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A high power quality anti-islanding method using effective power variation

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Abstract

Islanding phenomenon is undesirable because it leads to a safety hazard to utility service personnel and may cause damage to power generation and power supply facilities as a result of unsynchronized re-closure. In order to prevent the phenomenon, various anti-islanding methods have been studied. Until now, frequency or start phase shift methods of inverter current have much attention as active anti-islanding methods, which cause reactive power variation to the utility. However, these methods deteriorate usually the power quality like power factor or harmonic performance. This paper proposes a high power quality active anti-islanding method using effective power variation, which is implemented by periodically increasing/decreasing variation of inverter current magnitude. If it causes the large variation of inverter output voltage after islanding, active frequency drift (AFD) method as a simple anti-islanding method will be injected into the inverter current for a designed period and islanding can be detected. In case of large voltage variation when the grid is connected, AFD method will be removed after the designed period. Unlike most active anti-islanding method deteriorating power quality, the proposed method will have high performance of islanding detection and good power quality. For the verification of the proposed method, simulated results and experimental results in addition to analysis are presented using a 3 kW PV inverter.

Keywords: Anti-islanding method; Active frequency drift method; Effective power variation; High power quality

1. Introduction

Distributed generation (DG) including photovoltaic (PV), fuel cell, wind turbine is growing larger and more complicated in order to avoid future energy crisis. However, the advent of DG may be the cause of some problems to the stability and the power quality in the adjacent utility. Especially, the possible occurrence of islanding phenomenon has been one of the most issued problems in connection with the ongoing growth of DG (Bründlinger and Bletterie, 2005). Islanding phenomenon of DG refers to its independent powering to a portion of the utility system even though the portion has been disconnected from the remainder of the utility source. This is because 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 the non-islanding inverter (IEEE Std. 929-2000, 2000).

To prevent this phenomenon, various anti-islanding methods (AIMs) 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

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Nomenclature

Q_f	quality factor	I_n	nominal inverter output current (A)
Q_L	local inductive load (Var)	I(RMS)	RMS inverter current (A)
Q_C	local capacitive load (Var)	K	variation ratio to I_n (%)
P_R	local resistive load (W)	θ_I	start phase of inverter current (deg)
P_I	PV inverter effective output power (W)	*C0*	current magnitude control period [cycle]
Q_I	PV inverter reactive output power (Var)	*C1*	AFD injection period [cycle]
ΔP	grid effective power flow (W)	OFR	over frequency relay
ΔQ	grid reactive power flow (Var)	UFR	under frequency relay
R	local load resistance (Ω)	*T1*	islanding instant (s)
L	local load inductance (H)	*T2*	AFD injection instant (s)
C	local load capacitance (F)	*T3*	islanding detection instant (s)
Freq	frequency (Hz)	ΔV(RMS)	voltage deviation (V)
V_n	nominal inverter voltage (V)	$\Delta V(\text{RMS})_{,\text{ref}}$	reference voltage deviation (V)
V(RMS)	RMS inverter voltage (V)		
V_{i1}	islanding voltage (V)		

inverter has the basic passive anti-islanding methods. However, these passive schemes have relatively large non-detection zone (NDZ) of islanding because it only monitors the voltage (V_a) of the point of common coupling (PCC) at the PV inverter output in Fig. 1 (Ropp et al., 2000).

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. Consequently, the active anti-islanding methods are generally considered more effective than the passive ones for islanding detection (Yin et al., 2004). On the other hand, power quality and output power generation for AIM 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 AIMs are classified into three parts with respect to what the variation parameter is. As shown in Eq. (1), these are respectively to change magnitude (I_m), frequency (f), and the start phase (θ) of inverter output current.

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

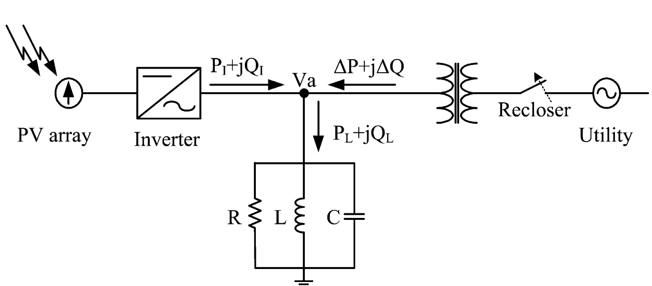

Fig. 1. Typical grid-connected PV system.

Until now, frequency or start phase shift methods of inverter current have much attention as active anti-islanding methods, which cause reactive power variation to the utility. As typical active anti-islanding methods, both frequency (f) shift and start phase (θ) shift anti-islanding method like active frequency drift (AFD) method and slide-mode frequency shift (SMS) make the islanding frequency of inverter output voltage drift away from the trip window of the frequency relay if islanding occurs (Ropp et al., 1999a,b; Ropp, 1998).

On the other hand, frequency variation method increases harmonic components of current, and start phase variation method decreases the displacement power factor, which cause the lower power quality. Especially, AFD with positive feedback and SMS make the worst case for harmonic generation and power factor when the grid is connected and the line frequency is near the boundary point of frequency relay trip window. This is because the deteriorating amount of power quality on both methods is determined by frequency variation from the nominal line frequency.

In response to these methods, this paper presents a novel active anti-islanding method using effective power variation which is implemented by periodically increasing/decreasing variation of inverter output current magnitude. If it causes the large variation of inverter output voltage after islanding, AFD method as a simple anti-islanding method will be injected into the inverter current for a designed period and islanding can be detected. The purpose of the other active islanding method injection like AFD method is to confirm the islanding phenomenon and to decrease the occurrence of nuisance tripping because the large voltage variation can be happened in the non-islanding condition. In case of large voltage variation when the grid is connected, AFD method will be removed after the designed period. Unlike other active AIMs deteriorating power