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An experimental Study of an Improved Active Frequency Drift Anti-Islanding Method for PV Application

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Abstract

Since the concept of an improved active frequency drift anti-islanding method is developed in the previous research, this paper presents the experimental results to verify the validity of anti-islanding capability for single and multiple PV micro-inverter cases. The proposed method detects islanding within 2s under all conditions in IEEE Std. 1547.1.

Keywords: Anti-islanding, grid-connection, inverter controller, photovoltaic generation, PV micro-inverter.

I. INTRODUCTION

Since islanding phenomenon causes safety hazard to the power system facility and utility service personnel, it is an undesired concern for grid-connected photovoltaic (PV) resources in which one part of the utility system connected to both load and PV remains active while the other utility system is not inactive [1-6]. To prevent it, various anti-islanding has been researched and evaluated for a single photovoltaic inverter [7-10].

The basic protection function and the independent operating load condition according to the power system specifications of each country are different from each other. In addition, threshold values to operate OVR / UVR (overvoltage / undervoltage relay) and OFR / UFR (over frequency / under frequency relay) are different each other with respect to the power system specification. There is a need to apply the single operation detection technique applied to each country differently. The anti-islanding methods, implemented in PV inverter, are not researched well for multiple PV systems connected to the same utility grid [10]. Because a PV micro-inverter for a single module is basically connected with the others, multiple PV micro-inverters should be carefully considered for anti-islanding function.

Corresponding to the multiple PV microinverter operation, an improved active frequency drift anti-islanding method has been proposed [10]. This paper presents the performance analysis and evaluation by using the proposed method for multiple PV micro-inverters operations. In the previous research, the concept and analysis with simulation results for the proposed anti-islanding method are presented only without experimental results. This paper focus on the feasibility of the proposed method with experimental results.

In this paper, the synopsis of the proposed method is introduced first. Then the experimental results by using the proposed method are presented for multiple operation

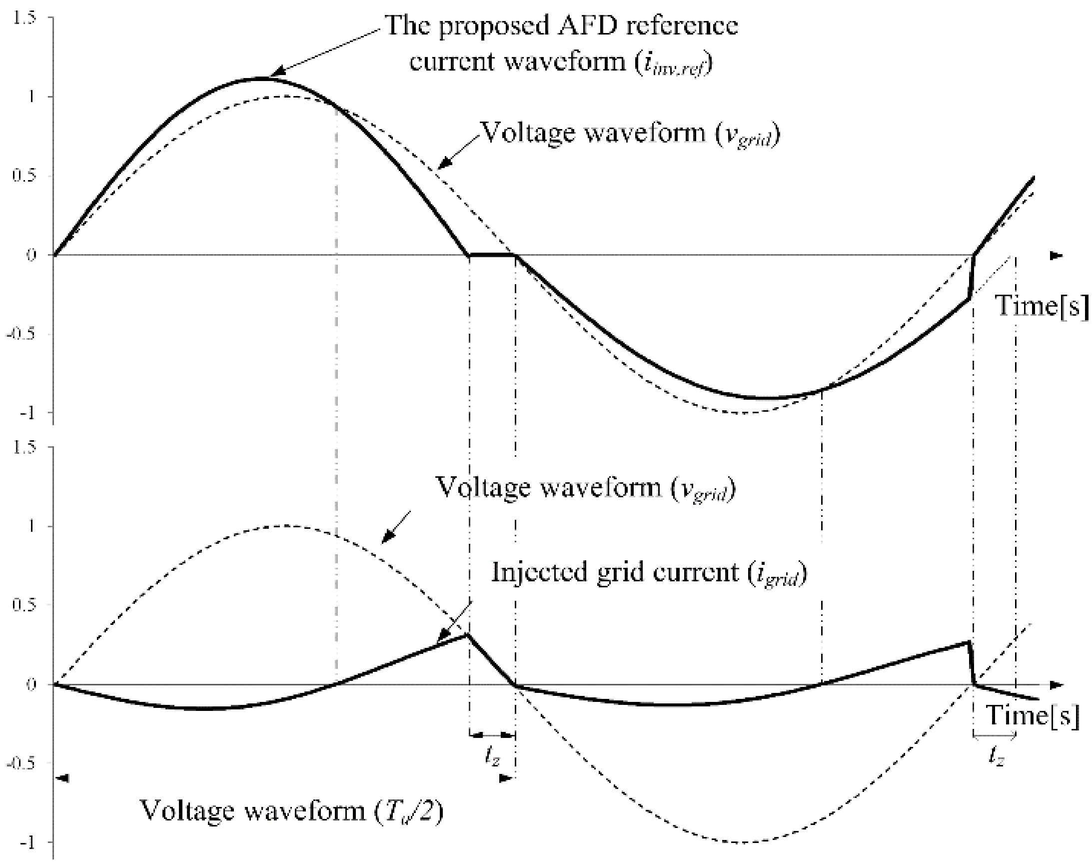


Figure 1. Operational waveforms for the proposed anti-islanding function.

II. SYNOPSIS OF THE PROPOSED ANTI-ISLANDING METHOD

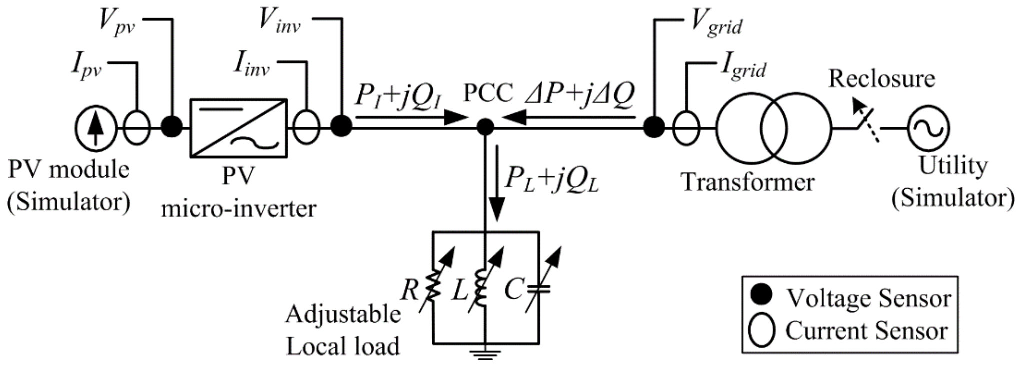
The proposed anti-islanding method is based on the correlation between the current perturbation every half line cycle and the corresponding half line period of the PV micro-inverter voltage, as shown in Fig. 1. The current perturbation is implemented by using two different chopping fractions every half-line cycle while the conventional active frequency drift (AFD) method uses a single chopping fraction (*cf*). In addition, the proposed correlation parameter (C_p) is increased enough to detect islanding because the frequency of PV micro-inverter has a strong correlation with the current frequency after islanding.

$$cf = \frac{t_z}{(T_1/2)} \tag{1}$$

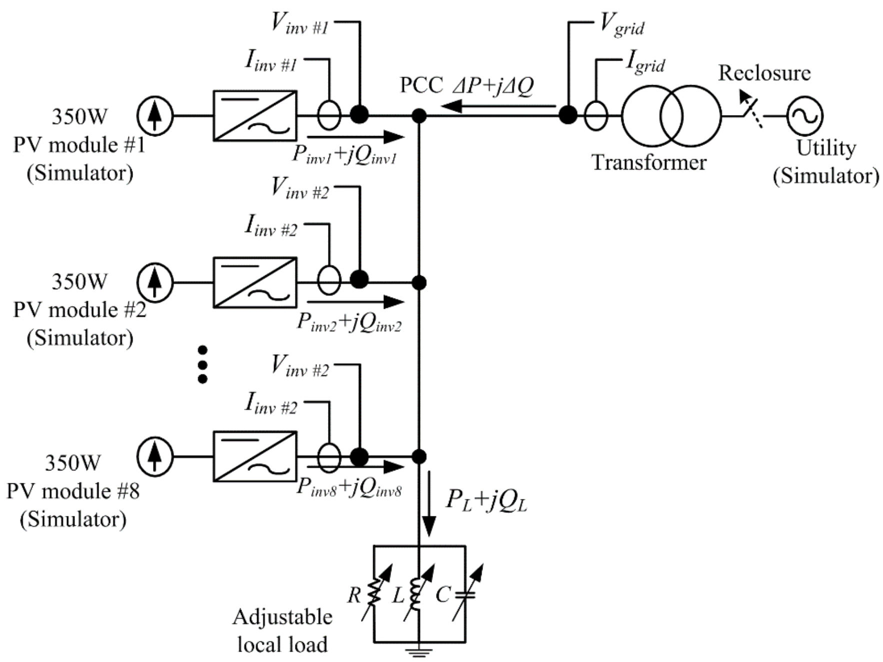
$$C_p[i] = \sum_{k=i-N}^{i-1} \left((2 \cdot f_{1p}[k]) \times cf_p[k] + (2 \cdot f_{1n}[k]) \times cf_n[k] \right) \tag{2}$$

where $C_p\,[i]$ is the correlation parameter at the *i*th instance, N is the observing line cycles to calculate the correlation parameter, $f_{1p}[k]/f_{1n}[k]$ are the measured positive/negative half-line frequencies of the micro-inverter output voltage in Fig. 1, and cf_p/cf_n are positive/negative chopping fractions are the perturbation ratio to the nominal current command.

The proposed anti-islanding method is based on the correlation between the current perturbation every half line cycle and the corresponding half line period of the PV micro-inverter voltage, as shown in Fig. 1. The current perturbation is implemented by using two different chopping fractions every half-line cycle while the conventional active frequency drift (AFD) method uses a single chopping fraction (*cf*). In addition, the proposed correlation parameter (C_p) is increased enough to detect islanding because the frequency of PV micro-inverter has a strong correlation with the current frequency after islanding.



(a)



(b)

Figure 2. Anti-islanding testing system configuration for PV micro-inverter. (a) Single PV micro-inverter operation, (b) multiple PV micro-inverter operation.

III. EXPERIMENTAL RESULTS.

In order to verify the performance of the proposed anti-islanding method, 350W class PV micro-inverters are tested under different experimental conditions like single operation and multiple operation as shown in Fig. 2. The electrical specification of a PV micro-inverter to be tested is described in Table 1. The implemented PV micro-inverter uses both a passive anti-islanding, such as OFR (Over Frequency Relay) /UFR

(Under Frequency Relay), and a proposed active anti-islanding method. The load condition for R, L, C resonant load is configured with a unity quality factor. Fig. 3 and Fig. 4 shows the anti-islanding performance for single PV operation and Fig. 5 shows the summarized anti-islanding performance for multiple PV operation.

Table 1: Electrical specifications for PV micro-inverter

Parameter	Value	Parameter	Value
Nominal power	350W	Nominal frequency	60Hz
Rated grid voltage	220V	OFR	60.5Hz
Number of phase	1	UFR	59.3Hz

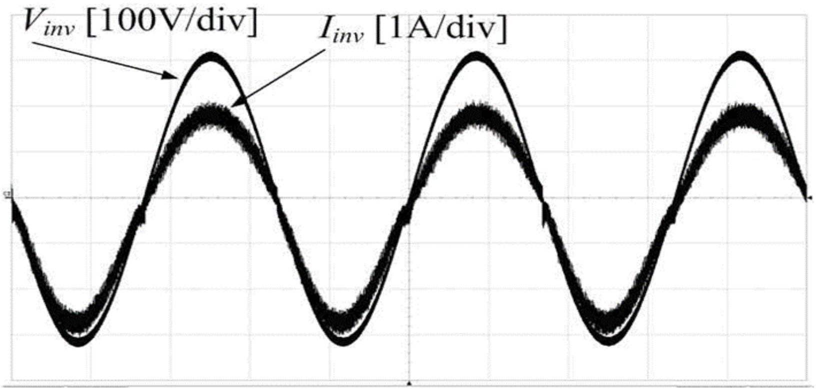


Figure 3. PV micro-inverter output current and voltage with +/- 2% chopping fraction.

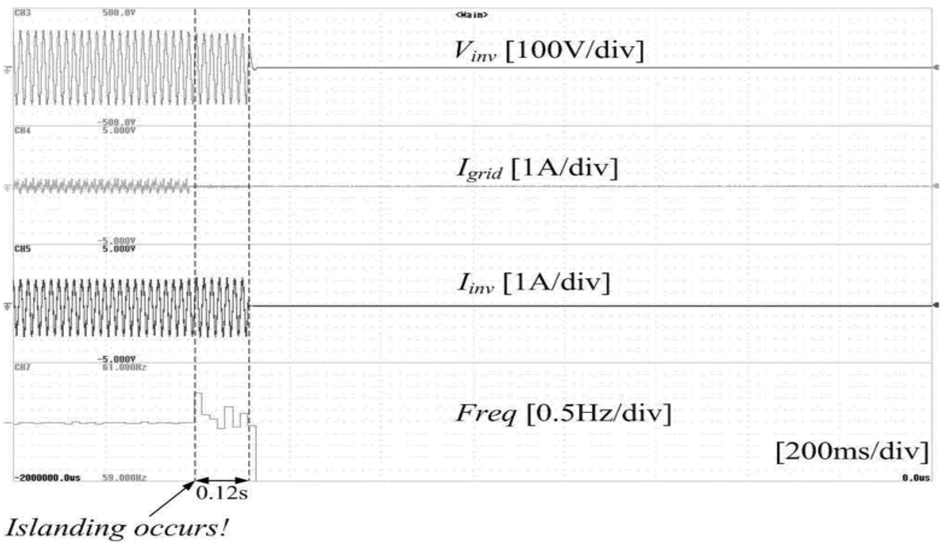
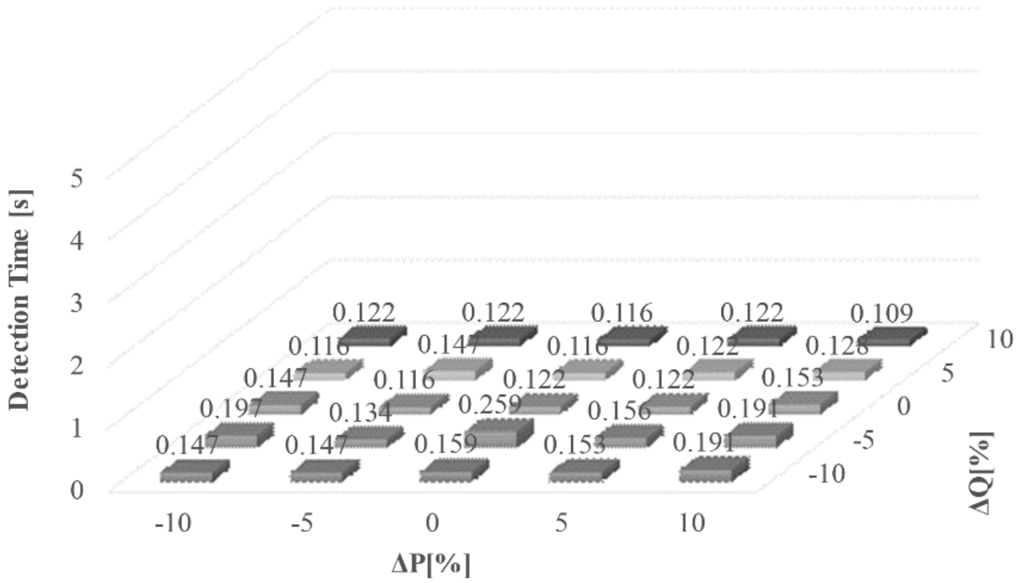
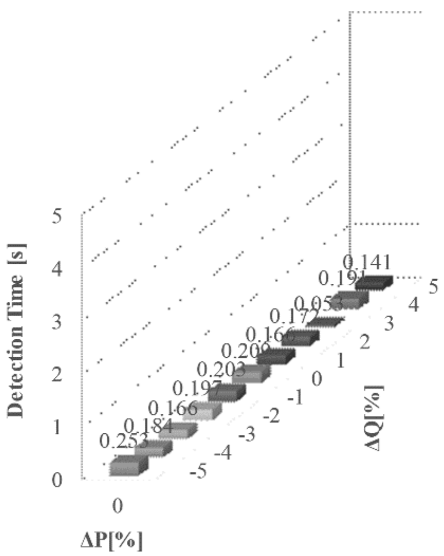


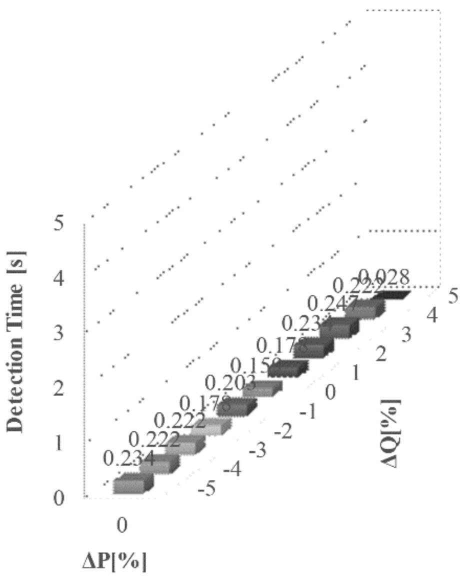
Figure 4. Anti-islanding test results for a single PV micro-inverter under a unity quality resonant load.



(a)



(b)



(c)

Figure 5. Anti-islanding test results for 8 PV micro-inverters under a unity quality resonant load with three different power load quantities. (a) 100% of the rated load, (b) 60% of the nominal load, (c) 30% of the nominal load.

In the experiment of PV micro-inverter, the chopping fraction is determined by +/- 2% every half line cycle. Fig. 3 shows PV micro-inverter output current, implementing the proposed anti-islanding method, with the corresponding PV inverter output voltage.

When the grid is within the positive half line cycle, the designed chopping 2% makes the inverter current frequency drift up, as shown in Fig. 3. While the grid is within the negative half line cycle consecutively, the designed chopping -2% makes the inverter current frequency drift down in the same figure.

For a single PV inverter operation, the anti-islanding function was tested as shown in Fig. 4. When PV generation was matched with local load power consumption, the anti-islanding was tested. According to IEEE Std. 1547, PV inverter should prevent islanding within 2s. After islanding occurs, the proposed anti-islanding method detect islanding within 0.12s and it stop the PV inverter operation [11,12].

As shown Fig. 2(b), eight PV micro-inverters are operated all together to evaluate the anti-islanding function of the proposed method under three different power load condition like 100%, 60%, and 30% of the nominal load according to IEEE Std. 1547.1. Fig. 5 shows the islanding detection times under these power load condition, respectively. Obviously, the proposed anti-islanding function detect islanding within 2s, which meets the IEEE Std. 1547 requirement.

IV. CONCLUSION

This paper presents the experimental results to verify the validity of anti-islanding capability for single and multiple PV micro-inverter cases. The proposed method detects islanding within 2s under all conditions in IEEE Std. 1547.1 for single and multiple PV micro-inverter operations.

ACKNOWLEDGEMENTS

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