

## **Review of Islanding Detection Schemes for Distributed Generation System**

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**ABSTRACT:** *Incredible growth in demand for electricity with reliable, eco-friendly and efficient power has motivated the use of Distributed Generation (DG). The main problem in a distributed generation system is islanding which gives rise to power quality problems in the grid. During islanded operation, nonconventional energy sources such as solar, wind which are used as distributed generation source supply power to the local area. This paper discusses islanding and its classification detection methods into local and remote islanding detection. Local islanding detection techniques are further divided into passive and active islanding detection techniques and also a comparison of several islanding detection methods are studied & Presented.*

**KEYWORDS:** *Distributed resource, Distributed Generation(DG), Islanding Operation, Islanding detection techniques*

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### **I. INTRODUCTION**

From the last two decades, renewable sources of energy have been developed due to zero release of hazardous impurities as compared to conventional energy resources such as thermal and nuclear complements. Inventive alternate environment-friendly generation techniques that are Distributed Generation (DG) become one of the most essential trends in the power system. DG is required for enhancing power quality and reliability of power supply [1].

DG can be defined as the generating station usually located at the customer site. The DG in the distribution system has numerous advantages like it reduces the necessity of building new distribution and transmission lines, reduces transmission and distribution line losses, increases the reliability of the electrical system, increases voltage profile of the system and better power quality [2]. But there are various problems associated with the distributed generation and one of the key problems is Unintentional Islanding which is happen due to various reasons including sudden fault, malfunction of equipment or failure of substation. This phenomenon can cause serious damage to equipment due to high variation in frequency and voltage at the point of common coupling (PCC) and it creates many power quality issues which increase maintenance level. it may also create hazard to workers by keeping a line to remain energized. Therefore, the power generation system needs fast and effective islanding detection methods [3].

#### **1.1 Types of Islanding**

Islanding has two types of modes, namely Intentional and Unintentional Islanding

##### **Intentional Islanding**

Intentional Islanding is the situation which is due to the pre-planned event (Intentional) and usually meant for maintenance purpose. whereas intentional islanding is a purposefully sectionalization of the utility system to form island during disturbances [1]. Reliability and power quality of the electrical power system can be enhanced by intentional islanding as the use of DG in intentional islanding provide power to various portions of the network and critical loads.

##### **Unintentional Islanding**

Unintentional Islanding is the situation which is due to accidental events (Unintentional) and occurs due to some natural tragedy or sudden fault due to switching operation of various protective devices. Unintentional islanding is an unexpected process that occurs when the grid section is energized by one or more distributed energy resource. Unintentional islanding may create some problems such as severe damage to equipment, power quality problems, frequency, voltage stability problem and interference [4]. Cascading failure and blackouts are the most important factor that is responsible for unintentional islanding. Due to

cascading failure, there is a successive failure of different elements of the power grid which leads to changes in voltage, frequency, phase angle. Further, this voltage, frequency instability can cause the falling of another region if not measured properly [5].

### 1.2 Islanding Operation

There are various faults arising in the power distribution systems. In such cases, loss of synchronization between load and generation occur result in variation of voltage, frequency, and phase angle and finally lead to tripping of generators. In such cases, a protective relay is used to clear fault occurring in the power grid that is located near to fault point. When the power grid fails to supply power to load, distributed generator plays an important role by supplying power to domestic loads that have been isolated from the distribution power system. When distributed generation keeps supplying power to loads even after the utility system is isolated from power grid such a condition is known as islanded operation.

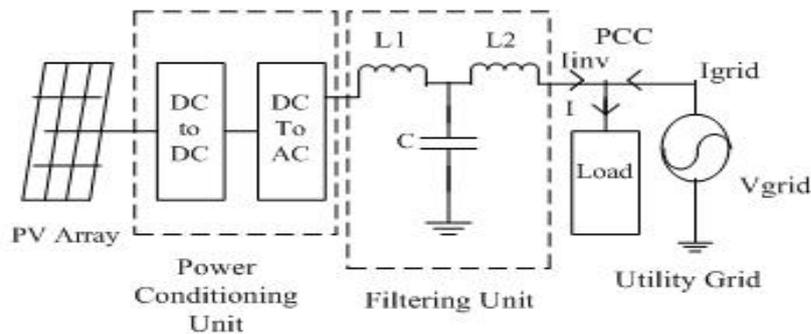


Fig.1. Normal operating condition of Grid-connected Distributed Generation System [1]

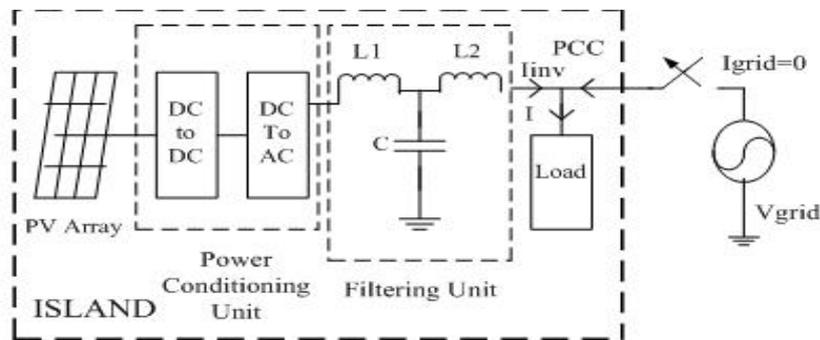


Fig.2: Islanded Condition of Grid-connected Distributed Generation System[1]

Figure 1 shows the grid-connected operation of the photovoltaic system involves Photovoltaic array, inverter, point of common coupling, utility grid and local loads. Under the normal operating condition, loads remain connected to grid and grid continue to supply power to local loads and Figure 2 shows islanded state of grid-connected distributed generation system. Under the islanded condition, loads get disconnected from grid and grid fails to supply power to local loads[7].

### 1.3: Threat from the islanded operation

Islanding condition has various adverse influences on the operation, safety and the controlling of distribution system so, it becomes mandatory to identify the islanding condition as quickly as possible and isolate DG from power grid [4]. If the islanded operation is still continued, there may be risks of physical injury to the public come in contact with the live part of the power system. Also when distributed generation supplies power, the quality of power gets affected as compared with the case when the power is supplied from the power company. Because of this, the loads may affect adversely [8]. Islanding also causes unsynchronized reclosing. automatic reclosing cannot operate if the DG source continues to serve fault in islanded state. It may create interference in automatic or manual restoration of normal service [6]. Islanding also affects the distributed generation reliability and efficiency of the power system network.

## II. ISLANDING DETECTION TECHNIQUES

Islanding detection techniques are divided in two classes as remote and local techniques. Local techniques can be further divided into active and passive techniques as shown in figure 3 [6]. This technique controls the grid side parameter and the DG side parameters to identify an islanding situation.

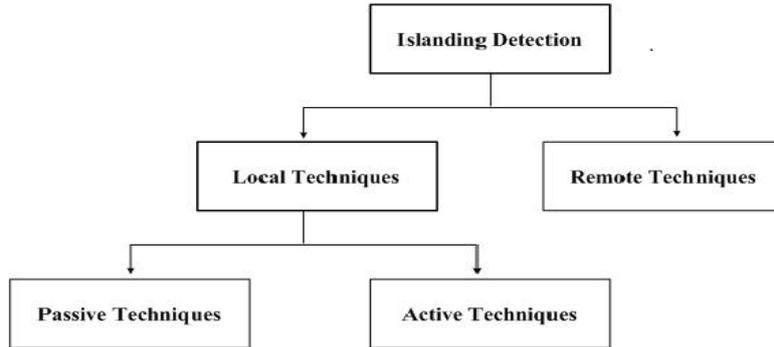


Fig.3. Classification of the Islanding Detection Techniques

### 2.1: Remote Islanding Detection Techniques

The remote islanding detection technique is usually available at the service level. They are more reliable than local islanding detection technique but these techniques are found to be more expensive to implement. Hence these technique is uneconomical.

#### i. Transfer Trip Technique

The requirement of Transfer trip system is to use Supervisory Control and Data Acquisition (SCADA) to control the position of all circuit breaker and reclosure that results in islanding.it requires better communication between the utility and distributed generation [3]. This technique used for multiple substations that are connected to DG located at the receiver side.it can trip feeders by stopping communication signal from the substation.Design complications and increased cost is a severe disadvantage for transfer trip scheme. Figure 4 shows the operating principle of Transfer Trip Scheme.

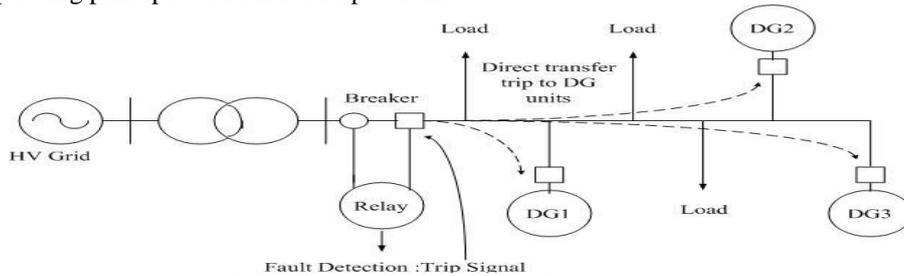


Fig.4. Operation of Transfer Trip Scheme

#### ii.Power Line Carrier Communication (PLCC)

PLCC is one of the technology to carry power for transmission and distribution of electric power. PLCC uses the power signal as a communication channel between grid and loads. PLCC uses transmitter and receiver to transmit and receive information from the grid to DG. if communication is interrupted due to disturbances in the grid, the transmission signal is not identified by a receiver located on the distribution side and therefore all distributed generation units are tripped. This scheme has good speed of response [9]. Figure 5 shows the operation of PLCC.This scheme has very smaller NDZ but the usage of transmitter and receiver makes the technique is costly.

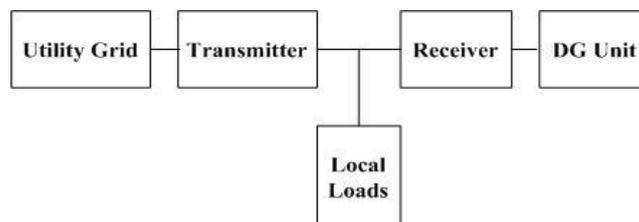


Fig.5. Operation of Power Line Carrier Communication

**iii. Impedance Insertion**

This technique consists of the insertion of low impedance usually a capacitor bank connected to PCC. When islanding occurs, there is a mismatch of power between generation and loads as the active power goes out of balance voltage and frequency at the utility level. These frequency deviations are detected by relay available at the distribution line. This technique is found to be more active to detect islanding. Here a capacitor is also used for reactive power compensation. Due to delay in switching time of capacitor and delay in switching to allow deviation in frequency, the response is slow [9].

**2.2: Passive Detection Technique**

Passive detection technique detects islanding situation by checking system constraints such as magnitude of voltage and frequency, harmonic detection, phase shift [10]. When the island occurs, great variation in parameters such as harmonic distortion, voltage, the frequency can be observed. Passive methods control such parameters to detect islanding condition. this method possesses large NDZ in which it is unable to identify islanding condition [6]. The various passive islanding detection technique is discussed below.

**i: Under/over voltage and Under/over frequency**

In this method, OUV and OUF relays are sited on distribution feeder to detect several abnormal conditions. During islanding, deviation in parameter like voltage magnitude and the frequency are measured to recognize isolated situation. The behavior of the system can be determined by the value of  $\Delta P$  and  $\Delta Q$  during islanding occur. If  $\Delta P \neq 0$ , the Frequency at the PCC will change. such changes will be detected by UFP/OFD relays and trip the DG source to supply power to loads. If  $\Delta Q \neq 0$ , the magnitude of the voltage at the PCC will change and such changes will be detected by UVP/OVD relays and trip the DG source [6]. Figure 6 shows the operation of grid DG.

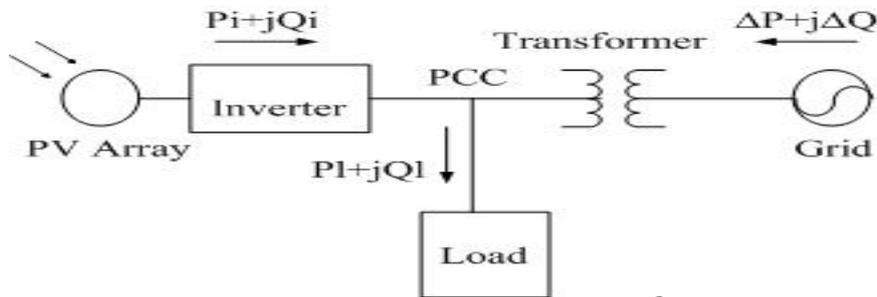


Fig 6. Operation of Grid Connected DG

**ii. Phase Jump Detection (PJD)**

In this technique, it involves measurement of the phase difference between voltage and output current of the inverter. Under normal grid-connected operation, Synchronism of output current of inverter and voltage at PCC are maintained by Phase Locked Loop (PLL) [1]. and during islanding, there will be a change of inverter output current and phase angle between the voltage, jump in the phase of PCC voltage can be observed as shown in figure 6 [6]. This method has smaller NDZ and its implementation is easy, does not affect the stability of the system[10].

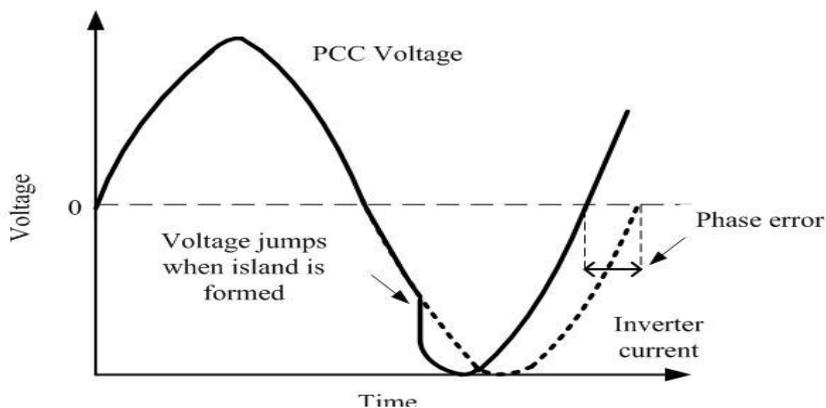


Fig.7. Representation of Phase Jump Detection

**iii. Harmonic Distortion and Voltage Harmonic (VHD)**

This technique controls the voltage unbalance and harmonics for detecting islanding [6]. change in voltage generally occurs due to variation in the load. Due to load unbalances, negative sequence component will appear along with positive sequence component [11].

$$\text{Voltage unbalance} = \frac{V_n}{V_p} \tag{1}$$

Where,  $v_n$  and  $v_p$  are negative and positive sequence component of voltage of DG. When the load on each of the phases are different, voltage unbalance will occur. under normal operating condition, load on all phases are equal but during islanding, voltage unbalance will observe due to load unbalance [3]. Harmonic content will be introduced in the signal, because of switching operation of PV inverter. Total Harmonic Distortion (THD) is responsible to identify islanding condition [6]. Two parameters such as THD of voltage and THD of current are controlled to identify islanding condition.

**iv. Rate of Change of Frequency (ROCOF)**

When grid operate in normal condition, frequency is regulated by the main grid but during islanding operation, utility system is detached from the main grid and active power between load and generation become unbalanced result in a change in frequency [10].

$$\text{ROCOF} = \frac{\Delta P \times F}{2HG} \tag{2}$$

Where,  $\Delta P$  is mismatch of power at the distributed generation side and  $H$  is moment of inertia of DG,  $G$  is rated capacity of DG,  $F$  is rated frequency. The set value has to be selected in such a way that the system can differentiate between the island and normal load change condition. The set value should be 0.1-1.2 Hz/s [6].

**v. Rate of Change of Power dp/dt (ROCOP)**

It observes ROCOP at DG output over a defined sample cycle. While islanding happens, the ROCOP is larger than during normal grid-connected operation for the same rate of change of load. This scheme seems to be very effective in case of unbalance load such as induction motor instead of balance load and due to this load, negative sequence harmonics affect power quality

**vi. Rate of Change of Frequency Over Power df/dp**

This scheme use parameter like  $df/dp$  for detection islanding situation. this method is much more sensitive than  $df/dt$  for small mismatch of power between the capacity of DG and load. It is highly efficient, reliable and has small NDZ [6].

**2.3:Active Islanding Detection Techniques**

In this techniques, slight disturbances will be introduced resulting in substantial variation in system constraints such as frequency, voltage, etc. when DG is islanded, it contains control mechanism or feedback technique to identify the fluctuations in the voltage or frequency at the PCC[13]. These techniques are discussed here.

**i. Active Frequency Drift technique (AFD)**

This technique can also be referred to as a frequency bias method [10]. it is used for detection of islanding condition by observing the variations in the frequency at the PCC. In this method, slight disturbances are introduced in the inverter output current. while islanding occurs, deviation in the frequency of utility grid is observed [1]. Chopping fraction is used to describe the distortion observed in the inverter output current [12]

$$\text{Chopping Fraction (CF)} = \frac{2t_z}{t_u} \tag{3}$$

Where,  $t_z$  is dead time and  $t_u$  is the time period of PCC voltage. Dead time indicates the time interval between zero crossings of voltage lag zero crossings of the current. Under normal grid operation, as the value of dead time is less, the value of chopping fraction is low and lesser is the disturbances but as the chopping fraction is greater, there is an increase in disturbances resulting in more THD in the inverter current output waveform[12].

**ii. Sandia Frequency Shift (SFS)**

In this technique, when positive feedback is applied to active frequency drift, it can be referred to as Sandia frequency shift. The effectiveness of this method depends on the chopping fraction. Small phase shift applied at the inverter output current at PCC resulting in a change in frequency. Due to this, there is a deviation

of inverter current frequency from grid frequency. chopping fraction is directly proportional to the difference of grid frequency and measured frequency and it is given by [14].

$$\text{Chopping fraction } (c_f) = c_{f0} + K(f - f_0) \quad (4)$$

Where,  $c_{f0}$  is chopping fraction without error in the frequency,  $K$  is controller gain  $f$  is grid frequency,  $f_0$  is measured frequency. This scheme has a narrow NDZ related to all other active detection methods. this scheme becomes powerful when used with combination with Sandia voltage shift.

### iii. Slip Mode Frequency Shift (SMFS)

Islanding condition can be detected by applying positive feedback to the inverter current which changes the phase angle of voltage at PCC [10]. the phase angle of inverter is given by

$$\theta_i = \theta_m \sin\left(\frac{\pi}{2} \times \frac{f_i - f_g}{f_m}\right) \quad (5)$$

Where,  $f_g$  is frequency of the grid,  $f_i$  is frequency of in the inverter,  $f_m$  is frequency obtained from SMFS,  $\theta_m$  is phase angle obtained from SMFS. This method has very small NDZ and one of the main benefits is that it is easy to implement. [3]. Figure 7 shows response curve of SMFS

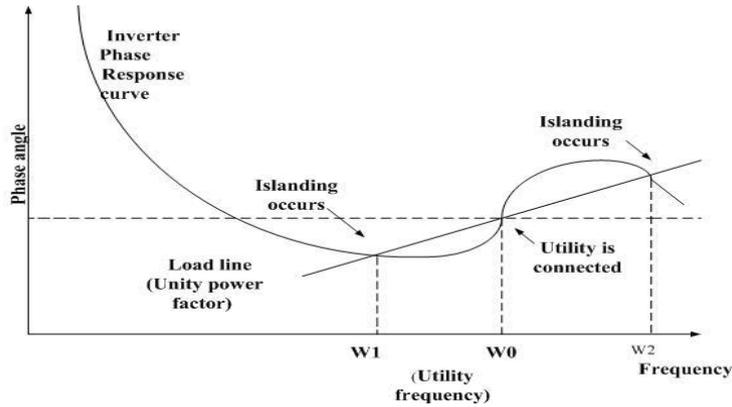


Fig.8. Operating Principle of SMFS

### iv. Automatic Phase Shift (APS)

In the case of AFD and SMS method, there is a possibility of non-detection zone for parallel RLC load as the starting angle of RLC load is a function of operating frequency. APS method is succeeding in dealing with this problem. the frequency of the preceding voltage cycle is calculated at  $p^{\text{th}}$  zero crossings of the voltage. Here phase angle of output current of DG fluctuates with frequency of earlier voltage cycle as [15].

$$\theta^{(p)} = \frac{1}{\alpha} \left( \frac{f^{(p-1)} - f_n}{f_n} \right) 360^\circ + \theta_0^{(p)} \quad (6)$$

when the frequency of terminal voltage reaches before UFP/OFP, the additional phase changes as

$$\theta_0^{(p)} = \theta_0^{(p-1)} + \Delta\theta \times \text{sgn}(\Delta f_{ss}) \quad (7)$$

Where,  $\Delta f_{ss}$  is steady state frequency deviation and  $\Delta\theta$  is constant

$$\begin{aligned} \text{sgn}(\Delta f_{ss}) &= 1, \Delta f_{ss} > 0 \\ &= 0, \Delta f_{ss} = 0 \\ &= -1, \Delta f_{ss} < 0 \end{aligned}$$

Table 1: Comparison of different islanding detection schemes

Parameters	Local method		Remote method
	Passive	Active	
Detection time	Short	Long	Very Short
NDZ	Large	Small	None
Cost	Low	Low	Very High
Effectiveness	Depend on supply and load condition	Effective	Very effective
Multi DG operation	Possible	Not possible	Possible
Reliability	Low	High	High

## III. CONCLUSION

This paper has discussed several remote, passive and active methods for distributed energy resource islanding detection. Assessment of these various methods can offer convenient data for defining a technique to use for islanding protection. Nowadays, high accuracy and detection of islanding within a short span of time is one of the key challenges in the power system. Review of numerous passive and active islanding detection techniques propose that active islanding detection technique as the most preferred detection technique with more cost effective, reliable and small non-detection zone.

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