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A review of current anti-islanding methods for photovoltaic power system

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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. Until now, various anti-islanding methods (AIMs) for detecting and preventing islanding of photovoltaic and other distributed generations (DGs) have been proposed. This paper presents an overview of recent anti-islanding method developments for grid-connected photovoltaic (PV) power generation, focusing on the concept and operating principle, mainly based on single phase system. For the performance comparison, the experimental results of the various AIMs with 3 kW PV inverter are provided based on the islanding detection capability and power quality. As a result, the active AIMs have better islanding detection capability rather than the passive one. However, the active AIMs have power quality degradation on harmonic distortion or displacement power factor based on the injected active signal type. In addition to the evaluation and comparison of the main anti-islanding methods, this paper also summarizes the related anti-islanding standards to evaluate anti-islanding capability for PV system. This paper can be used as a useful anti-islanding reference for future work in DG like PV, and wind turbine.

Keywords: Anti-islanding method; Photovoltaic; Islanding standard; Distributed generation

1. Introduction

In modern power system, distributed generation (DG) including photovoltaic (PV), fuel cell, wind turbine is growing larger and more complicated. However, the advent of DG makes some problems to the stability and the power quality in the adjacent utility. Especially, most issued problem is islanding phenomenon which DG has an 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 systems include the non-islanding inverters (IEEE Std. 1547, 2003; IEEE Std. 929, 2000).

To prevent islanding phenomenon, many anti-islanding methods have been studied until now. Fig. 1 shows the total number of anti-islanding research papers per year for the DG among IEEE published papers since 1980. As the world DG demand has increased for the last decade, the number of anti-islanding papers has grown rapidly due to the safety issue for the DG. Based on the survey, there are two types of AIMs as the remote AIM like power line carrier communication and the local AIM shown as Fig. 2. Due to the simplicity, the research trend mainly goes to the local AIMs.

In the paper, the non-detection zone representations of AIMs are introduced first. Then, the related standards to evaluate anti-islanding capability for PV system are summa-

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Nomenclature

Q_f	quality factor	C	local load capacitance (F)
Q_L	local inductive load (Var)	*d.p.f.*	displacement power factor seen from the grid
Q_C	local capacitive load (Var)	f_0	nominal line frequency (Hz)
P_R	local resistive load (W)	V_0	nominal line voltage (V)
P_I	PV inverter effective output power (W)	I_{inv}	inverter command (A)
Q_I	PV inverter reactive output power (Var)	*cf*	chopping fraction
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)	OVR	over voltage relay
L	local load inductance (H)	UVR	under voltage relay

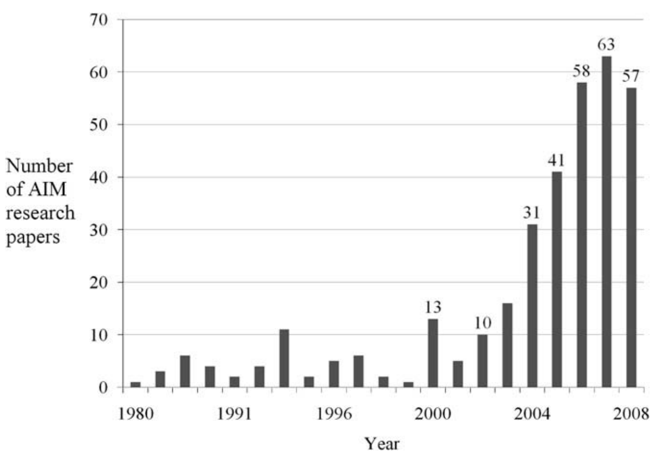

Fig. 1. Total number of anti-islanding papers per year, since 1980.

rized and compared. Typical islanding detection methods like the remote AIM and the local AIM are described, respectively. Lastly, this paper compares the AIMs and proposes the further works for islanding phenomenon.

2. Non-detection zone representation of islanding

The effectiveness of the islanding detection methods IDM is usually represented by the non-detection zone (NDZ) which depends mainly on the amount of local loads connected to the DG. The closer the active power consumed by these loads is to the active power supplied by the DG, the higher the probability to form an islanding. In the same way, as the resonant frequency of the local load approaches the local grid nominal frequency the potential formation of the islanding also increases. There are two kinds of representation methods up to now as follows: power mismatch space representation (PMSR), load parameter space representation (LPSR).

PMSR uses the amount of active power flow (ΔP) and reactive power flow (ΔQ) to the grid in Fig. 3. After islanding occurs, the islanding voltage and islanding frequency goes to the new operating point for the power balance between PV generation and local load consumption. Under the local passive AIMs, the quantitative NDZ of PMSR can be analyzed as Eqs. (1) and (2) (Ye et al., 2004). In the circuit, the quality factor Q_f, which is very critical parameter of islanding test condition, is defined as the strength of resonance of the islanding test load defined as Eq. (3).

$$\left(\frac{V}{V_{\max}}\right)^2 - 1 \leqslant \frac{\Delta P}{P_I} \leqslant \left(\frac{V}{V_{\min}}\right)^2 - 1 \tag{1}$$

$$Q_f\left(1 - \left(\frac{f}{f_{\min}}\right)^2\right) \leqslant \frac{\Delta Q}{P_I} \leqslant Q_f\left(1 - \left(\frac{f}{f_{\max}}\right)^2\right) \tag{2}$$

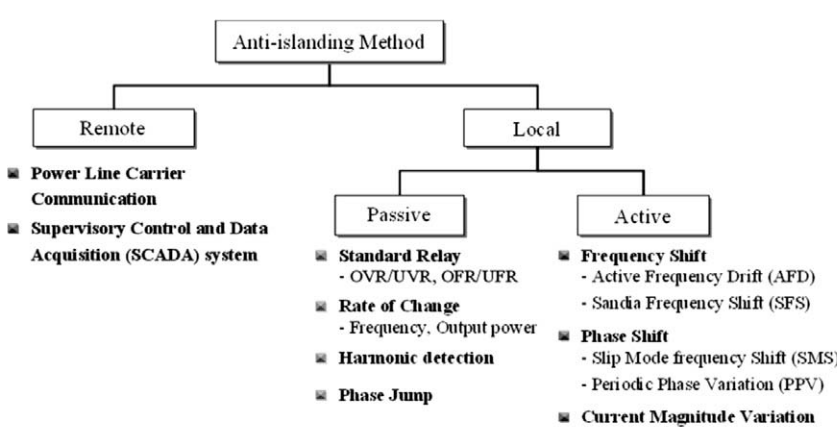

Fig. 2. Classification of anti-islanding schemes.