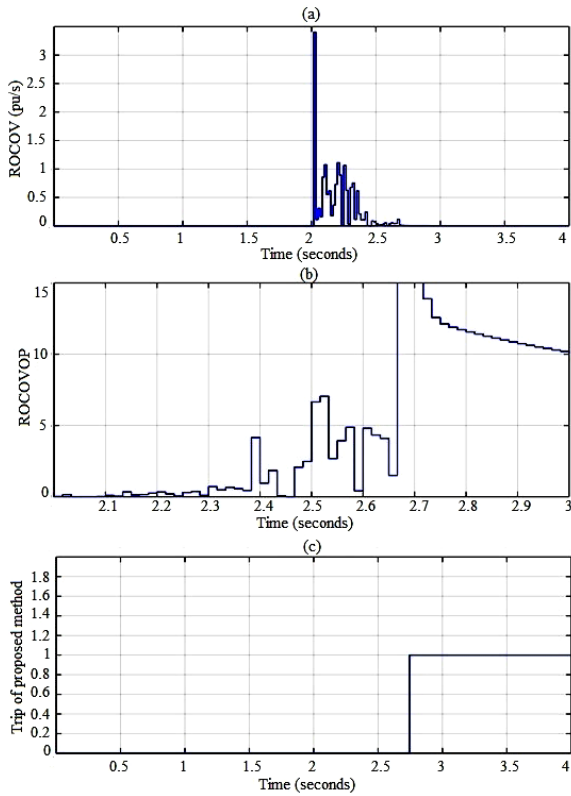


Fig. 6 Response of system for $\Delta P = -22\%$ and $\Delta Q = 16\%$. (a) proposed index (b) detection signal in the first system.

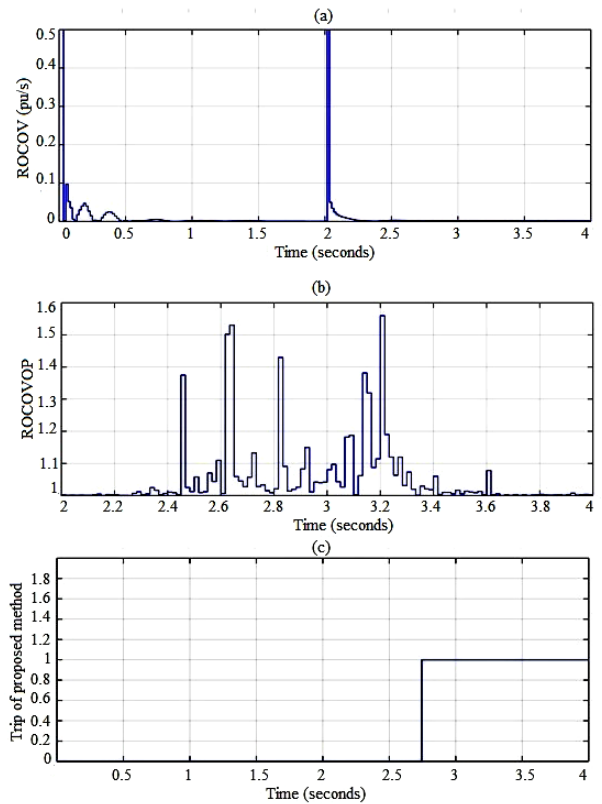


Fig. 8 Response of system for $\Delta P = 6\%$ and $\Delta Q = 3.2\%$. (a) proposed index (b) detection signal in the first system.

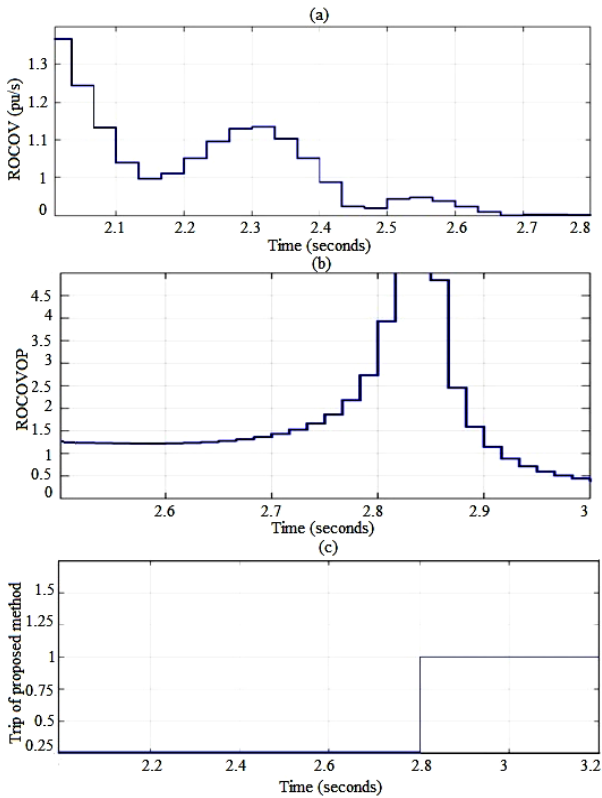


Fig. 7 Response of system for $\Delta P = 0\%$ and $\Delta Q = 15\%$. (a) proposed index (b) detection signal in the first system.

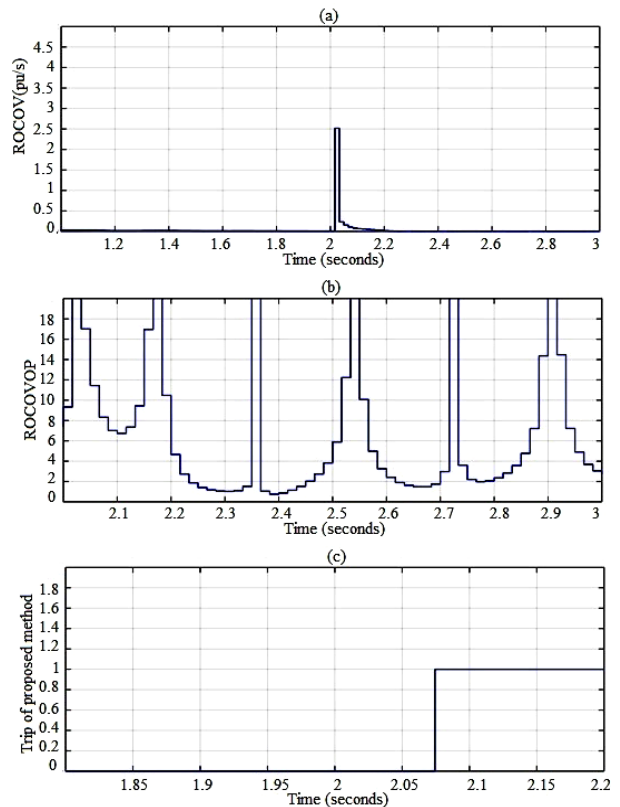


Fig. 9 Response of system for $\Delta P = -17\%$ and $\Delta Q = 11\%$. (a) proposed index (b) detection signal in the second system.

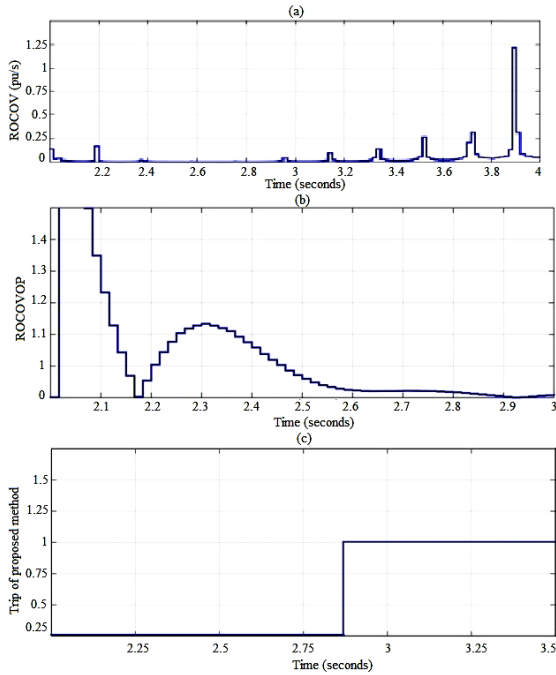


Fig. 10 Response of system for $\Delta P = 1\%$ and $\Delta Q = 2.7\%$. (a) proposed index (b) detection signal in the second system.

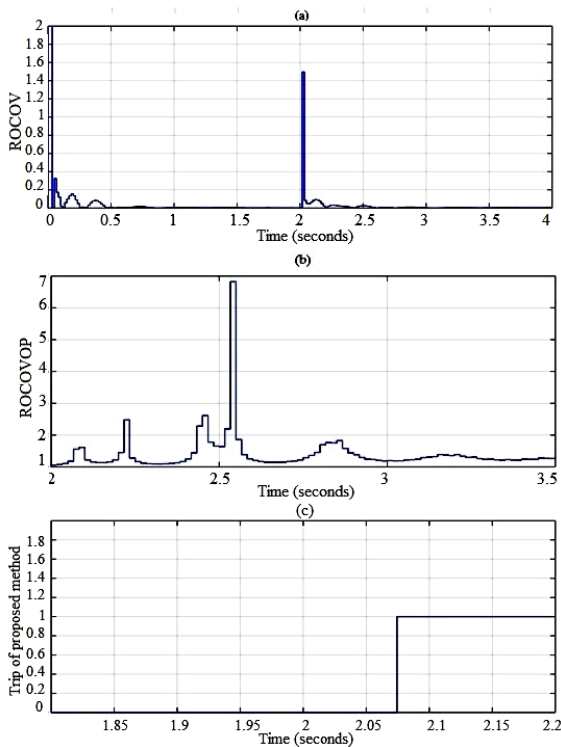


Fig. 11 Response of system for $\Delta P = 7\%$ and $\Delta Q = 5.5\%$. (a) proposed index (b) detection signal in the second system

But for less amounts of power mismatches ROCOV method has poor performance. From simulation results, it can be found that the proposed method can detect

islanding condition in 0% and 1% power mismatches in the first and second case study systems, respectively. From this section it can be concluded that the proposed method has small NDZ compared to ROCOV method and has good performance in very small power imbalances.

3.2 Different Loading Conditions

In this section, the proposed method is tested for different values of static RLC loads with different quality factors, induction motor load, and mixed static and dynamic loading conditions in the case study systems. All the information about the inductive motor load was presented in [14]. In The all cases, power imbalance value is close to zero, and microgrid disconnected from main network at $t = 2$ sec. four different cases have been investigated:

Case 1: static RLC load ($P_e = 100\%$, $Q_e = 105\%$ and $Q_f = 1.81$).

Case 2: static RLC load ($P_e = 125\%$, $Q_e = 102\%$ and $Q_f = 1.41$).

Case 3: mixed load (50% of overall load is inductive).

Case 4: induction motor load ($P_e = 54\%$, $Q_e = 0\%$ and $C = 34\%$).

Figures 12-19 show ROCOVOP index and ROCOV relay variations for different load cases.

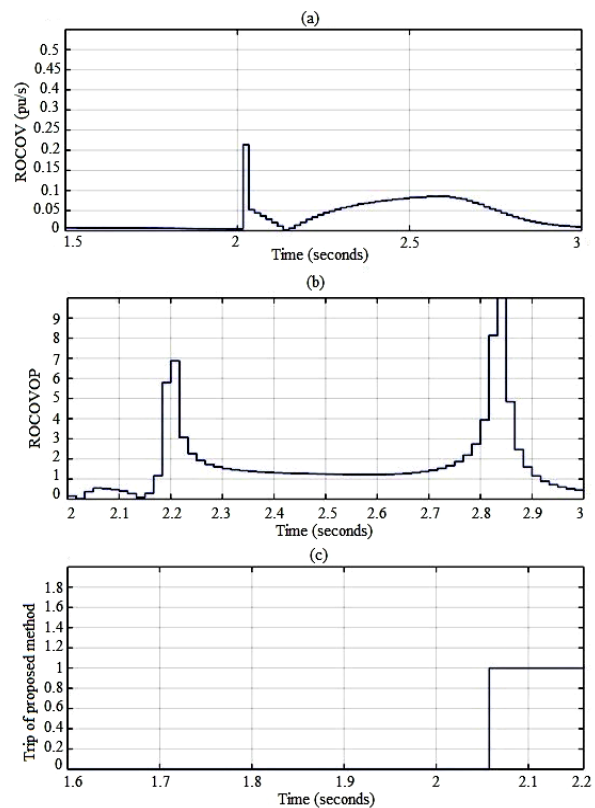


Fig. 12 Response of system for case (1) loading. (a) ROCOV method (b) proposed index (c) detection signal in the first system.

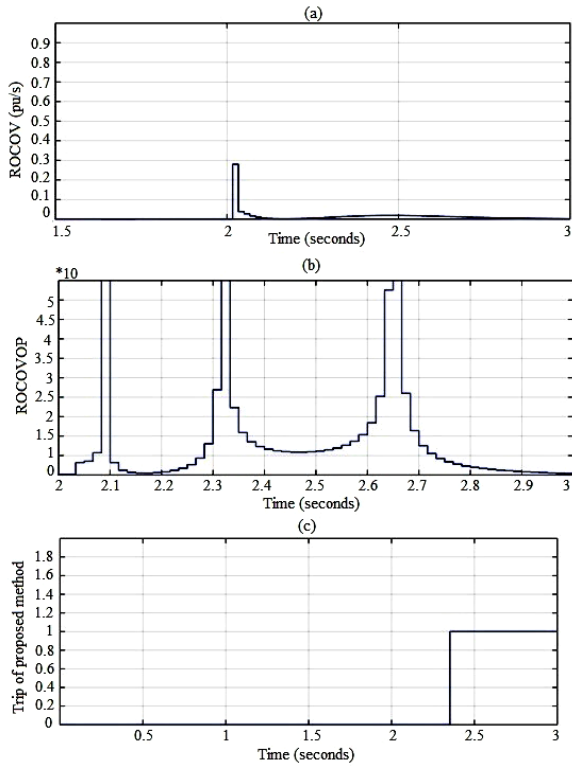


Fig. 13 Response of system for case (2) loading. (a) ROCOV method (b) proposed index (c) detection signal in the first system.

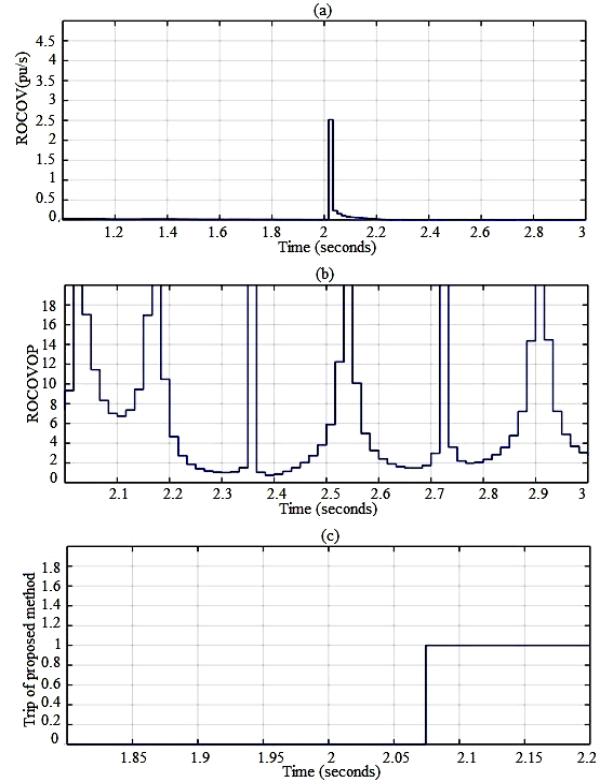


Fig. 15 Response of system for case (4) loading. (a) ROCOV method (b) proposed index (c) detection signal in the first system.

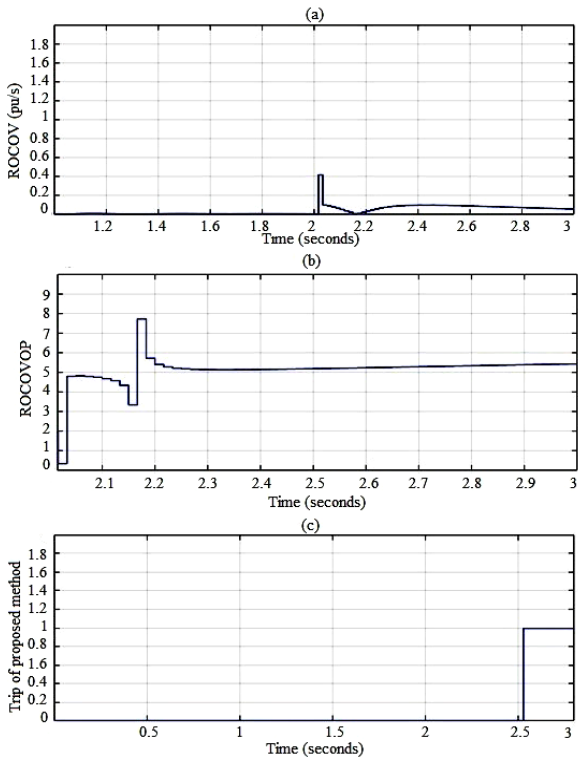


Fig. 14 Response of system for case (3) loading. (a) ROCOV method (b) proposed index (c) detection signal in the first system.

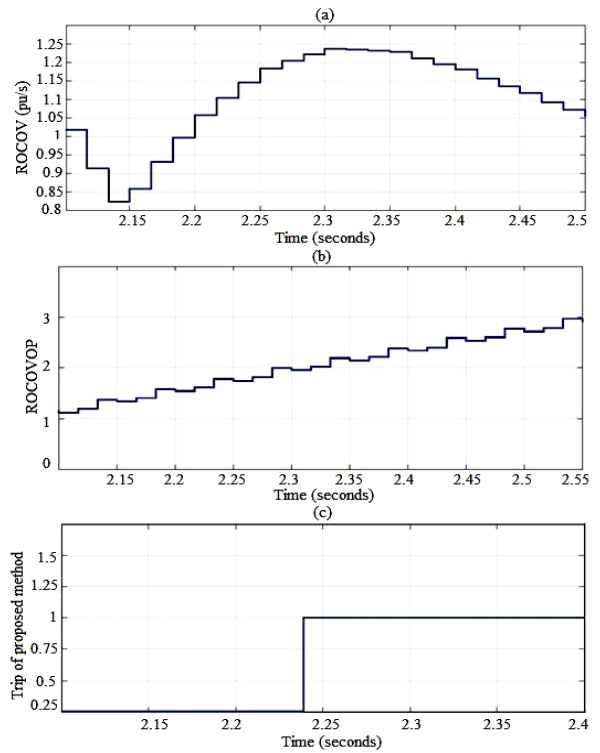


Fig. 16 Response of system for case (1) loading. (a) ROCOV method (b) proposed index (c) detection signal in the second system.

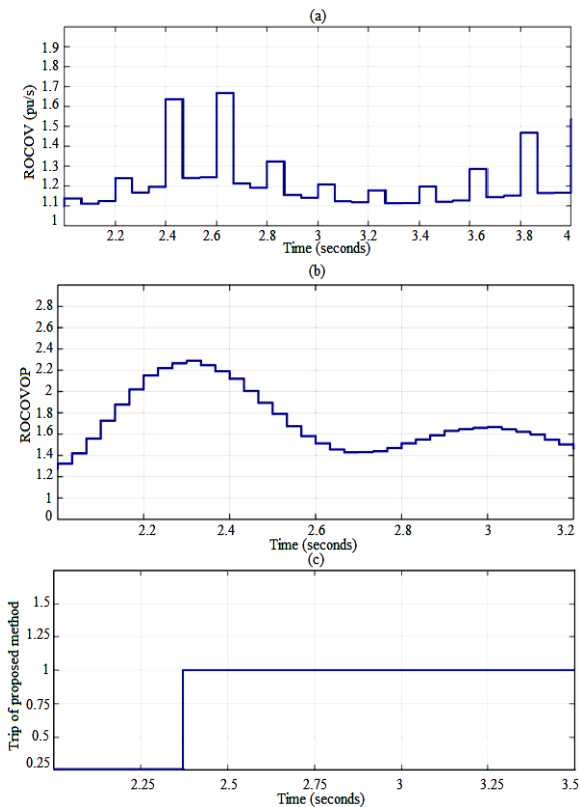


Fig. 17 Response of system for case (2) loading. (a) ROCOV method (b) proposed index (c) detection signal in the second system.

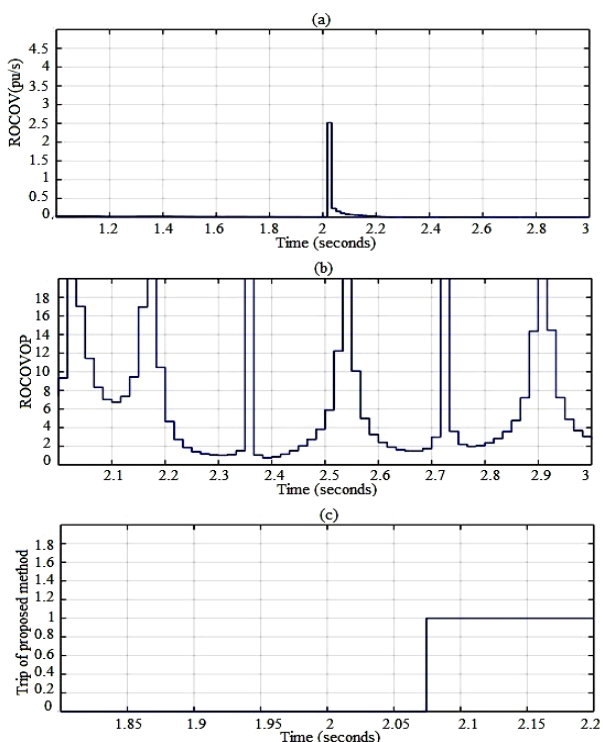


Fig. 18 Response of system for case (3) loading. (a) ROCOV method (b) proposed index (c) detection signal in the second system.

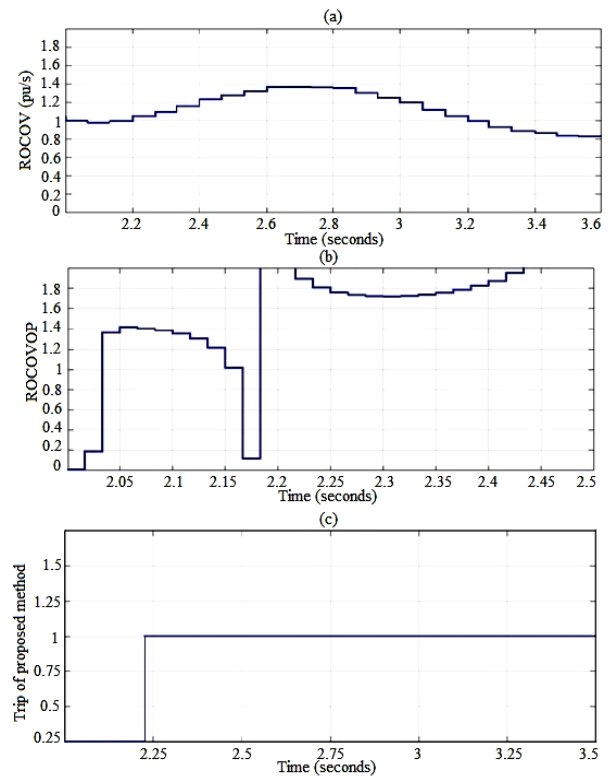


Fig. 19 Response of system for case (4) loading. (a) ROCOV method (b) proposed index (c) detection signal in the second system.

As demonstrated in simulation results, for all the cases, proposed detection method detected islanding in rated time (2 sec.), while ROCOV relay has poor performance in some cases.

3.3 Non Islanding Events

In this section, the performance of the proposed method is evaluated for non-islanding events such as short circuit faults, sudden load changes, and capacitor bank switching. Generally, a detection method is qualified if islanding conditions are properly detected at the rated time and does not declare non-islanding disturbances, islanding condition wrongly.

In this article, from 8% to 50% of voltage sag was applied for different faults with the lasting of 6 cycles and 150% of reactive power increment was applied for capacitor bank switching events. In Tables 1 and 2, simulation results for different faults, various load changes and capacitor bank switching, in the case study systems are demonstrated and compared with ROCOV and ROCOF relays. As mentioned before, values of 1 and 0 were applied for islanding and non-islanding situations, respectively, as recognized by detection methods. As seen in Tables 1 and 2 the proposed method did not have wrong recognition; but, the capability of both ROCOV and ROCOF relays wrongly declared non-islanding disturbances as islanding condition in some cases.

Table 1 Simulation results for different faults in the case study systems.

Experienced faults	Detection trip of the proposed method	Detection trip of ROCOV	Detection trip of ROCOF
Three-phase to ground with $R_f = 5 \Omega$ in the PCC in the first case study sytem	0	1	1
Double- line to ground with $R_f = 2 \Omega$ in the PCC in the first case study sytem	0	0	0
Single-line to ground with $R_f = 10 \Omega$ in the PCC in the first case study sytem	0	1	0
Three-phase to ground with $R_f = 5 \Omega$ in bus 846 in the second case study sytem	0	0	0
Double- line to ground with $R_f = 2 \Omega$ in bus 846 in the second case study sytem	0	1	1

Table 2 Simulation results for capacitor bank and load switching in the case study systems.

Capacitor bank switching values	Detection trip of the proposed method	Detection trip of ROCOV	Detection trip of ROCOF
Capacitor bank switching (25 Mvar) in the first case study system	0	1	0
Capacitor bank switching (30 Mvar) in the second case study system	0	1	1
Connecting of load (10MW,15Mvar) to the PCC in the first case study system	0	0	1
Connecting of load (25MW,35Mvar) in the second case study system	0	1	1
Disconnecting of load (20MW,15Mvar) to the PCC in the first case study system	0	1	1
Disconnecting of load (30MW,40Mvar) in the second case study system	0	0	1

4 Conclusions

In this paper, a new islanding detection approach in microgrids was proposed. In fact, the proposed method calculated the new detection index according to change rate of DG's voltage over active power and the studied signals were converted into the discrete type to distinguish operation mode of microgrids. The proposed approach was successfully tested under different islanding and non-islanding events on two different power systems. Simulation results illustrated the effectiveness of the proposed method.

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