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An active islanding detection technique for current controlled inverter

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ABSTRACT

This paper presents an active islanding detection technique suitable for current controlled inverters. The method is based on reducing the magnitude of the injected current periodically and monitoring the voltage at the point of common coupling (PCC). Under grid failure, the change in voltage at the PCC exceeds the allowable voltage threshold and islanding is detected. The change in the PCC voltage depends on the ratio by which current is reduced and is independent of the magnitude of current. Hence the voltage threshold remains the same irrespective of the loading conditions. A simple control circuit is incorporated into the inverter control to enable islanding detection. The perturbation caused by this method does not affect the zero crossing of the inverter current nor introduce any distortion as in case of other active anti islanding techniques. The performance of the proposed technique applied to a current controlled inverter is simulated in MATLAB/Simulink environment. The feasibility of the technique is ascertained by conducting experimental test on the prototype unit built in the laboratory. The algorithm is implemented on an ALTERA CYCLONE II FPGA board and the results are presented to show that the proposed method can effectively detect the islanding condition regardless of the load conditions.

1. Introduction

Rapid technological developments in generation and storage of energy, the growing concern on environmental issues have focused the attention on alternative energy sources such as solar and wind [1]. The power generated from these sources is transferred to the grid through utility interfaced converters. One of the main issues that are to be considered when a Distributed Generator (DG) is connected to the utility is capability of the generator to detect islanding conditions [2]. The islanding condition occurs when a portion of the utility system that contains both load and distributed resources remains energized while it is isolated from the remainder of the utility system [3]. IEEE standard recommends disconnecting all distributed generators immediately after the formation of island. Islanding can be intentional or unintentional [4]. Intentional islanding may be due to preplanned event such as maintenance and in case of an unintentional island, the DG should be disconnected within 2 s after the grid failure [5].

Islanding detection methods can be categorized into passive and active methods [6]. Passive methods detect the voltage abnormality at the point of common coupling (PCC) including frequency, phase shift and harmonics to identify an islanding [7]. The most basic and universal means of detecting islanding is by establishing an over voltage relay (OVR), an under voltage relay (UVR), an over frequency relay (OFR) and an under frequency relay (UFR) [8]. The relays operate to shut down the inverter when the utility voltage/frequency deviates from set values. In the phase jump detection method, the phase of inverter current is instantaneously synchronized at zero crossing with phase of voltage. Considerable phase difference can be identified in the event of islanding but problem arises when the load power factor is unity [9]. The advantage of passive method is that it is simple and does not have an impact on the normal operation of the DG system. However, when the inverter power matches with the load power, the amount of frequency or voltage deviation will not be sufficient to detect the occurrence of islanding. Thus, passive islanding detection methods suffer from large non detection zones (NDZs). NDZs are defined as the loading conditions for which an islanding detection method would fail to operate in a timely manner [10].

To overcome the shortcoming of the passive methods and improve the islanding detection capability, active islanding detection methods [11] are employed. These methods periodically introduce perturbations into the converters output to detect the variations in system behavior and relate them to an islanding condition. The active frequency drift (AFD) method [12] introduces

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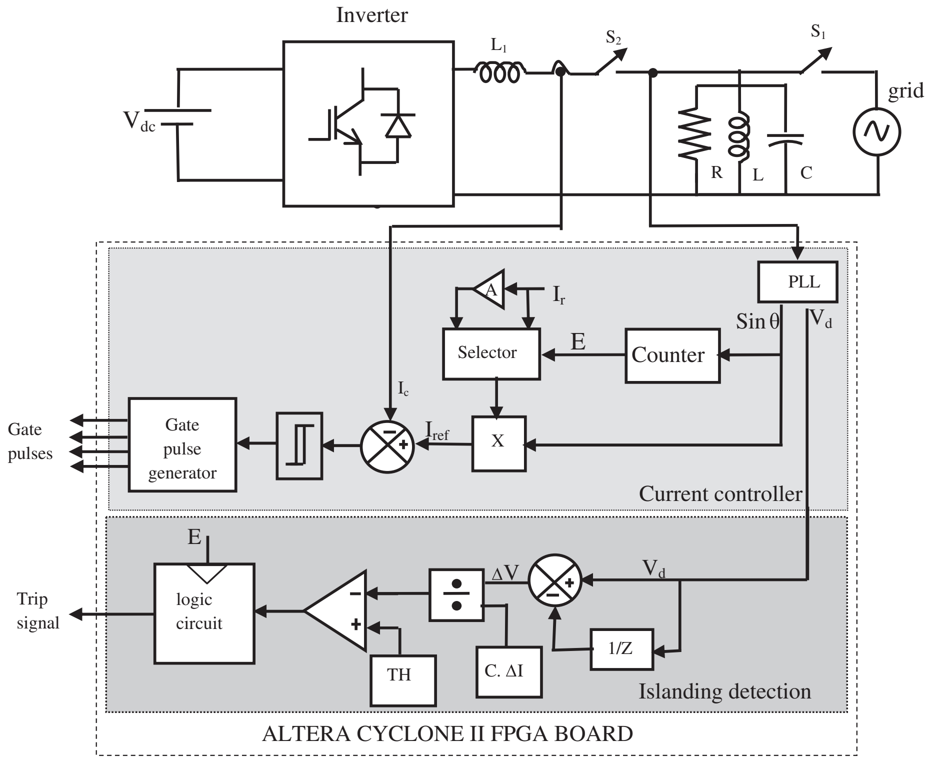

Fig. 1. Schematic of the PV system with islanding detection.

perturbations in the frequency of inverter current and any deviation in the voltage frequency indicates the occurrence of islanding. However, this method fails to detect the island when the load phase angle matches with the phase offset generated by perturbing the frequency. The active frequency drift with positive feedback (AFDPF) method [13] detects the islanding by forcing the frequency of PCC voltage to drift up or down. This method introduces zero intervals in the converter output current waveform and reduces the power quality. The sliding mode frequency shift method (SMS) [14] controls the phase angle of the converter output current as a function of PCC voltage frequency. Under grid failure, the method relies on an uncontrollable, externally controlled perturbation and if the perturbation is small, the islanding may not be detected within the specified time. The auto phase shift (APS) detection method [15] is a modified SMS method which introduces an initial value in the phase shift perturbation. However, several parameters are presented in the phase shift algorithm which is to be optimized. The improved IM-SMS method [16] which overcomes the limitations of SMS and APS methods, injects disturbances into the phase of converter output current. A small distortion exists in the current waveform under normal conditions. The Adaptive Logic Phase Shift (ALPS) [17] algorithm regulates the additional phase shift at an islanding situation and evaluates the effect of every phase shift. This algorithm yields a quick phase shift in an islanding situation but introduces a small phase shift in the output waveform. Though the active methods tend to have a faster response and a smaller non detection zone compared to passive methods, the power quality of the inverter is inevitably degraded by the perturbation.

This paper presents an active islanding detection algorithm suitable for current controlled inverters. The inverter current reference is modified periodically by reducing its magnitude and the voltage at the PCC is monitored. When the change in PCC voltage exceeds the allowable threshold, islanding is detected. The salient features of the proposed method are simple control circuit incorporated into the inverter control, voltage threshold independent of load and no phase shift or frequency shift or distortion in the output waveform and islanding detection without degrading the power quality.

2. System description

A simple active islanding detection suitable for current controlled inverters in which the DC link control is decoupled from the ac line current control [18–21] is developed. The system considered for study involves a grid interfaced inverter, a parallel RLC load connected at the PCC and the grid and the schematic of the system is shown in Fig. 1. The current control of the inverter is achieved by using a hysteresis current controller and the reference signal for the hysteresis current controller is generated as a function of the phase of the grid voltage. A PLL circuit is used to generate the phase angle of the grid voltage. The reference current for the controller is given by

$$\begin{bmatrix} i_d \\ i_q \end{bmatrix} = \begin{bmatrix} I_r \, Sin \, \theta \\ 0 \end{bmatrix} \qquad (1)$$

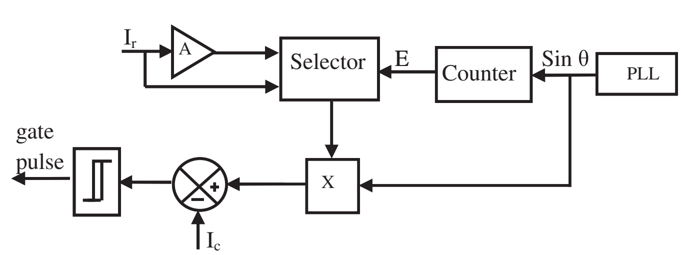

Fig. 2. Control circuit for periodic current perturbation.