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A combined active anti-islanding method for photovoltaic systems

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Abstract

In a modern power system, photovoltaic as distributed generated source is growing larger and it can cause a variety of problems. The most important problem is that of the islanding phenomenon. In order to prevent islanding phenomenon, three kinds of active islanding detection methods have been studied. These are, respectively, to change magnitude, frequency, and the start phase of inverter output current. Among those, both a frequency variation method and a start-phase variation anti-islanding method make the islanding frequency drift away from the trip window of the frequency relay if islanding occurs. This paper presents a novel combined active anti-islanding method, which consists of a frequency variation method active frequency drift (AFD) and a start-phase variation method slip-mode frequency shift (SMS). Clearly, the proposed anti-islanding method shows the islanding detection ability to IEEE 1547 Standard. To validate the performance of the proposed method, simulations and experiments were performed. Possible islanding conditions are implemented with a unity quality factor by the IEEE Standard 1547. The methodology presented can be extended to the other active anti-islanding methods.

Keywords: Islanding detection methods; Grid-connected PV inverter; Slip-mode frequency shift; Active frequency drift

1. Introduction

Islanding phenomenon of grid-connected photovoltaic (PV) inverters refers to their independent powering to a portion of the utility system even though the portion has been disconnected from the remainder of the utility source. Recently, the concern about this islanding operation has been raised by the spread of the distributed resources because the islanding can cause safety problems to utility service personnel or related equipments. Consequently, utility companies and PV system owners require that the grid-connected PV system include a non-islanding inverter [1,2].

To prevent this phenomenon, various anti-islanding methods have been studied, which are classified into passive and active methods. When an inverter is equipped with an over voltage relay (OVR), an under voltage relay (UVR), an over frequency relay (OFR), and an under frequency relay (UFR), it is considered that the inverter has the basic passive anti-islanding methods. However, these passive schemes have a relatively large non-detection zone (NDZ) of islanding because they only monitor the voltage magnitude or frequency of the point of common coupling (PCC) at the PV inverter output.

Unlike these passive anti-islanding methods, active anti-islanding schemes make a perturbation into the PV inverter output current by injecting an active signal. Due to the perturbation, the power balance between the PV generated power and local load power can be broken. As a result, the active anti-islanding methods are generally considered more effective than the passive ones for islanding detection [3]. On the other hand, power quality and output power generation for anti-islanding methods can be impaired by the perturbation because it can change the magnitude or frequency of the output current. Therefore, it is necessary to design PV inverter to satisfy the standards for the power quality and the islanding detection capability.

Active anti-islanding methods are classified into three parts with respect to what the variation parameter is.

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As shown in Eq. (1), these are to change magnitude (I_m), frequency (f), and the start phase (θ) of inverter output current:

$$I_{inv} = I_m \sin(2\pi f t + \theta). \tag{1}$$

On the one hand, the magnitude variation of inverter output current (I_m) can cause generally a change of output voltage magnitude after islanding occurs, which makes OVR or UVR to detect islanding. On the other hand, both frequency (f) and start-phase (θ) variation anti-islanding methods make the islanding frequency of inverter output voltage drift away from the trip window of the frequency relay if islanding occurs. As a typical frequency variation method, there is the active frequency drift (AFD) method as shown in Fig. 1 which makes the inverter output current to drift up or down with a parameter chopping fraction (cf) in Eq. (2):

$$\text{cf} = \frac{T_z}{T_{util}/2}, \tag{2}$$

where T_z is the frequency dead time (s) and T_{util} is the line voltage period (s) [4].

In addition, well-known typical start-phase variation method is slip-mode frequency-shift (SMS) method as shown in Fig. 2 which makes the start phase (θ) of output current be a function of output voltage frequency [2,5].

Even though each variation parameter in Eq. (1) can be controlled independently, the research on the combined active anti-islanding methods has been little studied until now.

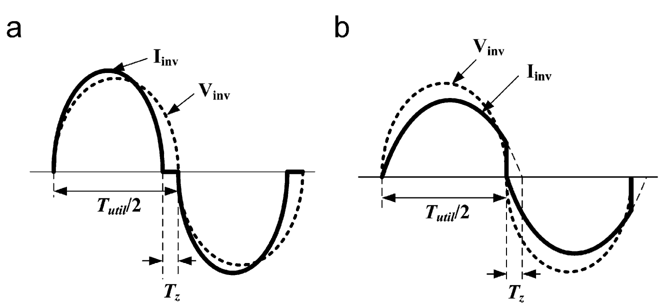

Fig. 1. Inverter output waveform using AFD method: (a) frequency drift up and (b) frequency drift down.

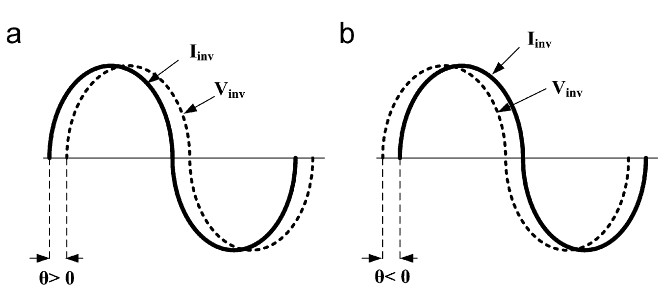

Fig. 2. Inverter output waveform using SMS method: (a) current-leading phase and (b) current-lagging phase.

Therefore, this paper presents a combined active anti-islanding method, which consists of AFD and SMS methods. The proposed method will give a more flexible

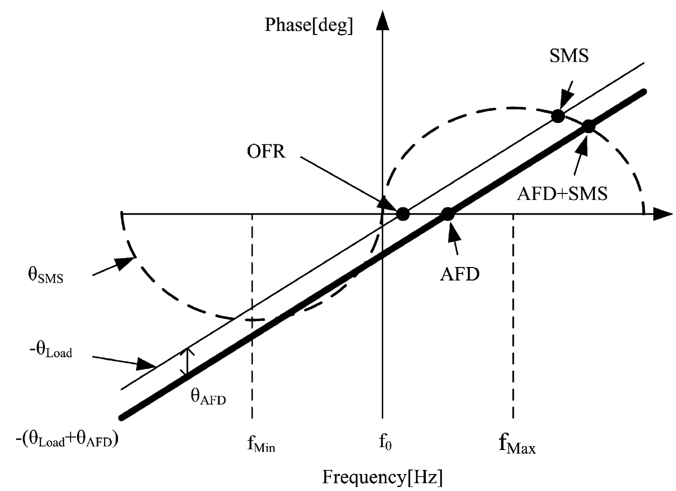

Fig. 3. Operating point of OFR (over frequency relay), AFD, SMS, and the combined method between AFD and SMS.

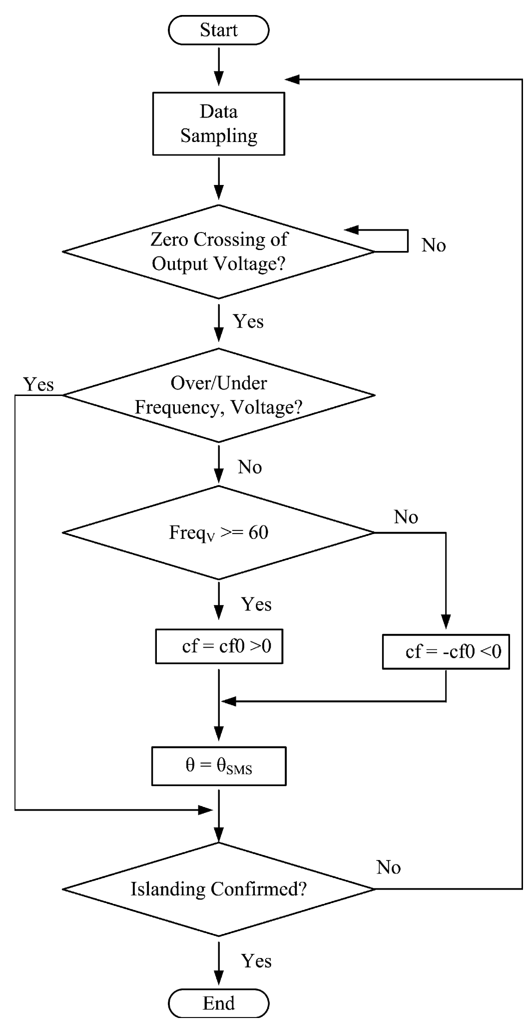

Fig. 4. Flow chart of the combined islanding detection algorithm.