STUDY OF ISLANDING DETECTION METHODS

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***Abstract*—** As the cost effective distributed generators technology increases their importance on the electric power system, then to a greater extent the parameters of the system have to be controlled in order to assure the proper operation of the utility. One of the main problem encountered with this kind of generation is the potential formation of Islands which could continues working in a normal way even if the utility grid has failed. Many methods have been developed to prevent this condition and they have been classified into three groups of method namely passive, active and hybrid methods. The wide use of Distributed Generators in Electrical and power systems made it a must to survey its functionality and the issues related to their connection to the grid. One of the main issue is unintentional islanding, which has been considered and studied for many years since it has serious consequences on electric systems and line workers safety.

***Keywords*—** Distribution Generation, Islanding, Anti-Islanding, Need , Anti-Islanding Methods.

I. INTRODUCTION

Distributed generation refers to a variety of technologies that generate electricity at or near where it will be used, such as solar panels and combined heat and power. In the residential sector, common Distributed generation systems include: Solar photovoltaic panels, Small wind turbines .Solar power generators, wind generators, gas turbines and micro generators such as fuel cells, micro turbines, etc.

It is a generating resources, other than central generating stations, that is placed close to load being served, usually at customer site. The number of DG in distribution system is rising as DG can avoid transmission and distribution (T&D) capacity upgrades, reduce transmission and distribution line losses, improve power quality, improve voltage profile of the system etc [9]. In fact, many utilities around the world already have a significant access of DG in their system. But there are many issues to be taken into account with the DG and one of the main issues is islanding.

Island mode operation relates to those power plants that operate in isolation from the national or local electricity distribution network. Generators connected to the electricity grid in parallel mode, which can generate independently in the event of a grid power supply Failure. A common example of Islanding is a distribution feeder that has solar panels attached to it. Island mode operation relates to power plants that operate in isolation from the national or local electricity distribution network. Generators connected to the electricity grid in .The parallel mode, can generate power independently in the event of a grid power outage.

The type of Connections of renewable power generators to the utility are set the structure of the electric power system (EPS). The system is including a tree structure with the generation produced by big power plants as well a net structure plenty of small distributed points of generation. These distributed generators (DG) offer the possibility to combine dispersed generation with local energy storage and use, reducing the energy losses produce along the transport and distribution lines and incrementing in this way the Electric Power System efficiency as well as the power quality.

One of the most important problems to fix is related with the potential generation of islands. Fig. 1 illustrate the situation of islanding. if the EPS fails and the DG keeps on working in normal operation, energizing distribution lines and local loads connected to it, an electric isolated island is formed. This problem, known as islanding operation, is to be avoided since it could involve important and serious consequences from the EPS side, security measures have to be adopted in order to ensure the safety of the personnel working on the utility along with the guarantee the reliability of the utility grid.

Islanding may occur because of the following conditions:

1. At the utility end, some fault is detected and a disconnecting device operates, but it is not detected by the PV inverter or protection devices.
2. Equipment failure may cause accidental opening of the normal utility supply.
3. Intentional disconnect for servicing either at a point on the utility or at the service entrance.
4. Human error or malicious mischief/sabotage
5. An Act of Nature[3]

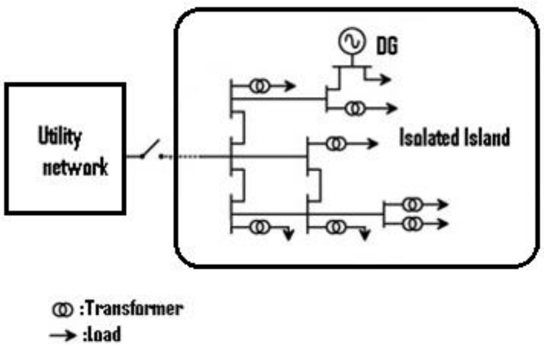

Figure 1: Islanding operation

II. ANTI-ISLANDING OR ISLANDING PROTECTION

As already explained that Islanding refers to the condition of a DG generator that continues to feed the circuit with power ,even after power from the electric utility grid has been cut off. Hence Islanding can pose a dangerous threat to utility workers, who may not realize that a circuit is still live while attempting to the work on the line. Distributed generators must detect islanding and immediately stop feeding the utility lines with power. This is known as Anti-Islanding. A grid tied solar power system is required by law to have a grid tie inverter with an anti-islanding function, which senses with the power outage occurs and shut itself off.

To avoid the Islanding problem, it is recommended that all distributed generators shall be equipped which devices to prevent islanding. The act of preventing islanding from happening is also called anti-islanding.

Islanding causes many problems, some of which are listed below:

A) Safety Concern

B) Damage to customer's appliances & equipments

C) Damage of Inverter, electric components & circuits

A) Safety Concern:

Safety is the main concern, as the grid may still be powered in the event of a power outage due to electricity supplied by distributed generators, as already explained . This may confuse the utility workers and expose them to hazards such as shocks.

B) Damage to customer's appliances & equipments :

Due to islanding and distributed generation, there may a bi-directional flow of electricity. This may cause severe damage to electrical equipment, appliances and devices Some devices are more sensitive to voltage fluctuations and should always be equipped with surge protectors.

C) Damage of Inverter, electric components & circuits:

In the case of large solar systems, number of inverters are installed with the distributed Generators. Islanding could cause problems in proper functioning of the inverters. Instantaneous reclosing could result in out of phase reclosing of DG. As a result of which large mechanical torques and currents are created that can damage the generators or prime Movers Also, transients are created, which are potentially damaging to utility and other customer equipment.

Out of phase reclosing, if occurs at a voltage peak, will generate a very severe capacitive switching transient and in a lightly damped system, the crest over-voltage can approach three times rated voltage Islanding causes Various risks resulting from this include the degradation of the electric components as a consequence of voltage& frequency drifts. Due to these reasons, it is essential to detect the Islanding quickly and accurately.

III. DISCUSSION ON DIFFERENT ANTI-ISLANDING METHODS OR ISLANDING DETECTION TECHNIQUES

The main thing of detecting an islanding situation is to monitor the DG output parameters and system parameters and decide whether or not an islanding situation has occurred from change in these parameters. Islanding detection techniques can be divided into remote and local techniques and local techniques can further be divided into passive, active and hybrid techniques as shown in Figure 2

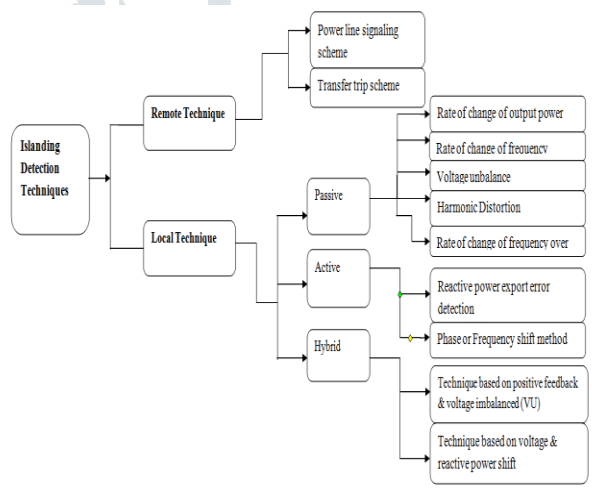

Figure 2 : Islanding detection techniques

3.1 Remote Islanding detection techniques:

Remote Islanding detection techniques are based on communication between utilities and DGs. Although these techniques may have better reliability than local techniques, they are expensive to implement and hence uneconomical .Some of the remote islanding detection techniques are as follows:

3.1.1 Power line signaling scheme:

These methods use the power line as a carrier of signals to transmit islanded or non-islanded information on the power lines. The apparatus includes a signal generator at the substation (25+ kV) that is coupled into the network where it continually broadcasts a signal as shown in figure (2.2). Due to the low-pass filter nature of a power system, the signals need to be transmitted near or below the fundamental frequency and not interfere with other carrier technologies such as automatic meter reading. Each DG is then equipped with a signal detector to receive this transmitted signal. Under normal operating conditions, the signal is received by the DG and the system remains connected. However, if an island state occurs, the transmitted signal is cut off because of the substation breaker opening and the signal can not be received by the DG, hence indicating an island condition. This method has the advantages of its simplicity of control and its reliability. In a radial system there is only one transmitting generator needed that can continuously relay a message to many DGs in the network. The only times the message is not received is if the interconnecting breaker has been or if there is a line fault that corrupts the transmitted signal.

There are also several significant disadvantages to this method, the fist message is not received is if the interconnecting breaker has been opened, or if there is a line fault that corrupts the transmitted signal. There are also several significant disadvantages to this method, the fist being the practical implementation. To connect the device to a substation, a high voltage to low voltage coupling transformer is required. A transformer of this voltage capacity can have prohibitive cost barriers associated with it that may be especially undesirable for the first DG system installed in the local network. Another disadvantage is if the signaling method is applied in a non radial system, resulting in the use of multiple signal generators. Another problem for power line communication is the complexity of the network and the affected networks. A perfectly radial network with one connecting breaker is a simple example of island signaling; however, more complex systems with multiple utility feeders may find that differentiation between upstream breakers difficult.

3.1.2 Transfer trip scheme:

The basic idea of transfer trip scheme is to monitor the status of all the circuit breakers and reclosers that could island a distribution system. Supervisory Control and Data Acquisition (SCADA) systems can be used for that. When a disconnection is detected at the substation, the transfer trip system determines which areas are islanded and sends the appropriate signal to the DGs, to either remain in operation, or to discontinue operation. Transfer tip has the distinct advantage similar to Power Line Carrier Signal that it is a very simple concept. With a radial topology that has few DG sources and a limited number of breakers, the system state can be sent to the DG directly from each monitoring point. This is one of the most common schemes used for islanding detection.

The weaknesses of the transfer trip system are better related to larger system complexity cost and control. As a system grows in complexity, the transfer trip scheme may also become obsolete, and need relocation or updating. Reconfiguration of this device in the planning stages of DG network is necessary in order to consider if the network is expected to grow or if many DG installations are planned. The other weakness of this system is control. As the substation gains control of the DG, the DG may lose control over power producing capability and special agreements may be necessary with the utility. If the transfer trip method is implemented correctly in a simple network, there are no non-detection zones of operation.

3.2 Local detection techniques

It is based on the measurement of system parameters at the DG site, like voltage, frequency, etc. It is further classified as:

3.2.1 Passive detection techniques

Passive methods work on measuring system parameters such as variations in voltage, frequency, harmonic distortion, etc. These parameters vary greatly when the system is islanded. Differentiation between an islanding and grid connected condition is based upon the thresholds set for these parameters. Special care should be taken while setting the threshold value so as to differentiate islanding from other disturbances in the system. Passive techniques are fast and they don't introduce disturbance in the system but they have a large non detectable zone (NDZ) where they fail to detect the islanding condition.

There are various passive islanding detection techniques and some of them are as follows:

(a) Rate of change of output power:

The rate of change of output power *dp/dt* at the DG side, once it is islanded, will be much greater than that of the rate of change of output power before the DG is islanded for the same rate of load change. It has been found that this method is much more effective when the distribution system with DG has unbalanced load rather than balanced load.

(b) Rate of change of frequency:

The rate of change of frequency *df/dt* will be very high when the DG is islanded. The rate of change of frequency (ROCOF) can be given by ,

$$\text{ROCOF, } df/dt = (\Delta p/2HG)\times f$$

Where, ΔP is power mismatch at the DG side

H is the moment of inertia for DG/system

G is the rated generation capacity of the DG/system

Large systems have large H and G where as small systems have small H and G [4]

giving larger value for *df/dt* ROCOF relay monitors the voltage waveform and will operate if ROCOF is higher than setting for certain duration of time. The setting has to be chosen in such a way that the relay will trigger for island condition but not for load changes. This method is highly reliable when there is large mismatch in power but it fails to operate if DG's capacity matches with its local loads. However, an advantage of this method along with he rate of change of power algorithm is that, even they fail to operate when load matches DG's generation, any subsequent local load change would generally lead to islanding being detected as a result of load and generation mismatch in the islanded system.

(c) Voltage unbalance:

Once the islanding occurs, DG has to take change of the loads in the island. If the change in loading is large, then islanding conditions are easily detected by monitoring several parameters are voltage magnitude, phase displacement, and frequency change. However, these methods may not be effective if the changes are small. As the distribution networks generally include single-phase loads, it is highly possible that the islanding will change the load balance of DG. Furthermore, even though the change in DG loads is small, voltage unbalance will occur due to the change in network condition.

(d) Harmonic distortion:

Change in the amount and configuration of load might result in different harmonic currents in the network, especially when the system has inverter based DGs. One approach to detect islanding is to monitor the change of total harmonic distortion (THD) of the terminal voltage at the DG before and after the island is formed. The change in the third harmonic of the DG's voltage also gives a good picture of when the DG is islanded.

(e) Rate of change of frequency over power:

df/dp in a small generation system is larger than that of the power system with larger capacity. Rate of change of frequency over power utilize this concept to determine islanding condition .Further more, test results have shown that for a small power mismatch between the DG and local loads, rate of change of frequency over power is much more sensitive than rate of frequency over time.

3.2.2. Active detection techniques:

With active methods, islanding can be detected even under the perfect match of generation and load, which is not possible in case of the passive detection schemes. Active methods directly interact with the power system operation by introducing perturbations. The idea of an active detection method is that this small perturbation will result in a significant change in system parameters when the DG is islanded, whereas the change will be negligible when the DG is connected to the grid.

(a) Reactive power export error detection:

In this scheme, DG generates a level of reactive power flow at the point of common coupling (PCC) between the DG site and grid or at the point where the Reed relay is connected. This power flow can only be maintained when the grid is connected. Islanding can be detected if the level of reactive power flow is not maintained at the set value. For the synchronous generator based DG, islanding can be detected by increasing the internal induced voltage of DG by a small amount from time to time and monitoring the change in voltage and reactive power at the terminal where DG is connected to the distribution system. A large change in the terminal voltage, with the reactive power remaining almost unchanged, indicates islanding. The major drawbacks of this method are it is slow and it can not be used in the system where DG has to generate power at unity power factor.[3]

(b) Phase (or frequency) shift methods:

Measurement of the relative phase shift can give a good idea of when the inverter based DG is islanded. A small perturbation is introduced in form of phase shift. When the DG is grid connected, the frequency will be stabilized. When the system is islanded, the perturbation will result in significant change in frequency. The Slip-Mode Frequency Shift Algorithm (SMS) uses positive feedback which changes phase angle of the current of the inverter with respect to the deviation of frequency at the PCC. This detection scheme can be used in a system with more than one inverter based DG. The drawback of this method is that the islanding can go undetected if the slope of the phase of the load is higher than that of the SMS line, as there can be stable operating points within the unstable zone.

4.2.3 Hybrid detection schemes:

Hybrid methods employ both the active and passive detection techniques. The active technique is implemented only when the islanding is suspected by the passive technique. Some of the hybrid techniques are discussed as follows:

(a) Technique based on positive feedback (PF) and voltage imbalance (VU):

This islanding detection technique uses the PF (active technique) and VU (passive technique). The main idea is to monitor the three-phase voltages continuously to determinate VU which is given as ,

VU=v+sq/v- sq

*V +Sq*and *V-Sq*are the positive and negative sequence voltages, respectively. Voltage spikes will be observed for load change, islanding, switching action, etc. Whenever a VU spike is above the set value, frequency set point of the DG is changed. The system frequency will change if the system is islanded.

(b) Technique based on voltage and reactive power shift:

In this technique voltage variation over a time is measured to get a covariance value (passive) which is used to initiate an active islanding detection technique, adaptive reactive power shift (ARPS) algorithm.

IV. METHODOLOGY

4.1 Proposed Islanding Detection Technique

Fig. 3 shows the system model was used to test the performance of the proposed Islanding detection technique. The modeled circuit is the same as the Anti-Islanding testing circuit defined in UL 1741 (Standard for Inverters, Converters Controllers and Interconnection System Equipment for Use with Distributed Energy resources) and the testing procedure requires that the active and reactive power supplied from the DG match the power required by the test load Because the load is very close to the DG compared with the grid, almost all the power required by the load is taken from the DG Therefore, when Islanding takes place, the detection is difficult.[4]

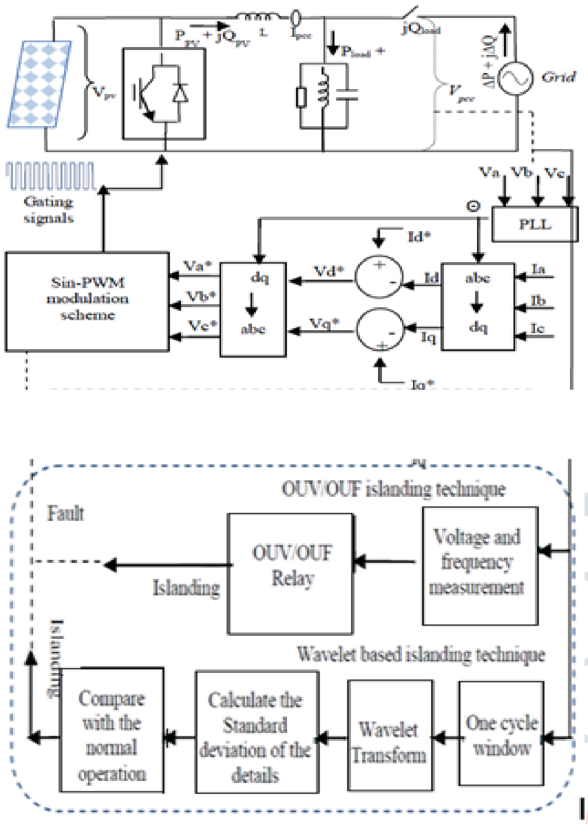

Figure 3: Circuit diagram of proposed circuit

4.1 OUV/OUF passive islanding technique

The first discussed passive method is the Over/under voltage and over/ under frequency (OUV/OUF), which is one of the most used passive anti-islanding detection technique. These 2013 IEEE GCC Conference and exhibition, November 17-20, Doha, Qatar 978-1- techniques basically monitor the system's voltage and frequency in order to decide whether or not an islanding has taken a place [4].

Thresholds for UOV and UOF can be calculated as follows:

$$\left(\frac{V}{V_{max}}\right)^2 - 1 \leq \frac{\Delta P}{P_{DG}} \leq \left(\frac{V}{V_{min}}\right)^2 - 1 \qquad (1)$$

$$Q_f.\left(1 - \left(\frac{f}{f_{min}}\right)^2\right) \leq \frac{\Delta Q}{P_{DG}} \leq Q_f.\left(1 - \left(\frac{f}{f_{max}}\right)^2\right) \qquad (2)$$

Where Vmax, Vmin, f max and fmin are the UOV and UOF thresholds. Typically, Vmax=110% and Vmin=88% of the nominal voltage. fmax= 60.5 Hz and fmin=95.3 Hz

Then for Qf= 2.5:

$$-17.36\% \leq \frac{\Delta P}{P_{DG}} \leq 23.46\% \qquad (3)$$

$$-4.22\% \leq \frac{\Delta Q}{P_{DG}} \leq 4.12\% \qquad (4)$$

These limits define the non detection zone shown in Fig 2.

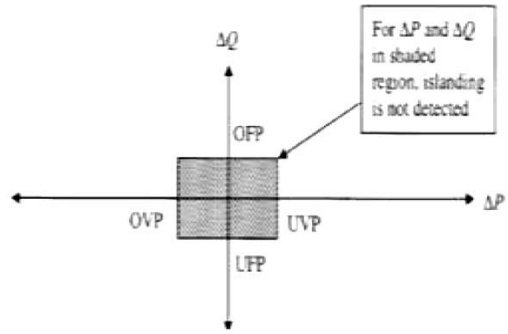

Figure 4: None- detection zone for UOV and UOF passive techniques

The shaded area in Fig. 4 is defined as the NDZ where the islanding is not detectable. In fact the efficiency of Islanding detection methods are categorized according to the area of the no detective zone (NDZ),defined in power mismatch space (ΔP versus ΔQ) at Point of Common Coupling (PCC). ΔP is the real power output of the grid, ΔQ is the reactive power output of the grid, PDG and QDG are the real output power and reactive output power of the distributed generation respectively.

Pload and Qload are the real output power and reactive output power of load respectively.

$$P_{load} = P_{DG} + \Delta P$$

$$Q_{load} = Q_{DG} + \Delta Q$$

The behavior of the system at the time of utility disconnection will depend on ΔP and ΔQ at the instant before the Breaker open to form island. Active power is directly proportional to the voltage. After the disconnection of the grid, the active power of the load is forced to be the same with the power generated by the distributed generation; hence the grid voltage changes. The change in reactive power corresponds to the change in frequency and the amplitude of the voltage. The worst case for islanding detection is represented by a condition of balance of the active and reactive power in which there is no change in amplitude and frequency, i.e. ΔP=0 and ΔQ=0 [4].

As the islanding occurred the change in active power and reactive power leads to changes in voltage and frequency. Considering the proportional relationship between the active power and voltage and the reactive power and frequency respectively; a large mismatch in power results a drift in voltage and frequency to exceed the limits of the NDZ and to detect an islanding.

V. CONCLUSION

The paper introduces number of Anti-Islanding detection techniques, and illustrates the differences among them and the advantages of each one. The passive methods should be enough protection in most cases, active methods should be added to all the new systems to ensure the correct functioning .In this paper we discussed two passive Islanding techniques namely OUV/OUF(over/under voltage / over/under frequency) and the wavelet based islanding detection, these techniques have shown no effect on power quality. Though ,OUV/OUF is easy and simple to implement it has the disadvantage of having large NDZ(Non-detection zone). In contrast, the wavelet based technique showed potential in detecting islanding even if the power mismatch is smaller.

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