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Overview of Islanding Detection Methods

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Abstract: ***Islanding is detected by all distributed generations (DGs), especially those connected at secondary distribution grids. Islanding methods are mainly classified in three main categories: Passive, Active, Communication based. Hybrid methods are first time discussed in this paper. These methods are under evolution and as their advantages are coming they become an important part of islanding detection techniques. Passive methods discussed are the over/under voltage (OUV), over/under frequency (OUF), monitoring of phase angle, and monitoring of harmonics in voltage methods, rate of change of phase angle difference. Active methods discussed are impedance measurement, harmonic injection and positive feedback methods. Communication based methods discussed are power line used for communication, signal generated from disconnection, SCADA based and Wide Area Measurement System (WAMS) based. Three hybrid methods are discussed and these methods are combination of active and passive methods. This paper is focused on discussion of different islanding methods and introduction of the hybrid methods.***

Keywords: Wavelet, Frequency, Harmonics, detection zone, non-detection zone

1. Introduction

Renewable energy resource based distributed generation registered a high growth rate. Distributed generation (DG) have a many important advantages such as peak shaving, reliability, improved environmental performance, fuel switching, and improved power quality. These advantages leads to a fast and continuous development in technology in this area of distributed generation bring these systems at a point where their reliability and complexity is not any more discussed. An inverter is used at grid end for the DG system which produces DC voltage and based on certain control strategy the switching of inverter is determined [1]. The DG is designed to produce either active and reactive power or active power only. However, for connecting the DGs to the grid certain conditions have to be met. IEC and IEEE normally published these conditions but also local regulating authorities (country). Every technology has some advantages and disadvantages. Similarly DG systems also have some technical issue inadvertent islanding is one of them [2]. Islanding operation is defined as the condition in which part of the grid having both DG and the load is disconnected from the remaining of the utility and remain energized. Faults are the main cause for the grid disconnection. Ideally, faults will be detected by the protection system of the DG and DG tripped before an islanding. DG grid connected islanding may occur as a result due to fault that is detected by the grid and not detected by the DG, accidental disconnection, intentional disconnection of the line for servicing, human error, and an act of nature. In this case the normal protection does not stop the PV system to energize the PCC.

Inadvertent islanding causes a number of a safety, commercial, system integrity, and power quality. In case of islanding all utilities will be disconnected from the grid as soon as possible. IEEE 1547-2003 standard [3] stipulates a maximum delay of 2 sec for the detection of an unintentional island and all DGs should stop energizing the area distribution system. Hence, it is essential to detect the islanding both quickly and accurately. Islanding will be detected by many techniques. The core concept of most of the islanding detection techniques remain the same that some of the system parameters (v, f, etc.) change greatly with islanding but not much when the distribution system is grid connected.

This paper gives an overview of the available methods for detecting islanding, without going too much into technicalities for each individual method. Many studies have been devoted to islanding detection methods [4]-[5] and the main techniques can be classified into three categories 1) passive methods; 2) active methods; 3) communication methods [6]. In this paper we introduce a new classification of islanding detection method is hybrid methods. The overview of Passive, active, communication and hybrid methods is given in section 2, 3, 4, and 5. In section 6 we will compare the different islanding methods. Passive methods are based on monitoring of grid parameters, Active methods are based on injection of disturbances into the system and observe their behavior, communication islanding detection techniques are based are based on the communication between utilities and DGs. In these methods monitoring of the distribution network at different location and compare the grid parameters to conclude islanding or not, and hybrid methods are the combination of any of the above two methods.

2. Passive Methods

Passive methods are based on monitoring of grid parameters by a installed algorithm setup in the control domain of distributed generator or outside in a dedicated device. Most of the passive methods are looking for abnormal changes in frequency, voltage or phase angle but also in some specific harmonics and the total harmonic distortion (THD). If the monitoring algorithm detects large or sudden changes of these variables at a point of connection with the utility grid, the inverter will trip. The most common islanding methods are [7].

2.1 OUV and OUF

In this method voltage and frequency limits are set in the protection system because of the fact that the active power is directly proportional to the voltage and the reactive power is tied up to the frequency and amplitude of voltage. But the grid has numerous disturbances as voltage dips, over voltage, harmonic distortion and frequency variations. It is necessary to create islanding protection immunes to these disturbances. Voltage limits for islanding detection is Vmin 0.9 pu and Vmax is 1.1 pu and frequency limits are 49 Hz and 51 Hz so the corresponding relay setting is done accordingly to distinguish from other disturbances.

Advantage of this type of method is that grid parameter based relays with advance setting can be implemented in the system and it can save cost. These are easy in installation and grid friendly. They do not cause and disturbance in the power system. In these methods it is possible to calculate the NDZ area from the mismatches of active and reactive power and setting the values of threshold for frequency and amplitude of the voltage but it have high probability that the power mismatch will fall into the NDZ of these methods can be significant so they are consider to be insufficient for the anti-islanding protection.

2.2 Voltage Harmonic Monitoring

The goal of this method is to monitor the voltage harmonic distortion to detect an islanding condition. In normal operation the voltage at PCC is controlled by the grid, in islanding condition DG controls the PCC voltage and its harmonics. It is possible to consider the all the harmonics using the Total Harmonic Distortion (THD) of the PCC voltage or only the main harmonics; the 3^{rd}, 5^{th}, and 7^{th}. It is possible to use a Phase Looked Loop (PLL) to provide the values of the monitored harmonics.

Sometimes the DG is connected through the transformer to the PCC and it effect the harmonic distortion and RLC parallel resonant load present a low pass filter characteristics in frequency that can filter low order harmonics more than other and influence the detection of islanding.

2.3 Phase Monitoring Method

The method consists in detecting a sudden "jump" in the phase displacement between inverter terminal voltage and its output current. The variation of the voltage frequency, consequent to islanding caused a shift of the voltage vector in comparison to the axe d and a consequence change of the phase. If islanding occurs with a load resonating at the grid frequency, the phase does not vary, while if the load is resonating at a difference frequency the phase changes.

2.4 Rate of change of phase angle difference [8]

In this method process starts with retrieving voltage and current signals at the DG end for islanding and non-islanding conditions and, the phasor estimation is performed using synchronous transformation based estimation algorithm. From the phase angle information of the voltage and current signals, the ROCPAD is computed for effective islanding detection in distributed generation.

2.5. Rate of change of frequency (ROCOF)

Rate of change of frequency (ROCOF) are widely used and they estimate the ROCOF within the measurement window depending upon the imbalance of active power during islanding condition. This method becomes ineffective when the variation of active power is very less or negligible. In active power match condition they will be ineffective.

3. Active Methods

Active methods inject a small disturbance to the utility grid and based on the grid response decide whether or not an island has formed. Active methods appeared as a necessity to minimize the non-detection zone of islanding detection methods in conditions when generation matches load. Disturbances in terms of shifts from the normal values to grid voltage magnitude, frequency or phase angle can be added by the DG. The most common active methods in use are [9]-[13]:

3.1 Harmonic injection/detection of impedance

This method injects a current harmonic at a specific frequency intentionally into the point of common coupling via the PV inverter. When the grid is connected, if the grid impedance is lower than the load impedance at the harmonic frequency, then the harmonic current flows into the grid and no abnormal voltage is detected. With grid disconnection the harmonic current can flow into the load. Then the load produces a harmonic voltage that can be detected. The main drawback is the fact that the amplitude of the harmonic voltage depends strongly on the load with a consequent decrement of the power quality. Moreover multiple inverters injecting the same harmonics may cause false trips.

3.2 Active and Reactive power variation method

This method based on the active and reactive power injection. It is assumed that the load consume the constant active and reactive power. In islanding condition the real power variation flows directly in the load, affecting the inverter current and the voltage in the point of common coupling similarly us the strong dependence between the frequency and the reactive power to develop another islanding detection method.

A main problem with this method is in an electrical island the frequency increases and it causes the inverter trip. If more inverters are connected in parallel false trips and stability problems can be experienced in the grid.

3.3 Grid impedance change detection method

The active method consists in the monitoring of grid impedance change during islanding transient called ENS or MSD (Mains monitoring units with allocated all-pole switching devices). To be able to complete a measure of impedance a dedicated external device can be used or it is possible to implement the measure in the inverter control. The goal is to isolate the supply within 5secs after an impedance change of 0.5 ohm due to a grid failure. Typically a small current at a certain harmonic order (h) is injected into the grid by the device to determine the impedance.

The disadvantage of this method is the increase of the harmonic pollution injected online by the inverter and if many converters are connected in parallel a contemporary injection can cause problems both for the effectiveness of the method and for the power quality with consequent problem for the control and the stability of the system.

3.4 Sandia Voltage Shift (SVS) and Slip mode frequency shift (SMS)

In SVS method positive feedback to the amplitude of voltage at the PCC (RMS value) and observe the PCC voltage response. In SMS inverter's current voltage phase angle, do not kept always zero but it is controlled to be function of frequency of voltage at the PCC. Outputs in these methods are controlled than grid connection mode if they are not controlled than islanding mode.

3.5 Capacitor insertion method

This anti-islanding method is usually installed as a backup protection on the grid on distribution line side. Specifically, low value impedance, usually a capacitor bank is installed on the grid system inside the potential island. The capacitor switch is normally disconnected. The capacitor switch was signaled to close after a short delay during islanding. The insertion of the capacitor forces the island to go out the reactive power balance condition.

The capacitor insertion is highly effective in preventing islanding but it is more expensive respect to other methods because it is necessary to install extra hardware on the grid side of the PCC. The delay time causes an increase of the islanding detection time and problems may arise by the installation of distributed generation in different time periods.

4. Communication Methods

Communication methods are based on communication between DG and the utility grid. This make necessary of the utility's involvement in implementation of islanding detection methods, and adds cost to both consumer and utility's installed infrastructure so they are less popular in past but as the world going toward smart grid functionality they can be practically possible in cost effective manner [4].

4.1 Power line as a carrier

Power lines are used as carrier for communication between the PV inverter and utility grid. A continuous signal is transmitted by utility network via the power line. Islanding will be detected by connecting the receiver at the DG and these receiver are also used for consider loss of signal.

The main advantage of this method is that it does not cause any degradation in power quality of the system. It is unaffected by the number of inverters. It has one drawback that PLCC transmitter must be installed on the utility system through which signal can be sent to all the inverter.

4.2 Signal produced by disconnection

This method assumes that the utility communicates with DG by re-closer and installed with a transmitter which opens when islanding occur. This method has unfortunately lot of drawbacks. First it would be necessary to instrument all the switches where potential islanding is possible. It would be much cost worthy task.

4.3 SCADA based method

It uses placement of voltage sensors at the location where DG is connected and integration of those sensors in the SCADA system for monitoring and alarming the PV system to disconnect in case of islanding. With an increasing number of DGs connected to the grid, real time monitoring of voltage for each generator in distribution grid can be cumbersome process.

4.4 WAMS based method [14-15].

Wide Area Measurement System (WAMS) uses measurement devices for the measurement of the grid parameters like voltage, frequency, and etc. WAMS is specifically built for the monitoring of the power system network and it overcome the drawback of the slow processing time of SCADA system. Its mode of communication is through Global Positioning System (GPS) so their processing time is in micro seconds. It uses mainly two devices for the process Phasor measurement unit (PMU) and Frequency network (FNET).

5. Hybrid Methods

5.1. Average rate of voltage change with Real Power Shift [16].

Most of the DGs around the world are required to operate at unity power factor. There will be deficiency of reactive power once the islanding condition occurs and capacitor banks are the sole source of reactive power in the islanding condition as the DGs operating at unity power factor. The amount of reactive power they produce is a function of the voltage and once the voltage changes, as a result of islanding, the reactive power generated by the capacitor bank will also change, which will further change the voltage.

5.2. Wavelet based detection method [17].

This method which can detect the islanding condition from the local measurements of PCC voltage and current signals, as in case of passive methods, but evaluates the high-frequency components injected by the PV inverter, which depend on the characteristics of the employed pulse width modulator, LCL filter, and current controller, to reveal the islanding condition, as done by active methods. Wavelet analysis is applied to obtain time localization of the islanding condition and in order to accomplish the time requirements applying the wavelet analysis to obtain time localization and tracking of a certain frequency band is proposed.

The Discrete Wavelet Transform (DWT) is a signal-processing tool which can be applied when time-varying harmonics must be evaluated and, as in the case of the detection of the islanding condition, time localization is required. This took advantage of the time and frequency localization of the DWT applied to the high-frequency components introduced by Distributed Power System Generation System inverter at the PCC. The advantage of this method is it suits the low voltage low power PV systems, where a reduced number of sensors is available and the computational burden and complexity of the anti-islanding algorithm must be minimized.

5.3. Intelligent- Base approach [18]

It uses multiple system parameters to identify and classify any possible islanding operation at a specific target location (the location at which the islanding detection is to be installed). This method uses the data-mining technology to extract information from the large data sets of these indices after they are screened off-line via massive event analyses using network simulations. So this method is the combination of passive and communication based techniques. It consists of three main modules input module, pattern classification module, and the output module.

Input module is a multifunction software model that executes signal- processing algorithm to calculate different system parameters. These parameters are the independent variables of the proposed system and are given in the form of input vector X. In the pattern classification module a pattern of the parameter vector X is obtained and represented as Xi. The pattern vector Xi is stored along with the corresponding class variable Yi and obtain the N type of pattern. It also had done the compilation of the pattern vector Xi and Yi to generate the pattern classification model output{X, Y}. The output of the pattern classification model is given to the islanding detection relay (output module) and it is a logic unit. If the islanding is detected, the output of this unit is logic 1. Conversely, if the islanding is not detected, the output of this unit is logic 0.

The drawback of this method is related to the implementation issue. It include the required simulation studies, the required measuring devices, the digital systems required for code implementation, and the speed of response of the overall scheme. In addition, issues such as the impact of system reconfiguration and the need to update the data should be conspired.

6. Comparison of different Islanding Methods

Passive methods are the basic protection packages of every distributed generator connected to utility grid. They are easy to implement and grid friendly. Protection settings for these methods are done in the relay by changing their threshold values. In last decade, Active methods are used for detecting islanding due their less detection zone than the passive methods and less cost than communication method. But the Active methods have main drawback of intentionally injecting disturbances in the system and make it unstable and reduce power quality of the power system. Communication based method are the future used method in respect to the cost compatibility as the power system is growing toward the intelligent system and called as Smart grid. Hybrid methods are the best alternatives for the compensation of drawback existing in the following methods. They are the combination of two methods and it will be cost effective than communication based methods.

7. Conclusion

This paper gives an overview of the islanding detection methods. In this paper the different islanding methods are discussed and their reach of detection and condition in which they are unable to detect the islanding condition are mention. The paper discusses the new islanding detection methods called as the hybrid methods. We compare the different islanding methods and seen how the methods are changing with time. This paper is very helpful for those who working in the field islanding to get an overview of all methods.

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