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Overview of anti-islanding US patents for grid-connected inverters

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ABSTRACT

Recent rapid interest in renewable energy generation, especially high penetration of the grid-connected photovoltaic system, is imposing new challenges to the anti-islanding protection. In practice, there is a potential risk of failure for anti-islanding protection due to the interaction between different islanding detection algorithms. It is of great importance to identify which kind of islanding detection methods are used in field applications for further analysis of this interaction problem. Although many anti-islanding detection methods have been reported in the last decades, most of them have been presented and discussed from the academic point of view, and they are very interesting, but complicated to implement and might not be practical for real applications. Therefore, the objective of this paper is to provide a comprehensive review of relevant international patents to find out the potential anti-islanding algorithms in real applications, which would be useful for the further investigations of interaction between different anti-islanding algorithms in a real distributed grid.

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1. Introduction

Integration of renewable energy systems into grid is an effective solution to the electric energy shortage and environmental pollution, and gaining more and more attention all over the world. A number of technical challenges may arise with increased grid-connected renewable energy systems. One of the most important issues is how to achieve the fast and reliable anti-islanding protection [1–4].

Islanding refers to the condition in which a grid-connected inverter continues to power the local loads even though electrical grid power from the electric utility is no longer in service [5]. Some hazards associated with islanding include

(1) Utility workers sent out to repair the utility grid may not be aware that the portion of the utility grid is receiving power from a grid-connected renewable energy system even though the utility grid itself is not powered. Serious injury or death may occur if the utility worker makes contact with a portion of the utility grid.
(2) The utility has no control over the voltage or frequency supplied to an islanded location which creates the possibility of damage or potential hazards to the local devices and equipments.
(3) It may interfere with restoration of normal service and prevent automatic re-connection of devices. Therefore, the anti-islanding detection and protection is a mandatory function for the grid-connected renewable energy systems.

Many anti-islanding detection methods have been reported in the last decades. Most of them have been presented and discussed from the ***academic*** point of view. For example, wavelet-based islanding detection [6–8], fuzzy rule-based islanding detection [9], neural network based islanding detection [10], and so on. They are very interesting and insightful, but complicated to implement and might not be practical for commercial applications.

There is an interesting question which kind of anti-islanding method is used for grid-connected inverter in industrial fields? It is of great importance, since the interactions between different anti-islanding algorithms in practical applications become more and more significant with the high penetration of grid-connected renewable energy systems, and there is a high potential risk of failure about anti-islanding detection due to the their interactions. Therefore, it is crucial to carry out further investigations about the interaction analysis of the anti-islanding algorithms in practical applications to avoid anti-islanding failure. Unfortunately, the detailed information about anti-islanding algorithms from the relevant inverter manufacture companies is unavailable for commercially confidential reasons.

On the other hand, there is a way of investigating the international patents to find out the potential anti-islanding algorithms for practical applications. The objective of the paper is to review the US patents of the international electrical corporations to provide a new insight of the anti-islanding issue. Note that only patents from international electrical corporations are discussed in this paper, aiming at providing a useful guidance for commercial applications.

2. Anti-islanding patents

Fig. 1 illustrates the block diagram of grid-connected inverter. The islanding occurs when the utility grid is disconnected. In general, islanding detection methods of grid-connected inverters can be classified into two categories. One is the passive method, and the other is the active method.

Passive methods are based on local monitoring of the electrical signals at the inverter output terminal, such as, under or over voltage, under or over frequency, rate of change of frequency, phase jump, and harmonics. In an early patent [11], the islanding detection is achieved by the voltage relay, frequency relay and distortion relay. In another patent [12], the RMS voltage changes are utilized as an indicator of islanding. However, when the power supplied by the inverter and the power of the local load are balanced, the electrical components at the inverter output remain unchanged, and the passive methods fail to detect the islanding. It is the so-called non-detection zone (NDZ). That is why most of the islanding detection patents are active. Following will present and classify the active islanding detection patents.

2.1. Phase disturbance method

2.1.1. Phase shift with positive feedback [13]

In the patent of Ballard Power Systems Corporation, it introduces a small intentional phase disturbance for the output voltage of the inverter in each voltage cycle. This small phase angle shift can be a positive, negative or random value. The accumulated small phase angle error is corrected at each voltage cycle in synchronization with the grid. If the grid is lost, the small phase angle shift will not be corrected, causing an initial frequency change. The initial frequency change can be accumulated, and frequency drift will occur, from cycle to cycle. When the frequency drift rate is over a preset level, for example 2 Hz/s, a positive feedback loop is enabled for accelerating the frequency drift. When the frequency drift is over a preset level, the islanding can be confirmed.

Because the injection phase angle is very small and corrected in each voltage cycle, it does not cause the frequency shift, power factor change and extra harmonics if the grid is present. On the other hand, it can detect the islanding operation of an inverter without NDZ in case of grid disconnection. Also, it can be extended to multi-inverter applications on condition that a synchronization mechanism is enabled to avoid canceling each other's effects.

2.1.2. Phase shift with PLL [14–16]

In the patent of Enphase Energy Inc., it injects a small phase shift through the Digital Phase Locked Loop (DPLL). A phase shift of magnitude 50 μs over a period of one cycle is injected at 0.5 s

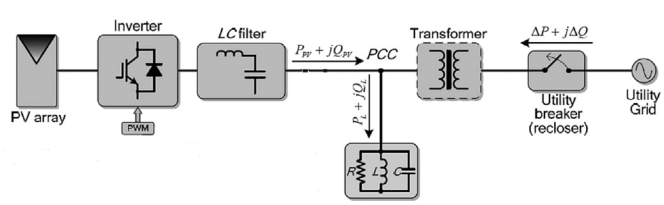

Fig. 1. Block diagram of grid-connected inverter.