International Journal of Interdisciplinary Innovative Research &Development (IJIIRD)
ISSN: 2456-236X
Vol. 05 Special Issue 01 | 2020

Passive Islanding Technique for Distributed Grid: A Review on Smart Grid Technologies and Optimization Techniques

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ABSTRACT

This review paper focuses on the research done on the passive islanding technique for smart grid. Energy crisis and environmental issues have encouraged the adoption of islanding techniques as an alternative energy option which when uses renewable sources as standby distributed generators becomes environmental friendly. The use of distributed generators including solar photovoltaic, wind, small hydro, biomass etc. are playing an important role in the restructured power system. However, there are certain issues related to grid integration of DGs including islanding detection. Hence, it becomes an important area of research nowadays for power engineers. There are various islanding detection techniques including passive, active, hybrid, utility, communication based etc. This paper reviews the framework, benefits and challenges of the passive islanding technology. This paper also summarises the main optimization techniques to achieve different passive islanding technique objectives while satisfying multiple constraints.

***Keywords:* Passive islanding technique, Smart grid, Distributed generators, Islanding detection, Optimization techniques.**

1. INTRODUCTION

Today's power system operates through the synchronized operation of large power plants producing bulk power and transmitting it through long transmission lines at high voltage before reducing the voltage for consumption in customer premises. This is mainly due to the cost of production of bulk quantities of electricity being much lower than the cost of producing many small quantities of electricity. But the advancement in technologies like fuel cells, gas turbines, micro-hydro, wind turbines and photovoltaic, new innovation in power electronics, electricity market deregulation, customer's demand for better power quality and reliability, and above all environment concern are forcing the power industry for yet another shift and this time back to the distributed and dispersed generation.

Over the past decade, with the increase in worldwide consumption of electricity and increasing loads, the traditional model of the grid is no longer sufficient to fulfil the load demands. This gives rise to the concept of distributed generation . Distributed generators or DGs are secondary power sources, renewable in nature that may be connected to the grid at various places and essentially fulfil the load demand that is required. DGs are usually wind powered turbines, hydroelectric dams or array of PV cells acting as a solar power producing unit [1].

Islanding takes place when part of the network becomes disconnected from the grid, and is powered by one or more DGs only [2]. Although this is not an entirely undesirable mode of operation, it does pose problems. Current standards dictate that the voltage and frequency of the system must be maintained within specific operational limits, and this is not guaranteed in an island [3], [4]. Line worker safety is also put at risk since lines that are thought to be disconnected are still energized by the DGs. Thus, it is important that DGs are equipped with an islanding detection method.

From perspective of the electric utility, the concerns with the islanded network are [5]–[7]:

- loss of control over voltage and frequency;
- safety issues since a portion of the system remains energized while it is not expected to be;
- excessive transient stresses upon reconnection to the grid;
- uncoordinated protection;
- in-adequate grounding.

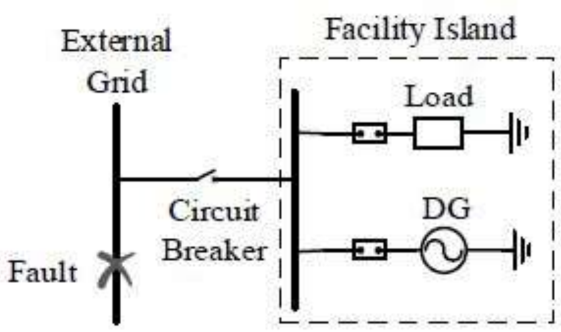

Fig. 1. An island defined in IEEE 1547.4-2011 [8].

Islanding detection has been studied for synchronous-based and inverter-based DGs. Some methods can be applied to both while others are specific to one type. Islanding detection methods are broadly divided into three categories: active, passive, and hybrid communication-based methods.

Passive islanding methods infer the occurrence of islanding based only on measurements made at the point of common coupling (PCC). This is an advantage diluted only by the fact that it is often not easy to rely only on system parameters for accurate detection; many other non islanding disturbances will produce transients that mimic very closely those of an islanding event. For this reason, thresholds on measured parameters (for example, frequency or voltage) are set wide, but this results in large non detection zones (NDZ). Passive techniques that have been developed include over/under voltage and over/under frequency (OVP/UVP and OFP/UFP) [9], system input impedance [10], rate of change of frequency with time [11], rate of change of power with time [12], rate of change of frequency with

Hybrid -based techniques have been recently proposed in the literature for islanding detection. An intelligent-based approach was developed in [22], where islanding and non islanding conditions were simulated for a system with synchronous-based DG. Eleven parameters, including the frequency and voltage deviations, the total harmonic distortion, and others were measured. These parameters were then fed to a classifier along with their respective classes, and a classification tree was obtained. The proposed classification tree was capable of detecting non islanding conditions with a 0% misclassification rate, but did not perform as well for islanding events (16% misclassification rate).

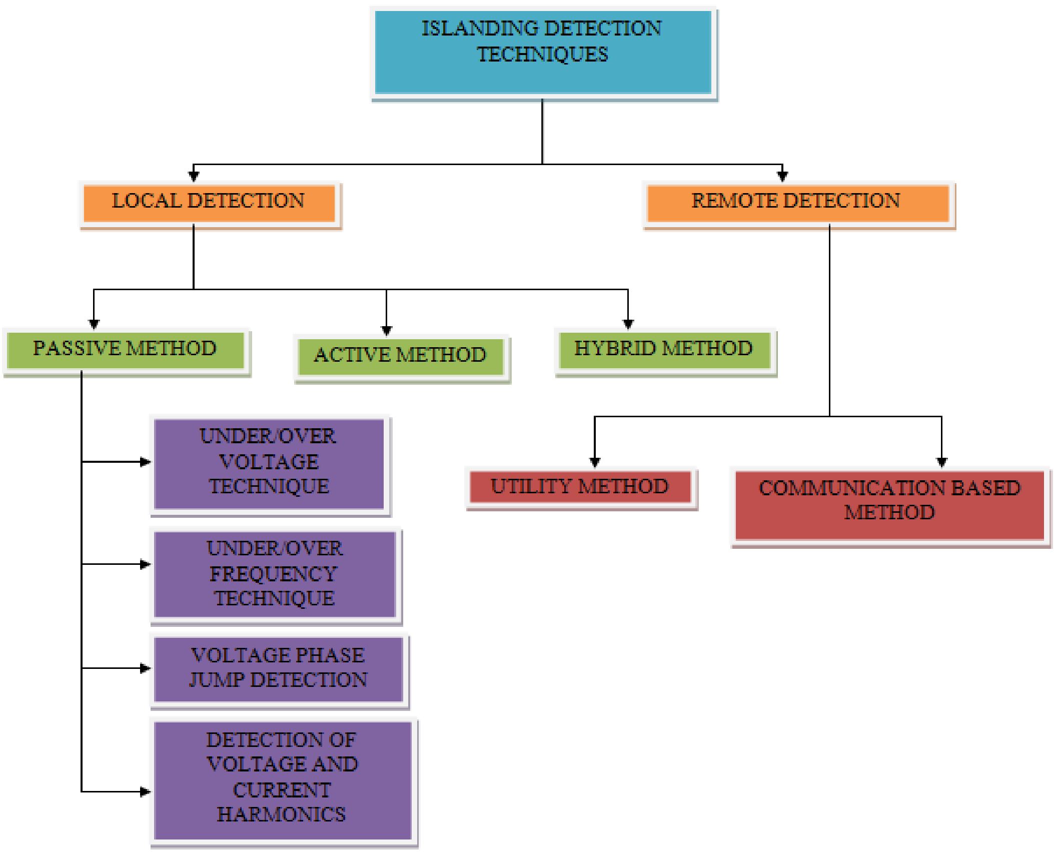

Fig. 2. Classification of islanding detection techniques

2. ISLANDING DETECTION TECHNIQUES

Mainly the islanding detection techniques are classified into two groups, one is Local detection technique and other is remote detection technique [23]. Local detection method can further be classified into Active and Passive methods.

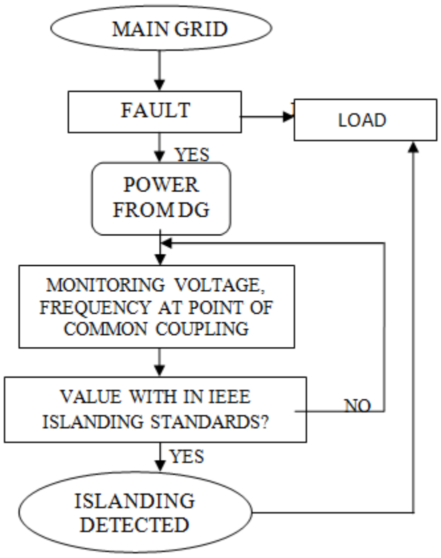

Fig 3. Flow chart of smart grid Islanding

A. Passive Islanding Detection Technique

Passive islanding detection technique (PIDT) is based on measurement of system parameters. In this method, parameters like voltage, frequency, harmonic distortion, power, and sequence impedance which affect the output of grid connected converters are measured and accordingly analysis of islanding is carried out [24]. The detection of healthier or faulty power system is determined at pee. At pee, if the parameters are within well defined range, then no islanding will occur otherwise it will be an islanding condition.

B. Active Islanding Detection Technique

Active islanding detection technique (AIDT) involves feedback control technique which measures the variation in parameters such as voltage or frequency at the point of common coupling. In AIDT, small disturbance is introduced at PCC and then system corresponding parameters are identified and detect the islanding condition [25].

C. Hybrid Islanding Detection Technique

Hybrid islanding detection technique is the combination of both passive and active islanding detection methods. In this method first the parameters are measured at pee and compared at comparator which checks its limits and if it is within threshold limits then injects the disturbance signal to clarify more preciously the islanding condition. Since it is a combination of both methods, it has high effectiveness as compared to other methods [26,27,]. Menon and Nehrir [28] detected the new hybrid techniques for synchronously rotating DGs so that the DG can be isolated from the system safely as the grid is not injecting power.

Before going in the detailed procedure of passive islanding detection method, one needs to understand the basic requirement of the passive islanding. The two main attributes of passive islanding is Non detection zone (NDZ) and Quality factor [29].

Non Detection Zone (NDZ) is an area where DG fails to detect island after occurrence of islanding. The area under this region represents the power mismatch between distributed generator power (P_{DG}) and load power (P_d which creates deviation in real as well as reactive power that is ΔP and ΔQ respectively. The NDZ can be used as a performance evaluator for islanding technique.

$$P_L - P_{DG} = \Delta P$$

$$Q_L - Q_{DG} = \Delta Q$$

The second attribute is power quality factor (Q_f). Q_f may be defined by the equation below. For better islanding, the quality factor should be low.

$Q_f = 2\pi$ *x ratio of maximum energy stored to energy dissipated per cycle at a given frequency*

Quality factor is directly proportional to the non detection zone. The more the quality factor, the more will be non detection zone and the less effective will be the islanding detection. Hence for enhancement of islanding methods, the system should have low power quality factor and shrivel non detection zone area.

3. IEEE STANDARDS FOR ISLANDING

The IEEE std. 1547, IEEE standard for Interconnecting Distributed Resources with Electrical Power Systems[I], provides the technical specifications and requirements for interconnecting distributed resources with power system so that operation, testing, maintenance and safety considerations can be imparted on the complex power system. As per the standard, the requirements should be met at the point of common coupling (PCC), irrespective of the devices location.

TABLE I. Default Response to Abnormal Voltages

Voltage Range (% of base voltage)	*Clearing Time (in sec)*	*Clearing Time: adjustable up to and including (in sec)*
V < 45	0.16	0.16
45 ≤ V < 60	1	11
60 ≤ V < 88	2	21
110 < V < 120	1	31
V ≥ 120	0.16	0.16

TABLE II. Default Response to Abnormal Frequencies

Default Settings			*Range of adjustability*	
Function	Frequency (in Hz)	Clearing time (in sec)	Frequency (in Hz)	Clearing time (in sec) adjustable up to and including
UF1	< 57	0.16	56-60	10
UF2	< 59.5	2	56-60	300
OF1	> 60.5	2	60-64	300
OF2	> 62	0.11'6	60-64	10

As per IEEE standard 1547, the voltage threshold should be within the limits of 85% to 110% of the normal value and frequency should be ± 1 %. In India, the rated frequency is 50 Hz and according to current grid code by central electricity regulatory commission, the frequency can ranges from 49.8 Hz to 50.1 Hz. If the voltage or frequency varies from their respective limits, then the system is said to be islanded.

4. PASSIVE ISLANDING DETECTION TECHNIQUE

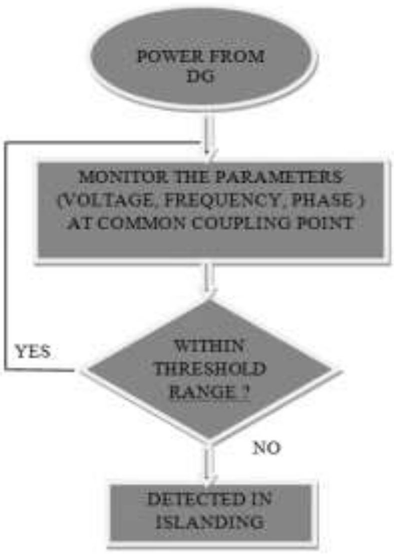

Fig.4 Passive islanding detection technique

Passive islanding detection technique is simply based on the variation in the parameters of the system. If the system deviates from the defined range then islanding detection takes place. If the system consists of RLC load, then the system is defined by the following equations:

$$f = \frac{1}{2\pi\sqrt{LC}}$$
$$R = \frac{V^2}{P}$$
$$L = \frac{V^2}{2\pi f P Q_f}$$
$$C = \frac{P Q_f}{2\pi f V^2}$$

Based on the parameters of the system, the methods of Passive islanding detection are classified as below:

a) Under/Over Voltage Protection (UVP/OVP)
b) Under/Over Frequency Protection (UFP/OFP)
c) Voltage Phase Jump Detection Method
d) Other Passive Islanding Detection Methods[1]

A. Under/Over Voltage Protection (UVP/OVP)

This method senses the abnormal voltage change at the PCC. The voltage at pee say V PCC must lie within the stipulated range that is V min :S V pee :S V max> where V min and V max are respectively the minimum and maximum threshold values. If the system deviates from these two end values, then island detected, and DG has to be disconnected. The active power at load of the system will be:

$$P_L = \frac{V_{pcc}^2}{R}$$

After isolation of grid from the load, the active power of the load will try to be same as that of DG [30] and thus the voltage of the grid changes to

$$V' = k \times V \quad \text{where,} \quad k = \sqrt{\frac{P_{DG}}{P_L}}$$

B. *Under/Over Frequency Protection (UFP/OFP)*

UFP/OFP is the detection of frequency variations from its defined range at the point of common coupling. The frequency of the system is related with the power defined by swing equations below. [31]
where,
ω is synchronous speed
δ is internal angle
P_m and P_e are the mechanical and electrical power respectively
H is inertia constant and f_r is rated frequency
The lower and upper limits of the frequency are set according to IEEE standard which is the variation of ±l% of the rated frequency. For 50 Hz supply, the frequency ranges from 49.5 Hz ≤ f ≤ 51.5 Hz. The frequency changes at PCC when the grid is disconnected from the system the reactive power of the load try to change till Q_L becomes equal to Q_{DG} as shown in equation below

$$Q_L = V^2{}_{pcc}\left(\frac{1}{\omega L} - \omega C\right)$$

The frequency, ω controls the reactive power at pee and is responsible to balance the reactive power between the load and the distributed generator.

C. Voltage Phase-Jump Detection

In this method of passive islanding detection, the phase difference between voltage and current of the DG is continuously observed to detect the sudden variation in the phase [34]. If this sudden phase jump observed in the system then it shows that the islanding has been detected. The difference in phase can be called as phase error. The non detection zone of voltage phase jump method depends on the power factor and the power factor depends on the type of load connected with the system. So it is necessary that the DG should be operating at unity power factor. This is the reason the voltage phase jump method is also called power factor detection or transient phase detection.

D. Advantages

Passive islanding technique posses following advantages:

- Passive methods are simple and fast but they leave some non-detection zone which can be avoided by having a proper set point [32,33]

- Passive islanding methods infer the occurrence of islanding based only on measurements made at the point of common coupling (PCC)[1]

E. Disadvantages

The main disadvantages of passive islanding technique is:

- Comparatively large non detection zone(NDZ)
- The main disadvantage, however, is power–quality problems due to the instabilities introduced on the system.

F. Other Passive Islanding Detection Methods

There are many new techniques in the passive islanding technique which researcher has reported. Saleh in his paper [35] has detected the new passive anti-islanding technique for three phase distributed generators in which transient high frequency components are extracted from the d-q wavelet transform packets of three phase instant apparent power. Islanding based on total harmonic detection (THD) is also a renowned passive islanding detection technique. In this method third harmonic of voltage at pee is changed during the islanding situation. This difference in original and changed value leads to islanding. Another new method of passive islanding detection is proposed in [36] by Liserre in which detection is based on the state estimation method. Some algorithm of islanding is based on Kalman Filters in which the islanding is based on the difference in the third and fifth harmonics of the grid voltage.

5. INTENTIONAL FACILITY ISLAND

Utility operators and PV owners can create an intentional island, presented in Fig. 1 [37], under external fault conditions if the following conditions are met:

(a) There should be sufficient power to maintain a voltage and frequency of the pre planned island within an acceptable range, typically within ± 5 percent of the rated voltage and frequency [38].

(b) There should be protection devices able to communicate with protection devices outside of a pre planned island [39,40].

(c) Mutual agreement between utility operators and PV owners, including safety issues [41].

6. CONCLUSION

Islanding detection is an important requirement for the modified power system scenario with increased perception of distribution sources. In this paper the passive techniques are used for islanding detection. The main purpose of the islanding detection is to continue the supply to load or providing an interruption free supply to the load. There are a many instruments or systems which required un-interrupted power supply. In such type of cases, islanding plays a significant role. Furthermore, it is easily integrates with the wind and solar power.

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