International Journal of Innovation and Scientific Research
ISSN 2351-8014 Vol. 8 No. 2 Sep. 2014, pp. 234-241

http://www.ijisr.issr-journals.org/

Comparative of Islanding Detection Passive Methods for Distributed Generation Applications

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ABSTRACT: One of the important protection characteristics in online distributed generation is to identify the islanding operation. And in accordance with standards of Distribution network in power system, this identification must take in less Than 2 seconds. There are several Methods in Micro grids islanding detection. Islanding detection technique may generally be divided into remote and local techniques. In remote, The detection algorithm is on the grid side, in local the detection is on the DG side. Local Techniques consisting of active and passive and hybrid methods. Passive methods have been studied in This paper. The most commonly used passive islanding detection techniques are presented in This paper. This paper aims to compare these methods with their non-Detection zone and speed of detection. The comparison can help researchers determine the best method for their product.

KEYWORDS: Distribution Generation, islanding detection, Micro grid, Passive method.

1 INTRODUCTION

Recently by introducing and increasing the penetration of distributed generation (DG), electricity restructuring and also the need of reducing greenhouse emissions Micro Grids have emerged. A Micro Grid (MG) can be defined as a Low-Voltage Networks comprising distributed generation resources(micro turbines, fuel cells, solar photovoltaic modules, small wind turbines and synchronous generators) plus its loads and storage devices (flywheel and capacitors) and it can provide both power and heat to local loads. MG is normally connected to Medium Voltage networks. In emergency mode micro grid can operate autonomously i.e. disconnected from upstream MV network. The most challenging issue of micro grids is power islanding, which is defined as “a condition in which a portion of utility system that contains both loads and distributed energy resources remains energized while isolated from remainder of utility system[1]. Islanding is either intentional or unintentional, the former is for maintenance and load shedding and the latter is because of fault and equipment failure. Unintended Islanding operation has several drawbacks including inadequately grounded system depending on the transformer connections[2], line worker safety risks, and significant variation in voltage and frequency, distributed resources damaging due to out-of-phase reclosing, tripping the line due to out of synchronism[3]. According to IEEE Std. 1547-2003 the anti-islanding relay must immediately disconnect the DG, in less than 2 seconds of the establishment of a power island[1]. Several methods have been proposed for islanding detection. In general islanding detection methods can be divided into two main groups: 1) remote methods and 2) local (active, passive and hybrid) methods. This classification is shown in Figure 1. Remote methods such as Power line communication, supervisory control and data acquisition, transfer-trip are based on communication between the grid and the DGs. They don't have a non-detection zone (NDZ) and also they have better reliability than local methods but they are more expensive to implement and uneconomical especially for small DG systems. Local methods are based on the measurement of DG output parameters. They classified into three categories: active, passive and hybrid. In active methods small external perturbation are injected locally into the system. In normal operation these Perturbation doesn't cause a significant Deviation in the operating conditions due to the presence of the utility. In the absence of the utility, however small deviations will be amplified, so it becomes easy to detect the islanding conditions. Since active methods inject abnormal inputs into the DG output, this degrades the power quality and it would be undesirable for the utility and its customers. In fact, the system responses of These perturbations are used to detect islanding conditions. If the active and reactive power imbalance in the islanded system is small, active methods will detect islanding conditions. It Means that these methods have very small NDZ. Passive methods are based on Monitoring system parameters such as voltage, current, frequency, harmonic distortion, etc. They make their decision to trip without directly interacting with system operation. Hybrid methods include a combination of an active and a passive techniques. It will overcome the short comings of both active and passive techniques. The active technique is used only when the islanding is suspected by the passive technique [3-5].The most significant advantage of Passive islanding detection is that it doesn't influence the power quality. The passive methods do not affect the waveform of high voltage. Only passive technique has the ability to be used in both anti islanding Protection Strategy and MG operation modes (disconnection from upstream network). So this paper aims to provide useful information in passive islanding detection techniques.This paper is organized as follows: section 2 represents most type of passive techniques, section 3 provide a comparison analysis between the passive methods. Finally some conclusions are represented.

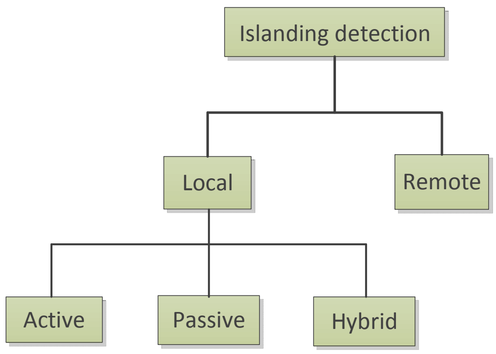

Fig1: Classification of islanding detection technique

2 PASSIVE ISLANDING DETECTION METHODS

The main philosophy of passive methods is to monitor the DG output parameters because when MG is isolated from the main grid the system parameters are start to vary dynamically. In following subsections some of passive islanding detection methods are presented.

2.1 UNDER VOLTAGE/ OVER VOLTAGE

Traditional voltage relays are commonly used. they measure the voltage magnitude at the DG side and trip the generator if the voltage have been abnormal during a certain time. The relay can respond to over and under voltage circumstances. In Principles the method relies on reactive power imbalances between production and consumption, which occurs after loss of mains. This leads to a change in voltage level, which can be measured locally[6].

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

There is relatively large NDZ therefore traditional relays are used as a secondary or backup protection relays.

2.2 UNDER FREQUENCY/ OVER FREQUENCY

A frequency relay makes its decision based on the frequency of voltage at the DG terminal. They are based on the frequency change introduced in island. If the frequency rises above (over frequency) or drops below (under frequency) predetermined thresholds, the relay will trip and DG will be isolated from the main grid [6].

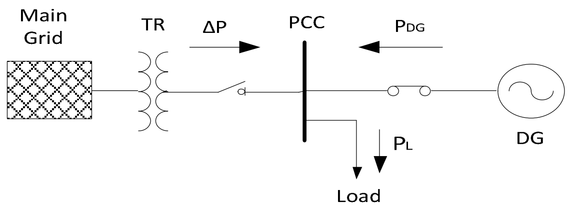

Fig2: System representation for anti-islanding methods

$$P_L = P_{DG} + \Delta P \qquad (1)$$

Equation (1) describe the power balance of the system. If P_L=P_{DG} there is no active power mismatch (ΔP=0) between the DG and Main Grid. It is worth to mention that the active power is directly proportional to the frequency. If the power imbalance in the islanded system is small, The frequency will change slowly so these relay can't detect islanding successfully, So it have a large NDZ.

2.3 RATE OF CHANGE OF FREQUENCY

Rate Of Change Of Frequency (ROCOF) is today the most commonly employed Loss Of Main (LOM) detection method because it is very simple and cheaper than that of other methods. ROCOF relays rely on the assumption that when islanding occurs, there is an imbalance between the generation and load in the formed island. Immediately after islanding, the resulting power imbalance will cause the frequency to change dynamically. The rate of change of frequency can be calculated from swing equation of the synchronous generator, which is given bellow:

$$\frac{df}{dt} = \frac{1}{2\pi}\frac{d\omega}{dt} = \frac{f_0}{2H}\Delta P \qquad (2)$$

Where ΔP is power mismatch at the DG side, H is the generator inertia constant for DG system, f_0 is the system nominal frequency, ω is the generator speed.

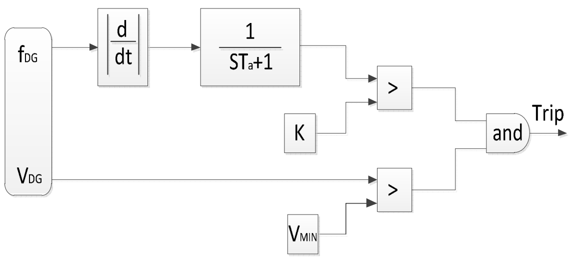

Fig3: ROCOF relay model

ROCOF relay model is illustrated in Fig 2 in which T_a is the time constant of the filters. If the output of low pass filter is larger than the relay setting and also the magnitude of the terminal voltage is larger than the minimum voltage setting, the ROCOF relay send a trip signal to the DGs Circuit Breaker. ROCOF relay method is highly reliable when there is large power mismatch but it may require an active power imbalance higher than 15% to detect islanding suitably[7-9].

2.4 VOLTAGE VECTOR SHIFT RELAY

If the MG becomes islanded, the generator will begin to feed a larger load (or smaller) because the current provided by (or injected into) the power grid is abruptly interrupted. Thus, the generator begins to decelerate (or accelerate). The increase (decrease) in current causes to change the DG terminal voltage(V_T). Consequently, the difference between V_T and generator internal voltage (E_I) is suddenly increased (or decreased) and the terminal voltage phasor changes its direction. as shown in Fig4. VS relay is very fast in comparison to other method such as ROCOF but it is sensitive to network faults and it has large NDZ i.e. for the setting of 6° it may require an active power mismatches more than 30% Sn to detect islanding situation[10, 11].

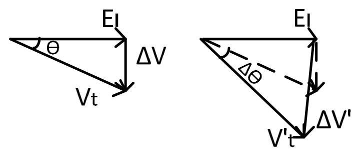

Fig 4: DG terminal voltage vector shift

2.5 PHASE JUMP DETECTION METHOD

Phase jump detection (PJD) method are based on monitoring the phase differences between the main grid voltage and DG current. In the presence of main grid, DG current is synchronized with the main grid voltage through a phase locked loop. When Mg is disconnected from main grid, the phase angle will change and it will exceed the predetermined threshold. The phase criterion for PJD is presented by:

$$\tan^{-1}\left[R\left(\omega_0 C - \frac{1}{\omega_0 L}\right)\right] \leq \theta_{th}$$

where *R*, *C* and *L* are respectively load resistance, capacitance and inductance. ω_0 is main grid voltage frequency.

The advantage of this method is its easy implementation, however the threshold selection cause difficulty in islanding Detection because the phase can be affected by certain loads such as motor loads or simply by presence of load that can not produce phase angle change. Also, this method can not detect islanding when the load power factor is near unity. Fig.5 shows the operation of voltage when it is disconnected from main grid[12].

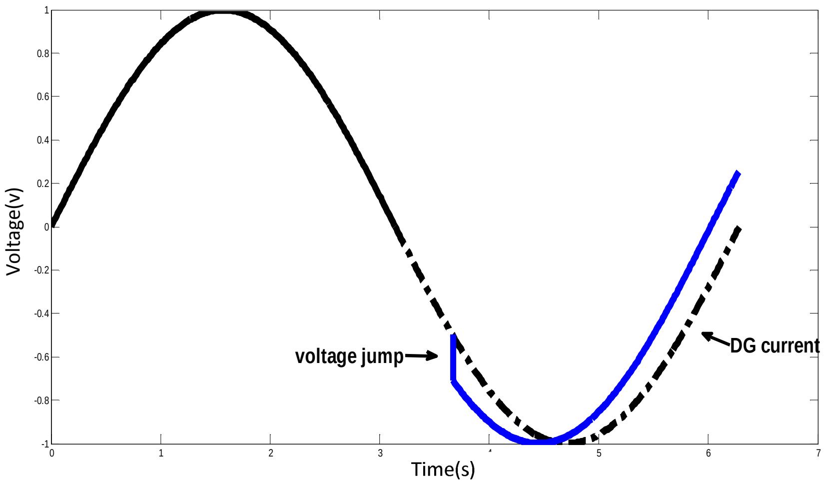

Fig5: Phase jump method Operation

2.6 VOLTAGE UNBALANCED AND TOTAL HARMONIC DETECTION

The principal of this method is to detect total harmonic distortion of the terminal voltage at the DG side. In normal operation main grid can be considered as a stiff voltage source which providing sinusoidal voltage waveform. when main grid is disconnected, the voltage harmonic will increase due to interaction between high impedance of islanding load and harmonic current produced by inverter. If the THD becomes higher than the certain threshold islanding condition can be detected successfully. This method have advantage that it does not have an NDZ when there is power balance in MG because it doesn't rely on active and reactive mismatches at the instant of islanding. But this Methods is similar to other methods which are suffering from determining appropriate threshold for islanding detection, because non-linear loads may cause voltage distortion to be high so it can be detected as islanding condition. Furthermore linear load doesn't affect THD voltage significantly so it can be hard to detect islanding[13]. In [2] a new islanding detection based on measuring voltage unbalance and change in the voltage total harmonic distortion from all the phase components are presented. This method is able to detect very fast and selectively islanding situations in a perfect power balance without NDZ. It also intelligently utilizes the available fault detection information with islanding verification logic.

2.7 RATE OF CHANGE OF ACTIVE POWER

This method is based on measuring the rate of change of power, dP/dt, at the DG side. There will be a significant change in dP/dt before and after islanding situations. The instantaneous three phase DG output power are illustrated by:

$$P_g = V_a i_a + V_b i_b + V_C i_C$$

Where V_a, i_a, V_b, i_b, V_C, i_C represent the sampled values of line currents and phase voltages measured at the generator's terminals. This algorithm monitors and integrates the changes in output power, ΔP_g and then compares it with predetermined thresholds which is defined by:

$$\sum_{n=-tx}^{n=0} (\Delta P_g)_n > K_s$$

Where n is sampling instant, tx is the length of measuring window and K_S is tripping threshold. The advantage of dP/dt is that they are economical but it cannot detect islanding properly under all LOM situations. For example, output power of some renewable sources are changing with time so finding an appropriate threshold for this method is difficult[8, 14, 15].

2.8 RATE OF CHANGE OF FREQUENCY OVER POWER

This method monitors the change of df/dP_L. This method has the merit of islanding detection even in situations that dP_L is small, because the value of df/dP_Lcan be large enough to be detected by relay. it also more reliable and has lower NDZ than ROCOF relay. This method have two different threshold so settings of these threshold would be rather difficult[15].

2.9 COMPARISON OF RATE OF CHANGE OF FREQUENCY (COROF)

COROCOF is based on measuring change of frequency such as ROCOF but at two location, i.e. main grid and DG side. COROCOF differentiate between rate of change of frequency due to LOM and network perturbations. At main grid the ROCOF is measured and if the value exceed the limits a block signal will transfer to the DG. At DG side the ROCOF will also be determined. When DG has not received any blocking signal and the value of rate of change of frequency has exceeded the threshold the Relay will send trip[16].

Due to much computational work the practical implementation of this method is very difficult.

2.10 RATE OF CHANGE OF PHASE ANGLE DIFFERENCE (ROCOPAD)

ROCOPAD method monitors the voltage and current signals at the DG side and estimating the phasors (amplitude, phase and frequency). Then the phase angle difference must be calculated and compared with the threshold. ROCPAD is obtained as follow:

$$ROCOPAD = \frac{\Delta(\delta_V - \delta_i)}{\Delta t}$$

Where δ_V and δ_i are voltage and current phase angles. The ROCPAD relay can successfully detect islanding condition even under active power balances in Mg. they also have fast response[17].

2.11 INTELLIGENT BASED METHOD

In these approach various system parameters that could affect islanding can be measured locally. Some important parameters are change of voltage, change of frequency, ROCOF, ROCOP, ROCOFOP, change of harmonic distortion, change of power factor and etc. These techniques use data-mining technology such as neural networks, support vector machines and decision tree to extract information from the large data sets which are obtained by network off-line simulations during predetermined events. These are more accurate methods to detect islanding in multi-DG system and has the ability to optimize the threshold values. Their NDZ are small and has faster operation time. However it involves much computational works so the implementation of this technique may be time consuming[18-20].

2.12 WAVELET TRANSFORM-BASED METHOD

Wavelet transform provide information about time and frequency of a waveform and it is efficient method for analysis of transient signals that are non-stationary data. Recently wavelet transform-based method have been used for islanding detection. In this method voltage and current are monitored and then the energy coefficient of these transient signals are extracted by wavelet transform. If these values exceed certain thresholds the protective relay will detect islanding conditions. Fig.6 shows the basic model of the transient-based islanding detection technique.

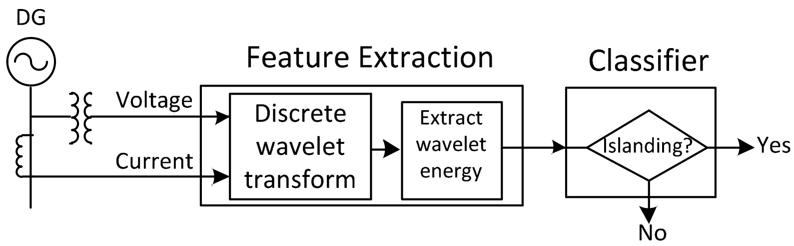

Fig.6 basic model of wavelet transform-based method

Wavelet transform-based has the privilege of being fast and reliable. However it is associated with high computational process. Reference [21]proposed a method using wavelet transform and S-transform in order to extract features for detection of islanding and power quality disturbances. The results show that wavelet degrades significantly under noisy signals, while ST is considered to detect the disturbances correctly under both noise free and noisy scenarios[22, 23].

2.13 ESTIMATION-BASED METHOD

The basic idea of this method is to estimate the voltage, current and frequency of signal in order to draw out necessary features. Reference [24] uses a fast gauss-newton algorithm for islanding detection. The algorithm can estimate current and voltage parameters accurately in a recursive manner for realistic power system even in the presence of significant noise. It also use data mining approach to classify estimated features.In [25] a statistical signal-processing algorithm known as estimation of signal parameters via rotational invariance techniques is utilized to extract features from power system voltage and frequency waveforms. It reduce the NDZ but in small voltage and frequency deviation it takes long time to detect islanding. Also the complexity of computational process for this algorithm is high.

Table 1 . comparison of passive islanding detection method

Technique	Concept	NDZ	Speed
Under/Over Voltage	Voltage Change	Large	Low
Under/Over Frequency	Frequency change	Large	Low
Rate of change of frequency	Frequency variation over time	Smaller than OF/UF	Faster than OF/UF
Voltage Vector shift	Terminal voltage vector change	Larger than ROCOF	Faster than ROCOF
Phase jump detection	Phase voltage change	Large	Low
Voltage unbalance and total harmonic detection	Measuring voltage unbalance and THD	Small	Faster than OF/UF & OV/UV
Rate of change of active power	Active power variation over time	Large	Faster than OF/UF & OV/UV
Rate of change of frequency over power	Frequency variation over power variation	Large	Faster than OF/UF & OV/UV
Comparison of rate of change of frequency over power	Comparing DG ROCOF with the main grid ROCOF	Smaller than ROCOF	Faster than ROCOF
Rate of change of phase angel difference	Change of phase angel between voltage and current	Small	Fast
Intelligent based method	Change in various parameters	Very small	Very fast
Wavelet transform-based method	Energy coefficient extraction	Almost Zero	Very fast
Estimation-based method	Parameter estimation	Very small	Fast

Tufts-Kumaresan signal estimation method [26] are used to detect islanding condition. This method uses a non-iterative algorithm for the estimation of the damping factor and oscillation frequency of DGs. This method is non-recursive and can estimate the signal parameters even in noisy status. It also has small NDZ. All of estimation based method are reliable, accurate, do not affect the system power quality but they suffer from high complexity in computation. Passive anti islanding classification is showed below. There is no exclusive passive method for islanding detection which will work successfully for all kinds of systems. It depends on the Type of DG systems to be protected. Also the most effective factors are time and the non-detection zones which can help the design engineer to choose the best method. Table 2 compare the speed of detection and the Non Detection Zone of different passive methods. It also illustrate

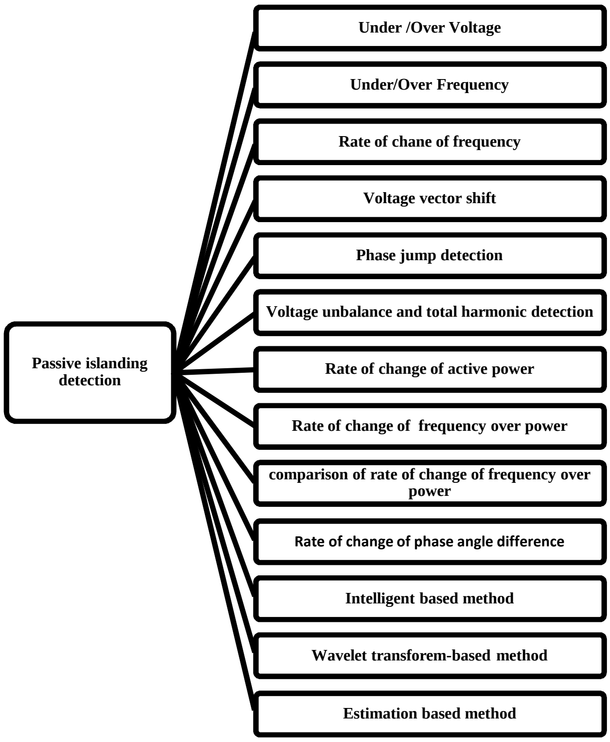

Fig7. Classification of passive islanding detection method

3 CONCLUSION

The main purpose of this paper was to review of different passive anti islanding methods. This paper compares different passive anti islanding methods. These methods can be used for all types of DG technology. They have the advantages of being cheap and easy to implement, using locally measured signal and making trip decision without impacting in system power quality. The drawbacks of this local method are that in some cases it has large non detection zones, in cases that NDZ are small the method is much more complicated and needs more computational process. The results shown in this paper indicate that the proposed methods has good performance.

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