

## Islanding detection of integrated distributed generation with advanced controller

J. Rajesh Reddy<sup>1</sup>, A. Pandian<sup>2</sup>, R. Dhanasekharan<sup>3</sup>, Ch. Rami Reddy<sup>4</sup>,  
B. Prasanna Lakshmi<sup>5</sup>, B. Neelima Devi<sup>6</sup>

<sup>1,2</sup>Dept. of Electrical and Electronics Engineering, Koneru Lakshmaiah Education Foundation, India

<sup>3</sup>Dept. of Electronics and Communication Engineering, Saveetha School of Engineering, India

<sup>4,6</sup>Dept. of Electrical and Electronics Engineering, Nalanda Institute of Engineering and Technology, India

<sup>5</sup>Dept. of Electronics and Communication Engineering, Nalanda Institute of Engineering and Technology, India

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### ABSTRACT

Grid integration of nonconventional energy resources is increasing in day to day life to supply the global energy utilization requirement. The major problem with such integrated Distributed Generation (DG) is islanding. The islanding is originated in the integrated system when a part of the power system is disconnected from the grid and continue to feed the local load. The islanding is not safe for field persons and equipment. As per IEEE 1547 standards, the islanding should be detected within 2 seconds with the equipment associated with it. In this paper, a new islanding detection method is proposed with fuzzy rule-based approach with inputs as the change in frequency and power. This method classifies the islanding and non islanding events efficiently compared to other passive methods. The simulations are carried on Matlab/ Simulink 2018b environment.

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### Corresponding Author:

J. Rajesh Reddy,

Department of Electrical and Electronics Engineering,

Koneru Lakshmaiah Education Foundation,

Green fields, Vaddeswaram, Guntur, Andhra Pradesh, India. 522502

Email: rajeshreddy.jetty@gmail.com

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## 1. INTRODUCTION

To supply the global energy requirement all countries looking towards renewable power generation sources. The small scale power generation system, connected to the grid at the distribution level of the power system is termed as DG [1]. The serious issue with such DG in power system is islanding [2]. The islanding is caused in the integrated system when a part of power system is isolated from the grid and continues to feed the local load [3]. The islanding is not safe to work persons and equipment. The major causes of islanding are grid failure, sudden changes in network load, the intentional opening of a circuit breaker for maintenance and an act of nature. The problems with such unintentional islanding damage the customer equipment, field persons and sometimes DG. Hence as per IEEE 1547 DG interconnection standards, the islanding must be recognized within 2 seconds [4].

In recent years many researchers developed different islanding detection techniques. The major classification of them is remote islanding detection methods and local islanding detection techniques [5]. The local methods are again classified as Passive, Active and Hybrid islanding detection methods. The local methods detect the islanding by observing the changes in local parameters [6]. These are simple to implement but are suffering from large Non Detection Zone (NDZ). The region of values where islanding detection methods fail to detect it is termed as NDZ [7]. The Over/ under voltage [8], Rate of change of frequency (ROCOF) [9], Rate of change of reactive power [10] are some of the passive methods. The active method detects islanding by injecting a continuous perturbation and observing the changes in it [11]. These methods

have less NDZ but degrading power quality. The Sandia voltage shift [12], Sandia frequency shift [13], Slip mode frequency shift [14], Negative sequence current injection [15], Reactive power injection [16] are some of the active methods. The Hybrid method combines the features of both active and passive methods [17]. The NDZ of these methods is less compared to passive methods and power quality degradation also less compared to active methods. But till they also suffering from power quality issues and NDZ [18]. The reactive power injection-based ROCOF, voltage unbalance and impedance, current injection-based voltage are some of the passive methods.

In this paper, a new passive islanding detection method for classifying the islanding and non islanding events accurately is proposed with the fuzzy rule-based approach for increasing the stability of the interconnected power system. This method is classifying the islanding and non islanding events accurately and detects islanding early than existing passive methods. The rest of paper is organized as in Section 2, the test system under study is presented. In Section 3, the proposed method, In Section 4, the simulation results and lastly the conclusions are drawn in Section 5.

**2. TEST SYSTEM UNDER STUDY**

The test system shown in Figure 1 is considered for studying the performance of the proposed islanding detection method for improving system stability. The 120 kV grid is connected by two parallel DG systems each of 9 MW capacity [19]. Each DG has 6 wind turbines of capacity 1.5 MW each. The transmission lines of 3 km long and loads are 6MW resistive loads. The detailed test system parameters are listed in appendix-I. When CB1 is opened intentionally or unintentionally, the DG1 and DG2 combinely form the islanding. When CB3 has opened the DG1 alone forms islanding and when CB5 is opened the DG2 alone forms the islanding.

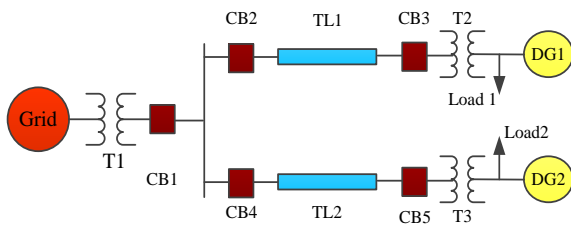


Figure 1. Test system under study

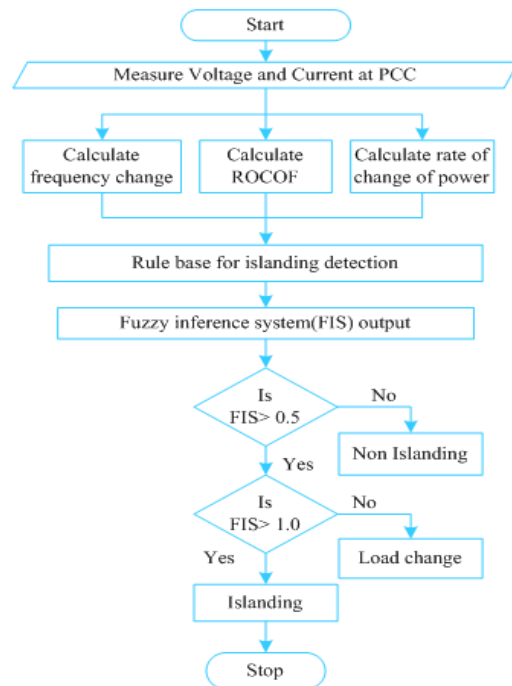


Figure 2. Flow chart of proposed fuzzy rule based controller

**3. PROPOSED METHOD OF ISLANDING DETECTION FOR STABILITY IMPROVEMENT**

The proposed method is a passive islanding detection method. The passive islanding detection method detects the islanding by observing the changes in local parameters such as voltage, current, frequency, phase angle, total harmonic distortion, etc. The fuzzy rule-based approach classifies the islanding and non islanding events. The inputs to the fuzzy rule-based approach are three parameters. They are changes in frequency, ROCOF, and rate of change of power at the point of common coupling (PCC). The islanding detection process with proposed fuzzy rule-based approach is depicted in Figure 2. The test system is initially

in grid-connected mode with a healthy environment, the window is simulated for 1sec and islanding is formed intentionally at 0.5 sec by opening the CB1. After islanding the changes in frequency, ROCOF and rate of change of power are taken as inputs to the fuzzy controller for classifying the islanding and non islanding events.

They are taken as A1, A2, A3 as inputs and output is A4. After examination of simulation data the boundaries are set for islanding events and other events. The trapezoidal membership functions and rule base for the proposed controller are shown in Table 1 and Table 2.

Table 1. Membership Functions of Fuzzy Controller

Parameter	Range	Membership Functions
A1	[-0.28 -0.28 -0.03 -0.03]	P1
	[-0.03 -0.03 0.064 0.069]	P2
	[0.0667 0.067 3 3 ]	P3
A2	[-12 -11.8 -3.3 -3]	Q1
	[-3 -2.68 3.7 3.7]	Q2
	[3.7 3.8 7.7 8.97]	Q3
	[8.6 9.3 12.5 12.5]	Q4
A3	[-9 -9 -3.8 -3.8]	R1
	[-3.8 -3.78 3.7 3.81]	R2
	[3.81 3.79 8.59 7.98]	R3
A4	[0 0 0.5 0.5]	N
	[0.5 0.5 1. 1]	LC
	[1 1 1.5 1.5]	I

Table 2. Rulebase of Proposed Controller

Sl. No	A1	A2	A3	A4
1	P2	Q2	R2	N
2	P1	Q1	R1	LC
3	-	Q1	R3	LC
4	P3	Q3	R3	I
5	P3	Q4	-	I
6	P2	-	R3	I

#### 4. SIMULATION RESULTS

The simulation studies are carried on the Matlab/Simulink environment with the proposed controller. The simulations are carried for 0.8 second and islanding is created at 0.5 sec. Two major cases are simulated in this environment. They are islanding by opening CB1 and non islanding case of load change at DG1 terminals with all breakers in working. The algorithm shown in Figure 2 is used to get the results. Figure 3 shows the changes in voltages, currents active power and reactive power at DG terminal in grid-connected mode. After islanding the currents observed are zero because the measurement is done in islanded area with open circuit. Figure 4 shows the variation of voltages, currents, active power and reactive power in islanding operation. These shows after islanding there are more variations in the voltage, active and reactive power at DG terminal.

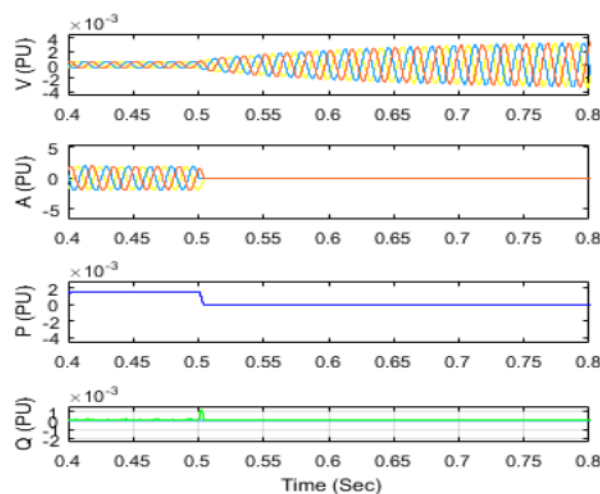


Figure 3. Voltages, currents, active power, reactive power in grid-connected and islanding operation

Figure 5 shows the fuzzy inference parameters for load change and islanding. By observing these deviations, the proposed controller initiates a trip signal to trip the inverter. Various islanding and non islanding events are presented in Table 4. The comparison of existing methods with the proposed method is listed in Table 3.

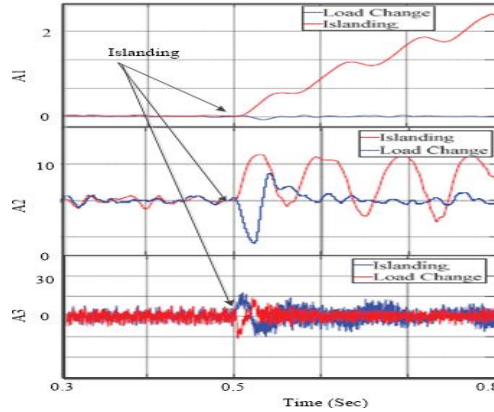


Figure 4. Fuzzy rule base coefficients A1, A2 and A3 in islanding and load change operation

Table 3. Review and Comparison of Various Passive Methods

Author & Reference	Parameter / Method	Detection time	NDZ	Type of DG	Multiple or Single DG
Redfern et.al., [20]	voltage, current	120 ms	more	PV	Single
Jonathan et.al., [21]	voltage, frequency	300 ms	more	Induction Generator	Single
Sun et.al., [22]	Resistance, Inductance	500 ms	more	PV	Single
Michael et.al., [23]	Negative sequence impedance	4 cycles	less	Wind	Single
Lidula et.al., [24]	Current, Wavelets, PNN, DT, SVM	4 cycles	Zero	Induction Generator	Single
Soo et.al., [25]	Switching frequency of inverter	20 ms	Zero	PV	Multiple
Syarkawi et.al., [26]	Voltage, frequency, DSP Processor	20 ms	Small	PV	Single
Ahmad et.al., [27]	Speed governer characteristics	200 ms	Small	Wind	Single
Reza et.al., [28]	Discrete wavelet transforms	5.5 ms	Zero	PV	Multiple
Walid et.al., [29]	Local and remote techniques	15.4 ms	Zero	Induction Generator	Single
Shi et.al., [30]	Frequency asymetry	500 ms	Zero	PV	Single
Jing et.al., [31]	Negative sequence voltage and current	40 ms	Small	Wind, PV	Multiple
Hanif et.al., [32]	Wavelet transforms, frequency	2.5 cycles	Zero	PV	Single
Ning et.al., [33]	Variation of signal energy	330 ms	Small	PV	Single
Omar et.al., [34]	Naïve baysian method	120 ms	Medium	PV	Single
Ankita et.al., [35]	Wavelet transforms,voltage	Half cycle	Zero	wind, Diesel	Multiple
Liang et.al., [36]	Fuzzy optmization	100 ms	Small	PV	Single
Osama et.al., [37]	Adaline	10 ms	Small	PV	Single
Laghariet.al., [38]	Artificial neural Networks	20 to 25 ms	Small	PV	Multiple
Proposed method	Fuzzy Inference System	10 ms	Zero	Wind	Multiple

Table 4. Results for Different Islanding and Non Islanding Events with the Proposed Controller

Sl. No	A1	A2	A3	Original Situation	Output of FIS
1	11	-0.13	0.43	Islanding	0.5
2	-7.2	-0.5	0.1	Islanding	0.5
3	1.80E-03	2.2	1.00E+04	Non Islanding	0
4	1.90E+05	2	1.6 e-4	Non Islanding	0
5	3	-0.145	-0.012	Islanding	0.5
6	4.5	-0.18	0.02	Islanding	0.5
7	30	10	-0.04	Islanding	0.5
8	-0.4	4.6	0.001	Non Islanding	0
9	-0.35	4.05	0.0017	Non Islanding	0
10	1.2	6.7	0.01	Non Islanding	0

## 5. CONCLUSION

This paper presents a fuzzy rule-based controller for islanding detection of integrated parallel DG. The proposed method detects the islanding based on the variation of FIS output. The input to the fuzzy controller is change in frequency, ROCOF and rate of change of power. The proposed method can detect islanding, non islanding events efficiently and improves the system stability significantly compared to the other existing passive methods. The FIS output indicates it is clearly distinguishing islanding and non islanding events.

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