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Islanding detection of integrated DG system using rate of change of frequency over reactive power

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ABSTRACT

This paper offers a passive islanding detection method that is effective for distributed generation. When a distributed generator (DG) keeps a location powered even when access to the external electrical grid is lost, this circumstance is referred to as islanding. The power distribution system currently includes distributed generators (DGs), which provide inexpensive electricity and have fewer environmental impacts. Sometimes, these DGs continue to supply the nearby loads because of line outages and islands made by system separations. As a result, there are scenarios with unacceptable power quality. The islanding is identified if the result of the rate of change of frequency over reactive power exceeds the threshold value. The MATLAB test results from this study demonstrate the effectiveness of the suggested approach for different islanding and non-islanding scenarios.

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1. INTRODUCTION

Energy production using renewable source techniques is proliferating to fulfill demands on energy consumption around the world. At the consumer end (DG), distributed generators are sustainable energy systems [1]. The main concern with a DG is islanding. Power system islands are parts of a power grid that are electrically isolated but are supplied with power by a nearby DG. Because service people are ignorant of the frame's presence, UPS with connected and providing DG nearby, islanding is risky to field workers and connected apparatus [2]. The primary effects of this unintentional islanding are grid failures, unintentional circuit breaker (CB) openings at the grid, purposefully opened CBs for maintenance, human error, and natural disasters [3]. When a DG keeps a location powered even when access to the external electrical grid is lost, this circumstance is referred to as islanding. There are two different sorts of islanding scenarios: intentional and unintentional. Intentional islanding is defined as planned main grid maintenance, whereas unintentional islanding is the emergence of faults or other uncertainty at any moment in the electrical system [4]. The most frequent cause of islanding occurrences is a fault in a tie-line between the distribution and transmission networks. A power system's islanding has various negative effects, including preventing automatic device reconnection. Some workers may be unaware that the system is still functional even after the grid supply has been cut off, which could result in fatal accidents [5], [6]. The system may experience a load vs. generation imbalance, and unusual voltage and frequency fluctuations could affect the system [7]. As these islanding causes many effects in the power grid, it is important to detect the islands in the grid.

To detect the islands, we have two different techniques, i.e., local detection and remote detection techniques. The measured data from the DG side are used in the local detection techniques, while the remote detection techniques are mostly designed according to measured data from the utility side [8]-[10]. The local detection technique is further classified into active and passive detection methods. Active approaches can be categorized as those that interrupt the system somewhat to discover potential islanding conditions. It is necessary to keep track of the adjustments the signal's attributes go through for this voltage, frequency, impedance, and others are among these characteristics [11], [12]. When using passive approaches, we try to incorporate a parameter that will consider the grid's transient changes and, with the help of that data, identify if the grid has failed or not by comparing it to a predetermined threshold value. This method essentially keeps track of how various system parameters change. A passive islanding detection technique is used in this study as it is easy to find and simple [13]-[15]. The parameter to evaluate the change in the grid is both frequency and reactive power. We can take any parameter, such as frequency, voltage, impedance, and power. The rate of change of frequency, rate of change of voltage, over under voltage, and over under frequency are a few passive islanding detection techniques. Using these methods, there will be some non-detection zone, but the blend of two passive methods may lessen the region of the non-detection zone [16]-[20]. Hence, we can detect the islanding condition precisely. In order to obtain precise results, we combine the rates of change of frequency and reactive power in this study. ROCOFORP is the method utilized in this situation because it provides a smaller non-detection zone and correctly classifies non-islanding and islanding cases [21]-[26]. The remaining paper is sectioned as follows. The second section discusses the designed system under consideration, section three at the proposed methodology procedure, section 4 discusses the outcomes, and conclusions are presented in the fifth section.

2. TEST SYSTEM UNDER STUDY

This research is implemented on a 33-bus system connecting to the various buses at various locations. Figure 1 shows the 33-bus system connections with loads and DG systems. A balanced three-phase network system with 33 buses and 32 branches is connected. Bus 1 is where the main substation is attached. There are 32 loads in the system, with real and reactive loads totaling 3.72 MW and 2.29 Mvar, respectively. Meanwhile, Table 1 displays the ratings of the four DGs, which are modelled as synchronous generators [6]-[8]. The initial load condition at each bus value of the system is adopted from Table 2 [7].

At the point where the electrical supply utility system meets, the microgrid separates from the main network, creating an island. Plot the ROCOFORP at the connection point after determining the ROCOFORP. Different cases were deliberated in the study to determine the cutoff or threshold value that separates islanding cases from cases that are not islands.

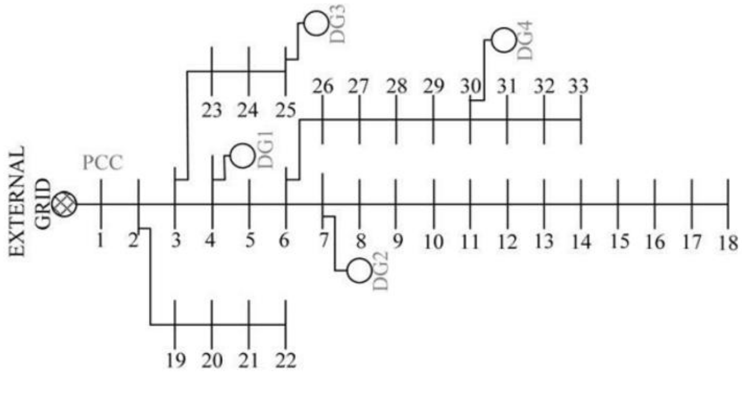


Figure 1. 33 bus system single line schematic under investigation

Table 1. DG installed nodes with operating conditions

Node	Max active power (kW/pf)	Base case rating (kW/pf)
30	175/1	100/1
7	175/0.9	100/0.9
25	300/0.9	100/0.9
4	193/0.8	50/0.8

*pf-power factor

Table 2. Load values of the 33-bus system

Line number	Receiving bus	Sending bus	Reactance (Ω)	Resistance (Ω)	Load at the receiving end bus	
					Reactive power (kVA)	Active power (kW)
1	2	1	0.0477	0.0922	60	100
2	3	2	0.2511	0.493	40	90
3	4	3	0.1864	0.366	80	120
4	5	4	0.1941	0.3811	30	60
5	6	5	0.707	0.819	20	60
6	7	6	0.6188	0.1872	100	200
7	8	7	1.2351	1.7114	100	200
8	9	8	0.74	1.03	20	60
9	10	9	0.74	1.04	20	60
10	11	10	0.065	0.1966	30	45
11	12	11	0.1238	0.3744	35	60
12	13	12	1.155	1.468	35	60
13	14	13	0.7129	0.5416	80	120
14	15	14	0.526	0.591	10	60
15	16	15	0.545	0.7463	20	60
16	17	16	1.721	1.289	20	60
17	18	17	0.574	0.73	40	90
18	19	2	0.1565	0.164	40	90
19	20	19	1.3554	1.5042	40	90
20	21	20	0.4784	0.4095	40	90
21	22	21	0.9373	0.7089	40	90
22	23	3	0.3083	0.4512	50	90
23	24	23	0.7091	0.898	200	420
24	25	24	0.7011	0.896	200	420
25	26	6	0.1034	0.203	25	60
26	27	26	0.1447	0.2842	25	60
27	28	27	0.9337	1.059	20	60
28	29	28	0.7006	0.8042	70	120
29	30	29	0.2585	0.5075	600	200
30	31	30	0.963	0.9744	70	150
31	32	31	0.3619	0.3105	100	210
32	33	32	0.5302	0.341	40	60

3. PROPOSED METHOD

ROCOFORP is the suggested strategy. At the point of coupling, or the intersection of the load and generator, we calculate the frequency change rate and the rate of change of reactive power [9] and determine the ROCOFORP. The variations in this parameter are compared with the predefined threshold value. If it crosses more than the threshold value, the situation is treated as islanding; otherwise, non-islanding.

The following flow diagram of Figure 2 illustrates the proposed method. At the connection point, the rate of change of frequency across reactive power levels is continuously compared with the established threshold value, which is 2*10^12. If the rate of change in frequency over reactive power (df/dq) is greater than a threshold value, the case is islanding; otherwise, it is not. The system is put through various instances to determine the threshold value, and depending on the results from each case, the threshold value is fixed.

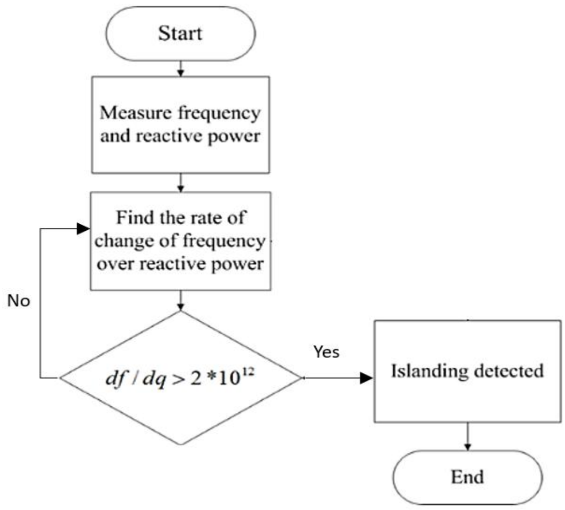


Figure 2. Flow diagram of procedure

4. RESULTS AND DISCUSSION

A range of islanding and non-islanding scenarios, including capacitor switching, DG switching, and others, are applied to the test system. In this article, we explore the differences between islanding and non-islanding conditions in the rate of change in frequency over reactive power.

4.1. Islanding case

Figure 3 shows the simulation's result for the ratio of reactive power to frequency change. The system is linked to the grid prior to t = 0.2 seconds; it is cut off from the mains at t = 0.2 seconds. The unexpected disconnection of the load from the main, which is how the graph's variance occurred, is powered by DGs. The ROCOFORP value exceeds the cutoff point.

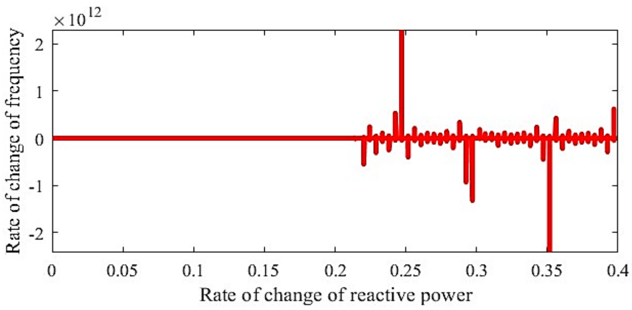
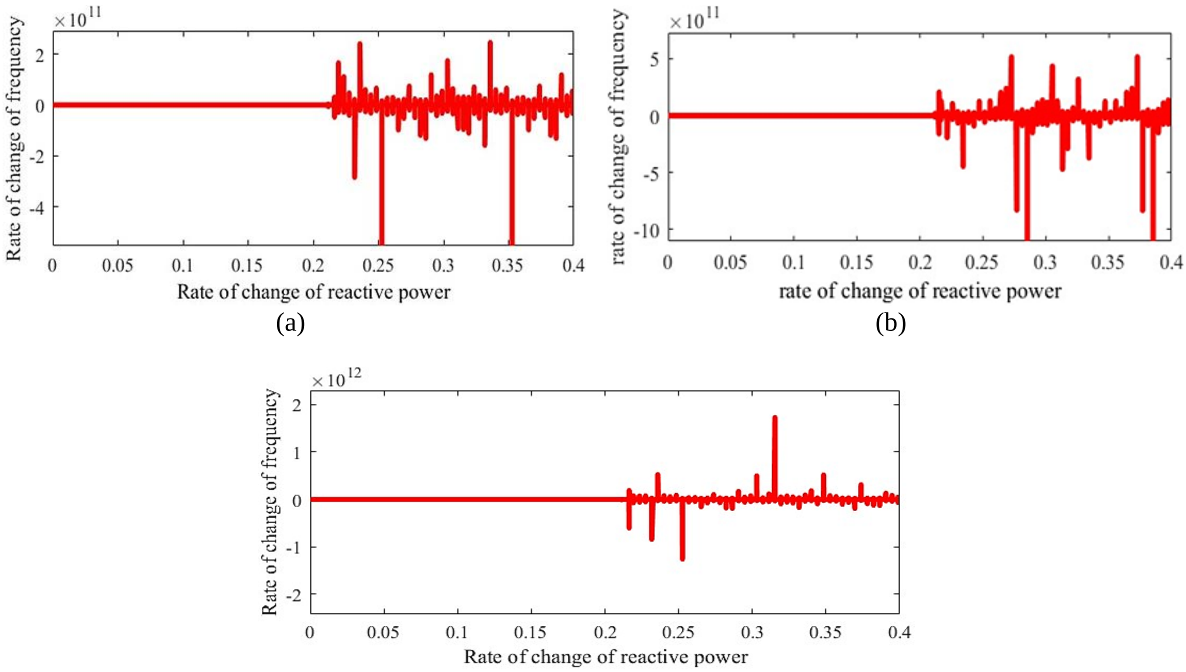


Figure 3. Simulation result of ROCOFORP for the islanding case

4.2. Different faults

Here, the test system is subjected to different faults such as line-to-line (LL), line-to-ground (LG), and double line-to-ground (LLG) [2] as shown in Figure 4(a)-(c). At t = 0.2 seconds, these faults are switched, and amplitude variations are seen but are seen from the results. The results indicate that the amplitude variations are below the threshold value. Hence, it eliminates the conflict between the islanding and non-islanding cases, and the proposed method detects the events accurately for these events.



(c)

Figure 4. Simulation results of ROCOFORP with (a) LL fault, (b) LG fault, and (c) LLG fault

4.3. Capacitor switching

A 1.5 Mvar capacitor bank linked to bus 4 is turned on at 0.1 seconds, while in another case, islanding is induced at t = 0.2 seconds. Figure 5 shows the effectiveness of the suggested method and the associated rate of change of frequency over the reactive power signal at the target DG's (DG-1) end. The ROCOFORP value is below the cutoff point. Hence, switching capacitors is treated as a non-islanding instance [10].

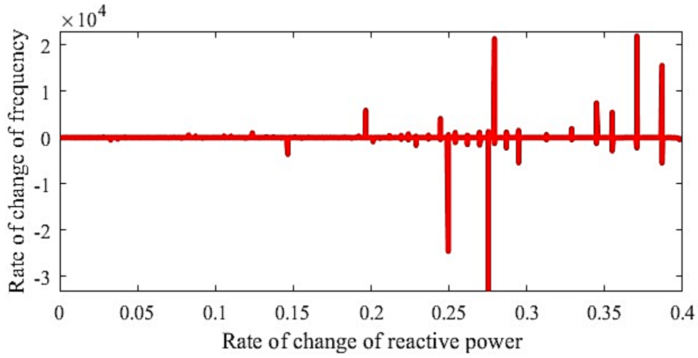


Figure 5. Simulation result of ROCOFORP for capacitor switching

4.4. DG switching

From the islanding state graph at t = 0.3 sec, when switching ON of the DG is complete, we extract the variation in the rate of change in frequency over reactive power as shown in Figure 6. The ROCOFORP amplitude is less than the cutoff value [10]. All these examples demonstrate that the suggested technique, ROCOFORP, easily distinguishes between islanding and non-islanding scenarios by using a threshold value. The test findings show that there is a smaller non-detection zone and that islanding and non-islanding cases are correctly classified.

Table 3 shows the comparison of various islanding detection methods. As per the IEEE 1547 standards, the islanding should be detected in less than 2 seconds. It is found from Table 3, many detection methods recognize the islanding events in less than 2 seconds. However, the proposed method detects the islanding in less than 2 milliseconds with zero non-detection zone (NDZ).

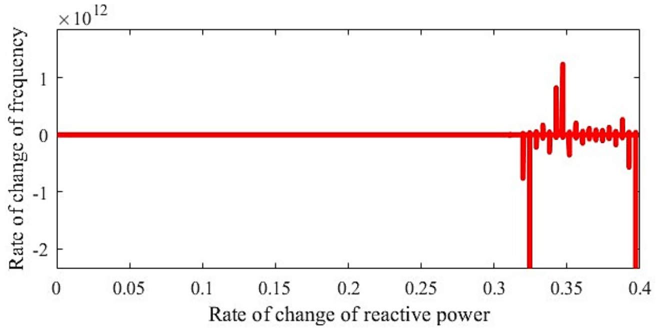


Figure 6. Simulation result of ROCOFORP for DG switching

Table 3. Differentiation of different detection methods

Technique	Detection time	Non-detection zone
Rate of change of frequency over reactive power	< 2 ms	Zero
Rate of change of frequency [14]	24 ms	Small
Rate of change of power	> 1 cycle	Small
Rate of change of frequency over power [18]	100 ms	Small
Over under-voltage/over under frequency [16]	4 ms to 2 sec	Large
Switching frequency [17]	< 40 ms	1.60%
Rate of change of phase angle difference [19]	Within 2 sec	Small

5. CONCLUSION

The ROCOFORP is suggested as a new islanding detection method. The comprehensive results showed that the method could distinguish between an islanding situation and all non-islanding occurrences, such as capacitor switching, DG switching, and short circuit occurrences. Every relay in the network, including relays at DG unit buses, feeders, and loads, can detect the islanding case with just one threshold value. The proposed passive detection approach does not even have an NDZ when there are no power imbalances. When determining the threshold amount, various situations are considered. Because the protection relays switch between the two modes of settings, the suggested islanding technique enhances the protection performance of the islanded microgrid.

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AUTHOR CONTRIBUTIONS STATEMENT

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Ch. Rami Reddy	✓	✓			✓		✓			✓		✓		✓

C : **C**onceptualization
M : **M**ethodology
So : **So**ftware
Va : **Va**lidation
Fo : **Fo**rmal analysis
I : **I**nvestigation
R : **R**esources
D : **D**ata Curation
O : Writing - **O**riginal Draft
E : Writing - Review & **E**diting
Vi : **Vi**sualization
Su : **Su**pervision
P : **P**roject administration
Fu : **Fu**nding acquisition

CONFLICT OF INTEREST STATEMENT

Authors state no conflict of interest.

DATA AVAILABILITY

Data availability is not applicable to this paper as no new data were created or analyzed in this study.

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