ISSN (Online) 2393-8021
ISSN (Print) 2394-1588

IARJSET

International Advanced Research Journal in Science, Engineering and Technology
National Conference on Emerging Trends in Engineering and Technology (NCETET'16)
Lourdes Matha College of Science & Technology, Thiruvananthapuram
Vol. 3, Special Issue 3, August 2016

Review of Islanding Detection Techniques for Distributed Energy Sources

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Abstract: An island is formed when one or more DR units and sets of loads are disconnected from the utility system and remain operational. This paper discuss about the different islanding detection methods used for anti-islanding protection in EPS. Anti-islanding methods are generally classified as passive, active, hybrid and communication based methods. Active methods are more preferred, passive methods are much simpler, communication based methods have perfect performance whereas hybrid methods is a combination of both active and passive methods and have improved performance. Here the advantages and disadvantages of different methods are compared and discussed.

Keywords: Islanding, anti-islanding detection, active, passive, hybrid, communication based

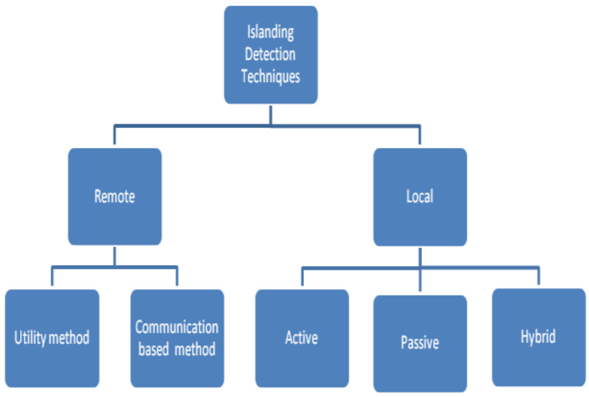
I. INTRODUCTION

In the present scenario to meet the scarcity of growing power demand, penetration of renewable energy sources based distributed generation DG is gradually increasing [1]. DG technologies include photovoltaic, wind turbines, fuel cells, micro turbines, gas turbines, internal combustion engines etc [2]. When the distributed generations systems operate in parallel with utility power systems there occur may power quality issues. In addition to this the most important problem is the islanding detection [3].

Islanding is a phenomenon that occurs when DG resources feed the local load and the utility grid is disconnected [1]. Unintentional islanding may arise many safety and protection issue in the islanded portion of an electric power system (EPS). Unintentional islanding UI) results in an uncontrolled frequency and voltage, which may damage or reduce the life of the appliances and the equipment present in the island. The safety of the utility workers is at risk as they may get an electric shock due to a live DG in the island. Instantaneous reclosing of the DG to EPS is another major concern as it may result in the out of phase reclosing of the circuit breakers. The heavy mechanical torque and the high transient inrush current may even damage the islanded DG [4].

Since UI has adverse effects on the EPS, islanding detection techniques are used to detect the island and trip the circuit breaker between power system and distributed generation. [3]. An islanding detection should be made within 2s immediately after the formation of an island and the DG operation must be ceased [4].

The islanding detection techniques can be classified as remote and local techniques [3]. The remote techniques are based on the communication between the grid and the DG and are very expensive. The remote techniques are further classified as utility based and communication based methods. The local techniques re based on the measurement of parameters at the local DG terminal and are generally preferred. These techniques are further classified into the passive, active and hybrid techniques.



II. ISLANDING DETECTION METHODS

This section deals with the various islanding detection methods available and their important remarks.

Two key features are to be defined for better understanding of islanding phenomenon namely Non Detected Zone (NDZ) and Quality factor (Q). These two are extensively used as the criteria to evaluate the islanding detection methods.

Non Detection Zone is the interval of failure in detecting the island by DG once islanding has occurred. This region relates the power mismatch between the DG and local load. There NDZ is considered as an evaluation index for islanding detection methods [7].

Quality factor is defined as 2π times the ratio of maximum storage energy to energy dissipated per cycle at a given frequency. It gives the relative amount of energy storage and energy dissipation in RLC circuits. Q factor is

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proportional to NDZ and therefore NDZ should be as small as possible [7].

A. Remote Techniques

Remote techniques are based on the communication between the grid and the DG. Islanding is detected based on status of the utility circuit breakers. These techniques are reliable but very costly to implement and hence are not popular. Some of the techniques are discussed below:

I. Trip Transfer Schemes

This scheme incorporates SCADA to monitor the status of circuit breakers and re-closers [5]. By monitoring the status of the utility circuit breaker close to PCC islanding is detected. Here voltage sensing devices are used in the local parts of the utility system. Alarms connected in series will alert the DG in case of any voltage present when the utility system is disconnected. Thereby corrective action will be taken.

The main drawback of the system is the use of SCADA systems and sensors increase the cost of implementation of the system.

II. Power Line Carrier Communication

Power Line Carrier Communication method uses the communication channel in the utility power line for islanding detection. In this method a low energy signal is send between transmitter (T) installed at the utility side and receiver (R) inserted on the DG side. This communication will be disturbed when islanding occurs and a stopping signal is send to PCU or a switch by the receiver to isolate the load [6].

B. Local Techniques

Local Techniques are based on the measurement and monitoring of output parameters in a system. These are classified into active, passive and hybrid techniques

I. Active Techniques

Active islanding methods are based on the injection of a small disturbance signal to certain parameters at PCC [2]. In this method a small disturbance signal given, will become significant upon entering the islanding mode of operation in order to help the inverter to cease power conversion. Hence, the values of system parameter will be varying during the cessation of power conversion, and by measuring the corresponding system parameters, islanding condition can be detected [7]. Some of the active techniques are discussed here.

a. Average Absolute Frequency Deviation Method

In this method, the inverter's classical q-axis current controller is modelled with a continuous periodic reference current of a small value[8].An average absolute frequency deviation value ($AFDV_{avg}$) based algorithm is proposed for the decision making. The method prefers an absolute value, so that the average frequency deviation over a cycle during an islanding state is always a positive detectable value. It averages the frequency deviation over 5–6 cycles.

The advantage of this method is that it avoids false detection during non-islanding switching events since the frequency deviations during the non-islanding switching events last only for first few cycles.

b. Advanced Frequency Drift Method

In this method, a continuous periodic reactive current injection of small value is done through q-axis current controller of the grid side VSC during the case when active power mismatch is 0%.

The apparent drift in the frequency is obtained during islanding state. A cumulative sum detector (CSD) is utilized to compute the cumulative sum of absolute value of frequency drift due to the reactive current injection for a measurement window which is given by

$$\mathrm{CSD} = \sum_{J=1}^{n} |\mathrm{FD(j)}|$$

The advantage of this method is it has negligible non-detection zone. It combines successfully combines frequency relay scheme, reactive current injection scheme and load shedding scheme [15].

c. Harmonic current injection method

In this method, a current injection method based on the Goetzler algorithm for islanding detection is proposed.

Multiple grid-connected inverters inject harmonic currents of the same and different harmonic orders and monitors the change in the magnitude of harmonic components at the point of common coupling and the islanding condition can be diagnosed.

The advantage of this method is that by using the Goertzel algorithm, the computation time can be reduced significantly and the islanding can be detected within one cycle of fundamental frequency.

d. Voltage Positive Feedback Control(VPF) Method

This method is a modification of conventional Voltage Feedback Control method. In conventional method during islanding when voltage increases the d-axis current increases which results in more active power generation accelerating voltage until islanding is detected.

The reverse happens when voltage decreases. This drawback is rectified in modified method. Here a variable voltage gain id designed. The positive feedback gain is the multiplication of voltage gain and d-axis current command given as

$$K_{pf} = K_v id^*$$

The limits of voltage gain are designed from the complex frequency dependent ZIP exponential load model.Since this method is independent of the load model it is advantageous over the conventional methods.[8]

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e. Reactive Power Drift

This method uses the system frequency as feedback into the inverter's reactive power control loop. In this ARPD scheme, the frequency shift keeps accelerating until the detection module acts. The time needed for detection depends on the difference between the slopes of ARPD curve and the load curve

Comparing with AFD and SMS, ARPD has the advantages that it doesn't deteriorate the harmonic quality of output current, and can be easily applied to all kinds of DG systems under real and reactive power decoupled control. It has a less reactive power deviation in normal operation, and no deterioration to the THD of output current. It can accurately control the output real power even in the transience after islanding, which helps to keep the inverter's dc bus voltage stable in transients.

f. A Q-f droop curve

The IEEE Std. 929Recommends the operations of the DG close to unity pf that is accomplished by setting Q ref to zero. During islanding, with a DG designed with zero reactive power the system frequency will deviate such the load consumes zero Q. The frequency at which the island will stabilize is the loads resonance frequency. Here the DG Q-f characteristic is represented bya linear function where slope is adjusted to be steeper than the load curve such that the DG loses its stable operation during an islanding condition.

The Q-f droop is chosen such that the DG maintains its stable operation while grid connected and loses its stability once an islanding condition occurs. By implementing Q-f droop, the UFP/OFP method will have a negligible NDZ [9].

II. Passive Techniques

Passive methods depend on measuringcertain system parameters and they do not interfere with DGoperation.Several passive techniques proposed are based on monitoring voltage magnitude, rate of change of frequency, phase angle displacement, and impedance monitoring. When the threshold for all above mentioned quantities is set to a low value, nuisance tripping becomes an issue; and in the case that set for a high value, islanding will not be detected.

a. Neuro Fuzzy Islanding Detection

This passive method is implemented by collecting the massive indices like voltage, frequency, current , active power and etc. of the practical distribution system by PSCAD/EMTP simulation. Adaptive Neuro Fuzzy system in MATLAB is used for classifying process. Using MATLAB fuzzy logic software the resultant logics and boundaries are implemented.[10]

This method provides 100% efficiency in islanding detection under noise disturbances and different load generation profiles. The main advantage is the ability to consider all five indices and producing one result.

b. SVM Approach

In this passive method of islanding detection the massive indices are classified using Support Machine Vector in MATLAB software. The best hyper plane that can separate islanding and non-islanding condition in two or more dimensions space is found using this technique.

c. Rate of Change of Phase Angle

The technique aims at the islanding detection of an inverter-based distributed generation (DG).The main emphasis of the proposed scheme is to reduce the NDZ and it does not affect the normal operation of the system.The proposed method utilises the output signal of the PLL circuitThe detection method is also capable of detecting islanding conditions with different local loads accurately within the minimum standard time [11].

III. Hybrid Techniques

Active and passive methods have some negative and positive aspects. Passive methods do not have any impact on power system; however, they have a large NDZ. Active methods are typically accurate, but they have undesirable impact on system's power quality [2]. When these two methods come together, it is not only possible to receive benefit from their advantages; it is possible to overcome their undesirable features also.

a. Voltage Unbalance and Frequency Set Point

This technique uses both voltage unbalance and frequency set point for islanding detection.The use of voltage unbalance technique alone may not be able to detect islanding.VU technique cannot discriminate between a large load switching and islanding, results in false tripping.Therefore another technique is used for detecting the islanding efficiently [12].

b. SFS and ROCF method

Optimized Sandia Frequency Shift (SFS) method is used as the selected active method, and Rate of Change of Frequency relay (ROCOF) is used as the passive method in this hybrid technique. In the proposed hybrid technique, SFS method gets activated only when islanded condition is suspected by ROCOF relay. System frequency is estimated using PLL. When ROCOF relay detects any variation in df/dt, a trip signal will be sent to a multiple switch which activates SFS signal; whereas, in the case of no disturbance in the system, ROCOF relay will not send any signal to the multiple switch, which results in the predefined Id-ref and Iq-ref current references get switched on. Therefore, SFS will not be implemented until the next disturbance occurs.

This method improves the steady state power quality of the system, because active method is not continuously operating; as a result, disturbance is not continuously injected to the system. This method can discriminate between the load switching conditions and the islanded condition; as a result, preventing false trips in the case of load switching occurrence.

c. Positive feedback Voltage Unbalance and Total Harmonic Distortion of Current

Any disturbance applied to the DGs, e.g. as a result of random load changes (switching) or islanding, could result in a spike in the VU. To discriminate between the VU spike due to islanding and that due to other reasons, PF method has been added to this technique. Whenever a VU spike above the set threshold is observed, then the frequency set point of the DG is gradually lowered from 60 Hz to 59 Hz. Islanding detection time is 0.5 seconds after the detection of island which is supported by IEEE 1547-2003 STD[13],[14]. Also this method correctly detects the islanding even in system disturbances like short circuit, load variations and capacitor switching

III.CONCLUSION

The paper presents a technical review on few of the islanding detection methods available. Islanding operations of DG usually occur when power supply from the main utility is interrupted due to several reasons but the DG keeps supplying power into the distribution networks. In order to reduce the damages and dangers caused by islanding operation of DGs, the islanding formation should be detected quickly and DG should disconnect itself from utility network in short time. Therefore the anti-islanding protection system of DG unit whose duty is preventing of the operation of these resources during network disconnection is one of the most important projects related to distributed resources. It is obvious that the local loads of DG are supplied by DG whether the utility network is connected or disconnected. Islanding detection techniques are broadly classified as local and remote techniques. Under each category there are different techniques which have its own merits and demerits. Active, Passive and Hybrid techniques are mostly used local techniques some of the methods under these are discussed. Also communication based methods are commonly used in remote techniques. Since no islanding detection scheme can serve all DG source types equally, the method will normally be selected according to its very nature (synchronous vs. static-inverter based) in order to maximize its efficiency and reliability. In addition, it is necessary to balance the costs and safety risks of non-intentional islanding events.

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