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An Intelligent Adaptive Method for Islanding Detection in Grid-tied PV System*

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Abstract

Photovoltaic (PV) systems can be tied to a utility grid to work more effectively as an alternative energy sources. One of the major issues about grid-tied PV systems is to avoid non-intentional operation in islanding mode. Many methods have been proposed to detect islanding operation of grid-tied PV systems. They have different non-detection zones for different kinds of load. This paper presents an intelligent adaptive method for islanding detection in grid-tied PV system. The simulation and test results prove its effectiveness and superiority.

Keywords: Grid-tied PV system. Islanding detection. Adaptive. Non-detection zone.

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1. Introduction

As an electrical power sources, PV systems can be connected to the utility grid to work more reliably and effectively. However, one of the most serious issues about the grid-tied PV systems is islanding operation. Islanding operation is a situation in which the PV system keeps supplying electric power to a section of the grid even when the section has been isolated from the main utility grid. Islanding is undesirable because it poses a safety hazard to utility service personnel, and also because it can lead to asynchronous reclosure which can damage the equipment [1][2].

For an island condition to occur, the situation must be such that the inverter does not recognize an interruption in utility service. If the loads that remain on the isolated portion of the grid are closely matched to the output of the inverter, it is possible for voltage and frequency to remain relatively constant after interruption of the utility grid. Anti-islanding schemes that depend on only monitoring the voltage and frequency may not detect this condition, and continue energizing the local load thus creating an island.

Many anti-islanding techniques have been proposed and a number have been implemented in actual grid-tied PV systems. A reliable anti-islanding scheme must work for all possible islanding scenarios [3][4].

2. Anti-islanding methods

A large number of methods for detecting the islanding condition are used. Requirements for the performance of these methods have been spelled out by the International Electrotechnical Commission (IEC), the Underwriters Laboratories Inc. (UL), the Institute of Electrical and Electronics Engineers (IEEE) and several other "National Standards" [5][6][7]. The typical PV system where the anti-islanding methods have to be implemented is shown in Fig. 1. It is the case of a photovoltaic (PV) generator connected to the grid. The components forming the system are: the PV panel, the power inverter, the isolation transformer and the parallel local load.

Currently, the anti-islanding methods are clearly grouped into three categories as a function of their operating mode. These three categories are:
- Passive methods resident in the grid tied inverter.
- Active methods resident in the grid tied inverter.
- Methods not resident in the PV system but communicating the PV system and the utility.

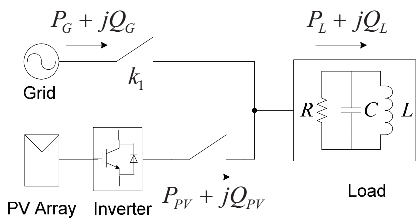


Fig. 1 Interconnection of PV system to the grid and the load

2.1Passive methods

This kind of methods lies in the inverter. They are base on the monitoring of certain characteristic parameters in the point of common coupling (PCC). The anti-islanding method causes the disconnection of the inverter from the utility grid under fault conditions when the parameter monitored, different for each method, gets out of the control range considered as usual during the normal operation.

2.2Active methods

Active methods residing in the inverter to detect the island operation mode introduce deliberated changes or disturbances to the AC output. Besides, certain parameters are monitored at the PCC in order to detect if the generator is functioning in island-mode or grid-connected mode. If the perturbation introduced by the inverter affects to the AC output characteristics further than the established limits, considered as normal utility fluctuations, the control circuit, or even the voltage and frequency protections in case of getting out of range, disconnects the power generator. On the other hand, if the perturbation leads to no changes in the PCC, the PV system can assume the grid is still on.

By means of the perturbation the response of active methods is faster and more effective than that of the passive methods, reducing the non-detection zone (NDZ) where the PV SYSTEM keeps on working once the utility grid has been disconnected. This NDZ depend mainly on the local loads connected to the PV system [8]. The closer the active power consumed by these loads is to the active power supplied by the PV system, the higher the probability to form an island. In the same way, as the resonant frequency of the local load approaches the grid frequency (50Hz) the potential formation of islands increases.

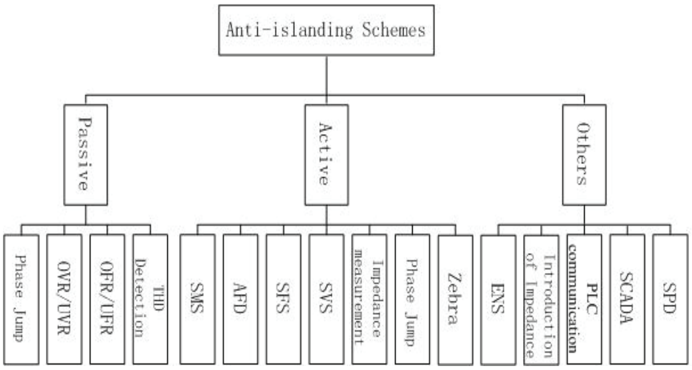


Fig. 2 The classification of all anti-islanding methods

3. Proposed detection algorithm

3.1APS method [9]

The additional phase shift (APS) algorithm is produced from SMS algorithm. At the *k*th zero-crossing of the terminal voltage, frequency of the previous voltage cycle is first measured. When frequency of terminal inverter voltage changes, the starting angle $\theta_{APS}[k]$ of the inverter output current is changed according to (1) , but the frequency remains at nominal line frequency.

$$\theta_{APS}[k] = \frac{1}{\alpha}\left(\frac{f[k-1]-50}{50}\right)\cdot 360^{\circ} + \theta_0[k] \quad (1)$$

Where α is a constant factor, f is frequency tested, θ_0 is additional phase shift.

If the steady state frequency of the terminal voltage reaches before UFR or OFR triggers, the additional phase shift θ_0 is also changed from:

$$\theta_0[k] = \theta_0[k-1] + \Delta\theta \cdot \mathrm{sgn}(\Delta f_{ss}) \quad (2)$$

where $\Delta\theta$ is constant, Δf_{ss} is change in steady state frequency, $\theta_0[k]=0 \ \ \forall k \le 0$;

$$\operatorname{sgn}(\Delta f_{ss}) = \begin{cases} 1 & \Delta f_{ss} > 0 \\ 0 & \Delta f_{ss} = 0 \\ -1 & \Delta f_{ss} < 0 \end{cases} \tag{3}$$

This APS is introduced each time the frequency of terminal voltage stabilizes to new operating point. This method assures that if utility is disconnected the frequency of the terminal voltage keeps deviating until OFR or UFR triggers. The method works well for multiple inverter case. It also works for purely resistive loads and parallel RLC loads with resonant frequency equal to line frequency. However, it is difficult to determine each stable operation point outside of OFR/UFR trigger window. If the limit is too small, there is no additional phase shift may cause, and too large, may lead to a large phase shift of inverter in normal operation mode. What is more, because additional phase shift is added in every possible stable point, the APS algorithm sometimes run very slow, even may fail in some load conditions.

3.2 IAAID method

An intelligent adaptive anti-islanding detection (IAAID) method is presented in this paper. It adopt SMS phase shift as basic tool. From the kth voltage cycle, phase shift between output current and terminal voltage can be calculated by (4):

$$\theta(k) = \pi \cdot \left(\frac{T_a - T(k)}{T(k)}\right) \tag{4}$$

where $T(k)$ is the measured period at the kth voltage cycle. T_a is the average of previous N cycles:

$$T_a = \frac{1}{N} \cdot \sum_{i=k-N}^{k-1} T[i] \tag{5}$$

In the APS algorithm, select the predetermined line frequency of distribution network as the output current cycle period, usually 0.02s. In the IAAID algorithm, select the average of previous N voltage cycles as the current cycle, which can reflect the frequency change of actual power system. When $\theta(k)$ is not 0, there are two possible conditions as following:

$$\theta(k) > 0 \Rightarrow \Delta T = T_a - T(k) > 0 \tag{6}$$

$$\theta(k) < 0 \Rightarrow \Delta T = T_a - T(k) < 0 \tag{7}$$

It implies that the system may operation in an islanding mode. To further confirm it, an additional phase shift is introduced:

$$\theta_0[k] = \theta_0[k-1] + \Delta\theta \cdot \operatorname{sgn}(\Delta T) \tag{8}$$

where $\Delta\theta$ is constant.

There are two advantages of this algorithm. First, it improves the reliability of judgements. Secondly, it may not add additional phase shift to the system in normal operation, which be good to stable grid operation especially in the case of multi-inverters tied to grid.

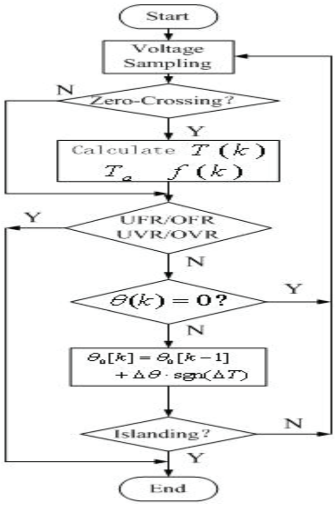


Fig.3. The flowchart of IAAID algorithm.

4. Simulation Results

The model of the islanding detection system with the presented IAAID method was developed with Matlab/Simulink and its SimPowerSystems toolbox. The inverter is modeled as a controlled current source. The inverter's model includes all the algorithms needed by the islanding detection system. A controlled switch disconnects the inverter from the grid when islanding is detected. The local load is modeled as a parallel RLC circuit. The value of the components can be changed according to the specific case that is to be tested. The grid is modeled as a controlled voltage source with a typical line impedance and a utility breaker used to simulate a grid disconnection. Fig.4 shows a successful anti-islanding with IAAID method.

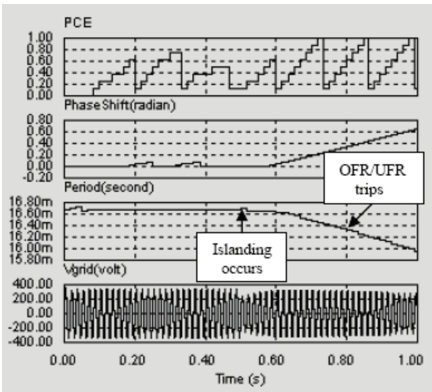


Fig.4 A successful anti-islanding with IAAID method

To verify the effect of IAAID method, a lab test circuit is built, shown as Fig. 5[9][10][11]. Both IAAID and APS methods is written to the DSP chip of control platform. Fig.6 shows that IAAID method is quicker to detect the islanding than APS [12]-[14].

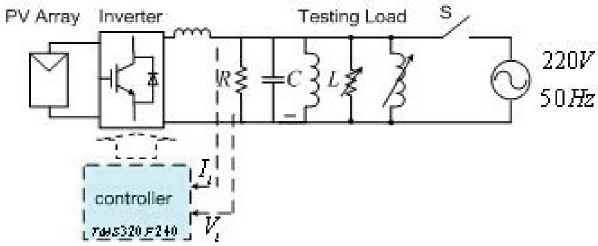
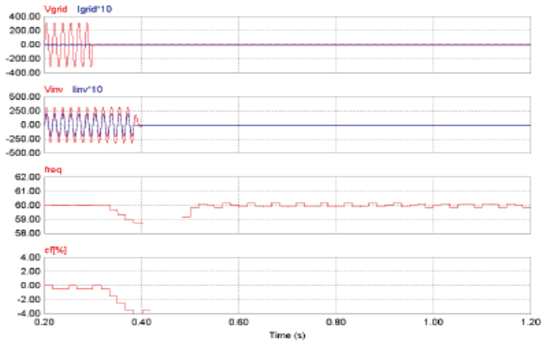
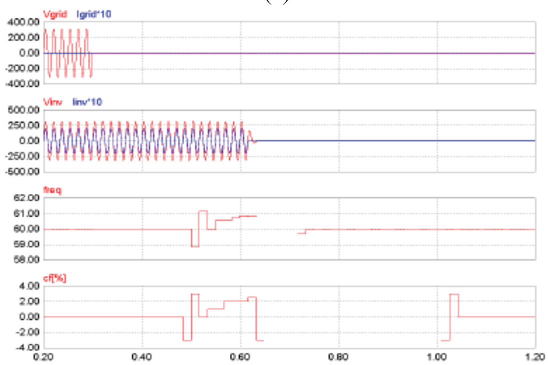


Fig. 5. Lab test circuit.



(a)



(b)

Fig. 6. The contrast of anti-islanding effect between AAID and APS. (a) The result of anti-islanding with AAID algorithms (b) The result of anti-islanding with APS algorithms

5. Conclusions

An intelligent adaptive method for islanding detection in grid-tied PV system is presented is presented in this paper. The simulation shows that the PV inverter with this method can detect islanding operation mode effectively. The experimental test results with lab test circuit show that IAAID methodcan detect islanding operation mode more quickly than APS method.

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