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An Overview on Grid Interfacing and Islanding Techniques

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ABSTRACT
In view of climate change challenge, forcing reduction of greenhouse gas emission, many countries have started the process of liberalization of their electrical power systems, opening access to grids and encouraging renewable energy sources. The existing power systems properties have changed by the presence of Distributed Generation (DG). This paper presents the review of DG with most commonly used inverter and islanding issues.
Keywords - Distributed Generation, Inverter, Islanding, PV modules, Renewable Energy Sources

I. Introduction

The growing concern on climate changes has recently increased the interest in Distributed Generation (DG) from renewable and traditional sources. Deregulation and growth of competitive supply markets also increases this interest. In general, distributed resources are defined as sources of electrical power that are not directly connected to a bulk power-transmission system. They include both generators and energy-storage technologies, with a power rating of 10 MW or less [1].

The impact of DG on distribution systems depends on the penetration level, a presence of approximately 20% on energy resources for the years 2010–2020 is predicted. During the first part of the current decade fewer industrial and commercial businesses have expressed an interest in adopting onsite DG equipment [2].

The widespread use of DG or distributed resources has created new problems, some of them closely related with power quality such as selective coordination of overcurrent protection and its effects on continuity , in addition to control of the voltage-sag magnitude and duration by using overcurrent protective devices considered as included in product quality. The most feared effect is the islanding that can be highly risky for user equipment, utility elements and personnel, but can be desirable from the power-quality point of view. Interaction and impact of DG on network operation, fault detection, fault clearing, and reclosing operations are also of important concern [3].

It has been reported that the use of new fast-clearance protection systems to protect DG would improve transient stability and also improve power quality and several issues are currently being considered. Besides, distribution systems have been mainly designed for energy flowing in just one direction. If the DG equipment does not belong to the utility, the customer decides about its connection to or disconnection from the system, based on its own needs. If the DG belongs to a cogeneration scheme, in the case of a blackout the customer could keep the equipment feeding the critical loads operating as an isolated circuit or island, and needing resynchronization when the external supply is restored. This scheme created several problem to the utility when it is applied during voltage sags caused by nearby faults [4].

The effect of DG greatly depends on the technology used and on the network characteristics. The main aspect is that now the energy source is not unique and then the energy flow could be changed or reversed under normal or abnormal conditions.

There are several types of power generators like wind turbines, fuel cells, photovoltaic cells, small and micro-turbines, internal combustion engines that can be used as DG. Each of these power generators has its own advantages and disadvantages, such as easy installation based on its small size, fast start, generates voltage distortion, and uncertain power availability. In spite of the distributed-generation promotion carried out by utilities, they have been expressing concerns related with potential distribution-system problems. These new operating conditions would require an increase in smart distribution and synchronization between components. This paper discusses about different inverter with islanding techniques.

II. Classification of PV Inverters

Increasing generation of renewable energy both domestic and commercial have enabled the possibility of hooking all isolated smaller power sources like photo voltaic cells and wind turbines to grid using multilevel inverter; see Fig 1. For the benefit of better sine wave approximation (lower harmonic content) distribution generation (DG) has already employing multilevel inverter despite their cost, complexity and islanding issues.

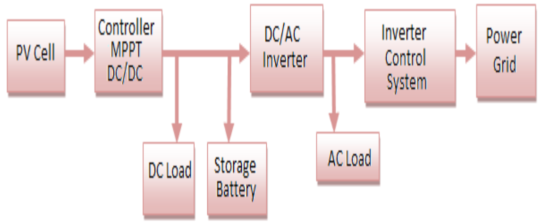

Figure 1: Configuration of PV grid-connected power system

There have been many multilevel topologies proved fruitful at this point in time, the issue of reduced efficiency without increase in levels of inverters and costly, complex design has provided the opportunity to investigate and improve the design.

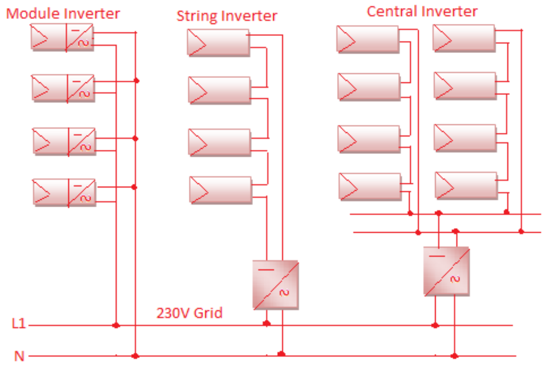

Figure 2 Classification of PV inverters

PV modules may be connected to the grid with module inverters, string inverters or central inverters; see Fig 2. Module inverters with small power ratings are fixed on the back side of every module. They can adjust a best possible MPP per device that results in a high total energy yield of the PV system. This type of concept necessitates high effort if a monitoring system should be applied. String inverters convert the DC power of a whole module string. Compared to the module inverter, the MPP control is less optimal if the incident light is unevenly distributed or shading arises on some modules. However, a monitoring system is easier to implement. Central inverters offer the best monitoring possibility because only one data interface and one processing unit are needed. Nevertheless, no individual MPP tracking is possible. The application of the inverter types depends on the monitoring needs, the incident light distribution, the shading and the module direction. PV units up to 4.6 kVA are single-phase connected and above this power level they are always designed as three-phase plants. The type of grid connection determines the possibilities for the choice of the islanding detection monitoring. Although many solutions have been proposed and either in design or experimental stage, it is apparent that such enhanced power electronics design will assist in the betterment of distribution systems even with market deregulation's and ever growing system complexities.

III. Islanding Techniques

"**Islanding** is the situation in which a distribution system becomes electrically isolated from the remainder of the power system, yet continues to be energized by DG connected to it". Traditionally, a distribution system doesn't have any active power generating source in it and it doesn't get power in case of a fault in transmission line upstream but with DG, this presumption is no longer valid. Current practice is to disconnect utilities in a DG from the grid as soon as possible in case of islanding. IEEE 929-1988 standard requires the disconnection of DG once it is islanded.

Islanding can be intentional or Non intentional. Intentional islanding is the purposeful sectionalisation of the utility system during widespread disturbances to create power "islands". These islands can be designed to maintain continuously supplying power during disturbances of the main distribution system. When disturbances are present on a distributed utility system, the grid sectionalizes itself, and the DERs supply the load power demand of the islands created until reconnection with the main utility system can occur once the disturbances have passed. Non-intentional islanding is caused by accidental shut down of the grid. Thereof some general rules for the handling of the islanding mode can be extracted. There are quite a few different methods used to detect islanding. All methods have benefits and drawbacks. The Islanding methods have traditionally been divided into two subgroups; passive and active methods; see Fig 3.

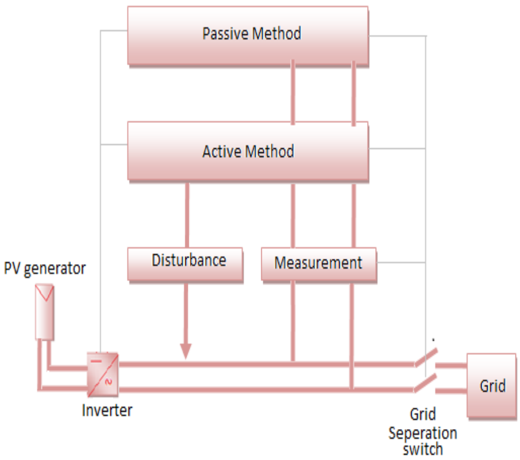

Figure 3: Active and passive islanding detection methods

3.1 Passive methods

Passive methods use locally available quantities such as voltage or frequency. The quantities are derived from the high voltage level using voltage and current transformers, which feed the detecting device. The passive methods do not affect the waveform of the high voltage. This is beneficial since it does not give rise to power quality issues such as voltage dips.

Under voltage/over voltage: Under voltage/over voltage (UV/ OV) island detection technique is one of the simplest passive techniques used in islanding detection. This technique is based on the voltage change introduced in island. As a disadvantage, if the load power and the DG-generated power in island are matched, the change in voltage and frequency is very small [5]. The time for island detection is less than a quarter of the supply voltage period.

Under frequency/over frequency: Under frequency/over frequency (UF/OF) island detection technique has been considered in [5]. UF/OF technique is based on the frequency change introduced in island.

Rate of change of active power: In islanding condition, the active power variation flows directly into the load varying the PCC voltage. This voltage variation can be an indication for islanding [6].

Rate of change of frequency: Rate of change of frequency (ROCOF) is used for island detection in synchronous generators. In grid-connected mode, the difference between the power supplied by the synchronous generator and the load power is covered by the grid so that the system frequency remains constant. In island mode, there is a power imbalance because of grid disconnection. This power imbalance causes a frequency change that can be used to detect the islanding. If the power imbalance is small, the frequency changes slowly. Thus ROCOF can be used to improve the island detection. ROCOF is calculated using a window over several cycles (between 2 and 50 cycles). This signal is filtered and the resulting signal is used for island detection.

Rate of change of frequency over power: The rate of change of frequency over power is used for islanding detection in [7]. If the detection index is larger than a threshold the counter is incremented by one. When the counter is greater than a preset threshold then the islanding is detected.

Voltage and power factor change: The rate of change of voltage and power factor has been employed for island detection. If the rate of change of voltage is positive and the change in power factor ranges from 0.1 to 0.5 then the island is detected.

Comparison of rate of change of frequency: Comparison of rate of change of frequency (COROCOF) is based on the sudden change in frequency due to the loss of mains as in ROCOF. Compared to ROCOF, COROCOF discriminates between changes in frequency due to loss of mains and changes due to system disturbances. COROCOF compares the DG frequency with the grid frequency, hence the name COROCOF.

Phase jump detection: When the grid is disconnected, the phase angle between the output current and the PCC voltage is load dependant [11]. If the change in the phase angle exceeds a preset threshold, the island is detected.

Voltage unbalance and total harmonic distortion: Voltage unbalance and total harmonic distortion (VU/THD) technique is used for island detection. VU at the PCC and THD of the DG output current are monitored and thresholds for both terms are used for island detection. As a disadvantage, a load switching can cause a change in VU/THD even in grid-connected mode.

Vector surge relay: Vector surge relay (VSR) (known as vector shift or voltage jump relay) is employed for island. When the gird is disconnected, the DG starts to decelerate or accelerate because of the power imbalance between the DG and the load; therefore, the terminal voltage vector changes. VSR updates its measured parameter every zero crossing of the terminal voltage. This relay has a blocking function triggered by a minimum terminal voltage. If the terminal voltage drops below a voltage threshold, the tripping signal from the VSR is blocked, avoiding tripping for generator start up or short circuits.

Wavelet: Wavelet can be used for island detection. A computation of continuous wavelet transform via a new wavelet function is proposed for the visualisation of electric power system disturbances. The discrete wavelet transform for electric power system was presented in different articles. The survey says a technique of ground fault detection using wavelets is introduced.

Neural network: An attempt to develop a technique for island detection based on the application of artificial neural network (ANN) was suggested in [10]. The ANN architecture used for island detection is based on back propagation, which consists of an input layer, an output layer and hidden layers. A disadvantage of the ANN is the amount of time required for training and testing the network off-line.

Kalman filter: A Kalman filter is implemented in [9] for island detection. This technique is based on energy mismatch between the estimated third and fifth harmonics and the real ones.

3.2 Active islanding:

Active Islanding detection methods either try to manipulate the voltage or the frequency at the connection point or the manipulation is a result of measurements used by the method. The active methods have a better reliability than the passive methods. However, the consequences is a negative influence on the power quality.

Impedance detection: To implement the grid impedance detection technique, the inverter-based distributed generation periodically adds a disturbance to its output current. If the PCC voltage presents no change during the disturbance, the inverter-based distributed generation assumes that the grid usually has a low source impedance is still maintaining the PCC voltage and the inverter-based distributed generation operation continues. If the PCC voltage provides a disturbance corresponding to the current disturbance, the impedance at the inverter-based distributed generation terminals is higher than the case when the grid is connected.

Change of output power: In this technique, the output power of the inverter-based distributed generation is changed periodically to break source-load balance condition. This technique is not practical as timing synchronization must be made among all the inverter-based distributed generation in the power system or it will not work because of the averaging effect [11].

Automatic phase shift: Automatic phase shift (APS) is based on changing the starting angle of the inverter-based distributed generation output current according to the frequency of the inverter-based distributed generation terminal voltage. An additional phase shift is introduced each time the frequency of the terminal voltage stabilises. The frequency of the terminal voltage keeps differing until UFR or OFR is tripped.

Active frequency drift: In active frequency drift (AFD) technique, the current is slightly distorted presenting a zero-current segment. When the grid is disconnected, the phase difference between the inverter-based distributed generation voltage and the current is load dependant. In order to eliminate the phase difference, the frequency drifts up or down till the OFR/UFR is tripped.

Slip mode frequency shift: Slip mode frequency shift (SMFS) is similar to AFD except that the starting angle of the inverter-based distributed generation output current also varies with frequency at each zero crossing of the terminal voltage. SMFS technique applies a positive feedback to shift the phase of the PCC voltage [11].

Reactive power export error: Reactive power export error is an improved phase shift where the reactive power of the system is changed periodically. The periodical change of the reactive power introduces a phase shift between the output current and voltage, which increases or decreases the frequency of the load voltage in the island condition and therefore the OFR/UFR is tripped.

Sandia frequency shift: Sandia frequency shift (SFS) technique is based on inserting a zero-current segment per half of the line cycle. A positive feedback is used to enhance the chopping factor.

Sandia voltage shift: Sandia voltage shift (SVS) technique is very analogous to the SFS, except that it applies a variation to the PCC voltage amplitude instead of frequency.

Harmonic current injection: Harmonic current injection technique [6] is based on injecting a disturbance into the grid through either the d-axis or the q-axis current components of the inverter-based distributed generation.

Harmonic distortion: Harmonic distortion-based island detection technique for inverter-based distributed generation is based on the PCC voltage change that occurs in islanding. In case of a close matching of the inverter-based distributed generation, generated power and load power, an active power–voltage locus is introduced to vary the reference active power hence transferring the operating point outside the NDZ. It ceases to deliver power while the inverter-based distributed generation is still electrically connected in case of undesirable disturbances as voltage sag.

IV. Conclusion

This paper presents an ample survey of PV inverters and islanding protection. The DG paradigm has created prevalent interest in power system planning and research in recent years amid energy planners, policy makers, regulators, generators and researchers. The main challenge of DG interconnection is the protection coordination of the distribution system with bi-directional fault current flows. In recent years, the rapid growth of DGs has made the researchers to look into diverse multilevel inverters and islanding techniques for protection and the quality.

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