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An effective passive islanding detection method for PV single-phase grid-connected inverter

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Abstract

This paper presented a low cost and effective passive islanding detection method for single-phase photovoltaic grid-connected inverters. An analog circuit for over/under voltage protection is developed to ensure fast detection and no delay to system. An under/over frequency circuit is also developed, for accurate and fast frequency detection with minimal external components. A new algorithm is developed in a low-cost PIC18F4550. An improved disconnection time in the proposed method compared with that in the previously developed method is an attractive solution for single phase grid connected inverters. The low cost, effective and minimal external component count are the advantages. A prototype is developed and tested to demonstrate the performance and feasibility of the proposed method. The experiment results verified that the proposed islanding detection method able to detect islanding operation effectively under various load types, inverter output powers and quality factors.

Keywords: Passive islanding; Distributed generation; Inverter

1. Introduction

Development for renewable energy sources produce low pollution compared to the fossil fuels and nuclear generation system (Yu et al., 2008). The new paradigm of distributed generation (DG) thus gains technical importance and creates business opportunities (Chowdhury et al., 2009). In principle distribution generation is a small scale generation unit that need to be installed to the load and also connected to the grid for selling or buying energy purposes. One of the most important criteria that need to be considered is the islanding issue (Yu et al., 2010). The islanding condition as specified in Recommended Practice for Utility Interface of Photovoltaic (PV) Systems (2000), occurs when "a portion of utility system that contains both load and distributed resources remains energized while it is isolated from the remainder of the utility system". Such an undesirable event could potentially occur due to the circuit tripping, accidental disconnection of the utility due to equipment failure, human error, temporary disconnection (for maintenance services) or uncommon network reconfiguration (Chowdhury et al., 2009; Yu et al., 2010). Integrating DG into utility is a major challenge to researchers. DG could still be supplying local load demand while network is already isolated from the main system. Existing methods are still lacking, hence successful detection of islanding is an ongoing challenge.

Two factors must be highlighted to better understand the islanding phenomenon. The first one is the available standards that have been established for the grid connected system. These standards addressed the issue of islanding as

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Nomenclature

PV	photovoltaic	APS	active phase shift
DG	distributed generation	SFS	Sandia frequency shift
NDZ	none detection zone	AFD	active frequency drift
PCC	point of common coupling	RPEED	reactive power export error detection
Q_f	quality factor	PLCC	power line carrier communication
LPS	load parameter space	T	transmitter
PMS	power mismatch space	R	receiver
$I_{n,a}$	negative sequence current	SPD	signal produced by disconnect
OV/UV	over and under voltage	SCADA	supervisory control and data acquisition
OF/UF	over and under frequency	V_{pcc}	voltage at point of common coupling
PJD	phase jump detection	RMS	root mean square
ROCOP	rate of change of power output	LED	light-emitting diode
ROCOF	rate of change of frequency	IGBT	insulated gate bipolar transistor
SMS	sliding mode frequency shift	DFT	digital Fourier transformation
PWM	pulse width modulation	V	grid voltage
MPPT	maximum power point tracking	f	grid frequency
R	resistor	C	capacitance
L	inductance	Q_f	quality factor

well as procedure for testing and qualifying DG system (Chiang et al., 2010). The second feature is associated with the so called “Non-detection zone” (NDZ) which can be defined as the zone for which an islanding detection method would fail to operate in time. NDZ is an evaluating criterion of islanding detection methods. In principle, islanding detection monitors changes in inverter output parameter or other system parameters that indicate islanding. There are two types of anti islanding methods which are the local and remote methods. The local methods can be divided into passive and active. Passive islanding detection detects changes in electrical parameters to determine the occurrence of islanding (Chiang et al., 2010). The advantages of these passive techniques are their easy implementation (no additional controller), no degradation of PV inverter power quality, and their inexpensiveness. The primary drawbacks are a relatively large NDZ and ineffectiveness in multi-PV inverter systems (Syamsuddin et al., 2009). The most commonly used passive technique for islanding detection are under/over voltage and under/over frequency (OV/UV & OF/UF), phase jump detection (PJD), voltage harmonic monitoring, current harmonic monitoring, rate of change of power output (ROCOP) and rate of change of frequency (ROCOF) Yu et al., 2010; Llaria et al., 2011; De Mango et al., 2006; Freitas et al., 2005; Redfern et al., 1993. Active techniques inject a small disturbance at the PV inverter output to detect islanding. The main advantage of these techniques is their relatively smaller NDZ than that of passive methods. Their main drawbacks are the possibly deteriorated output power quality causing instability to the PV inverter and normally require additional controllers which increased the complexity of the method (Syamsuddin et al., 2009). Active techniques developed include impedance measurement (IM), sliding mode frequency shift (SMS) or active phase shift (APS), sandia frequency shift (SFS) or active frequency drift with positive feedback, and reactive power export error detection (RPEED) Chowdhury et al., 2009; Mohamad et al., 2011; Lopes and Huili, 2006. AFD method varies the output current frequency through positive feedback. This method will inject a current with slightly distorted in frequency into the PCC. Upon grid disconnection, the phase error between the PCC voltage and the inverter current will be detected by the inverter, which then tries to compensate by increasing the frequency of the injected current until it exceeds the OF/UF limits. However, the performance of this conventional AFD method is inefficient and researchers are facing difficulty in choosing the suitable chopping fraction (*cf*) value to meet the limit of harmonics. Hence, a novel AFD method (Jung and Yu, 2007) with a periodic chopping fraction that deviates from the frequency in an instant way from nominal was proposed. Remote islanding detection techniques are based on communication between utilities and PV inverter units (Syamsuddin et al., 2009). This technique do not have the NDZ, do not degrade PV inverter power quality, are effective in multi-PV-inverter systems, but are expensive to implement (especially in small systems), and have a complicated communication technique for multi-PV inverter systems. Common techniques that are communication-based include power line carrier communication (PLCC), signal produced by disconnect (SPD), and supervisory control and data acquisition (SCADA). In application, each method has advantages and drawbacks. Among popular reference standards for islanding are IEEE 929-2000, IEC 62116, IEE 1547, VDE 0126-1-1, and AS 4777.3-2005.