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A new technique for islanding detection using voltage phase angle of inverter-based DGs

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ABSTRACT

In this paper, a new method is studied for the islanding detection of an inverter based distribution generation. The use of parameters at PCC (such as deviation of the voltage and frequency) as a feedback has been considered by researchers. The variation of voltage angle is used as a feedback in the proposed method. After an islanding occurrence the variation of voltage phase angle can change the references of active and reactive powers. The power variations cause the voltage and frequency deviations as detection parameters. The performance of islanding detection of the proposed method is investigated under the IEEE UL 1741 for the worst-case. The simulation results show that the adverse effects of this method are negligible and non-detection zone of the proposed method is small. Also, this method has no significant effects on the power quality and system normal operation mode. In addition, the results of tests for multiple DGs are suitable and there is not any significant interference between DGs in the normal operation mode.

1. Introduction

The rate of electric energy generation by distributed generations (DGs) such as wind farms, small diesel generators, tidal and wave generators and photovoltaic cells is growing in few last years and many distributed generators will be interconnected with the utility power systems [1,2]. The presence of DGs causes some system protection problems such as unintentional islanding. Unintentional islanding condition takes place when one or more distributed generators (DG) and some loads are separated from the main utility system while the loads are energized by DGs [3]. The voltage and frequency probably will be changed in the islanding situation by a power mismatch. The islanding situation causes damages for equipment, power quality problems and has safety hazards to personnel [4]. Thus, the island should be detected correctly by islanding detection methods and then DGs should be disconnected from the loads.

Researchers proposed various methods for the islanding detection. These methods are divided into two major categories; communication based methods and local detection methods. Local detection methods can be classified into two main groups: passive methods and active methods [5].

The passive methods detect islanding condition by measuring one or more parameters such as frequency and voltage level. Therefore, these methods have no adverse impacts on the system operation. Passive methods have significant non-detection zone. There is no enough parameters deviation for the islanding detection when the power mismatch is low. Thus, only system parameters deviation cannot be trusted for islanding detection [6]. Some of passive methods are Over/Under Voltage Protection (OVP/UVP), Over/Under Frequency Protection (OFP/UFP) [7], rate of change of frequency and power [8,9] and Phase Jump Detection (PJD) [10].

Active methods use disturbance injection into the power system through a point of common coupling (PCC). Disturbance injection causes significant variations in some parameters of the islanding condition versus the normal condition [11,12]. The non-detection zone of active methods is smaller than that of passive methods. Due to the nature of active methods, they have adverse impacts on the power-quality [13]. Some of active methods that have been proposed by researchers are slip-mode frequency shift (SMS) [14], Sandia frequency shift (SFS) [15] and negative-sequence current injection [16]. However, active methods have adverse impacts on the power-quality, but are usually used more than other methods, because active methods are cheaper than communication based methods and have smaller the non-detection zone than that of passive methods.

DGs should operate at a power factor of more than 0.85 when the output is more than 10% of the rating. Inverter-based DGs operate close to unity power factor to support the power system and loads in its highest active power capacity [3].

In the islanding detection studies, the RLC load is used in the simulation, because this kind of loads has the most problems in

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the islanding detection process [10]. In normal condition, the load consumes its required reactive power from the power system. But in the islanding condition, DGs cannot inject the requested reactive power, thus frequency goes toward the load resonance frequency. If the load resonance frequency is equal to the system nominal frequency, the frequency will not change.

This paper proposes a new active method in which the active and reactive powers will be changed immediately after an island is formed applying the variation of DG voltage phase angle (σ). There are some active methods which use active and reactive powers injection for destabilizing the parameters of system [11,17,18]. However, proposed method in this paper uses voltage phase angle of inverter-based DG as a feedback signal to change powers references which is different from others methods. Since inverter-based DG produces constant active and reactive powers in grid-connected mode, changes of the voltage phase angle will be insignificant. Therefore, the injected disturbances of powers by this method are not very considerable and during non-islanding situation such as load switching, voltage variations and other changes in network does not cause false detection. Thus, the adverse effects of this method on the power quality are negligible. Additionally, this method is simple to implement and does not cause any problems for the power with unbalanced loads or multiple DGs.

After islanding occurrence, the voltage and frequency will vary and the island will be detected in a sufficient time by changing in the voltage phase angle.

The paper is organized as follows. Section 2 presents modelling of the power system and DG control scheme. In Section 3 the new method will be explained. Section 4 provides simulation results.

2. System modelling and control scheme

The simple model of a test system including inverter-based DG and a load that both of them are connected to the power system network is shown in Fig. 1. The power system just was modelled by a voltage source with an impedance.

The power capacity of DG is rated at 0.1 MW. The DG is tuned to work near the unity power factor. The DG contains a DC source connected to an inverter as an interface with the grid [6].

The model of the three-phase RLC circuit is used as a load. As mentioned in Section 1, RLC loads have most problems in the islanding detection process. According to UL1741 the load resonance frequency is considered near the system operational frequency about 59.9–60.1 Hz [5], therefore the RLC load consumes the active power at unity power factor. There is no significant power mismatch between the load and the DG output. Actually the load should have the active power close to the DG output, because the worst-case assumption should be considered in the islanding detection test [3]. Under these conditions, the DG and the load will operate close to the network nominal operation point, when the island is formed. Based on the IEEE 1547, load parameters will be calculated as

$$L = \frac{V^2}{2\pi f Q_f P} \quad (1)$$

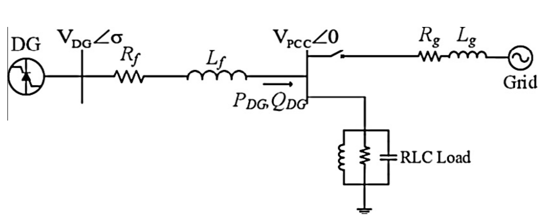

Fig. 1. System under study.

$$C = \frac{PQ_f}{2\pi f V^2} \quad (2)$$

$$R = \frac{V^2}{P} \quad (3)$$

The DG operates such as a constant active and reactive power source and it has current and power controllers. The DG control scheme is shown in Fig. 2.

To control the inverter based DG, a d–q synchronous reference frame is provided. The DG output active power relation is expressed in (4), as given [19]:

$$P = v_a i_a + v_b i_b + v_c i_c \quad (4)$$

By transforming to the d–q synchronous reference frame, the instantaneous active power will be equal to

$$P = \frac{3}{2}(v_d i_d + v_q i_q) \quad (5)$$

If the d-axis component coincides with the voltage vector and the q-axis is in quadrature with that. The active power will be equal to (6), as given by [19].

$$P = \frac{3}{2} v_d i_d \quad (6)$$

The reactive power could be calculated in term of the above conditions. It is equal to

$$Q = \frac{3}{2} v_d i_q \quad (7)$$

Eqs. (6) and (7) show that i_d and i_q can control active and reactive powers, respectively. The DG output power ((6) and (7)) will be compared with references of the active power (P_{ref}) and reactive

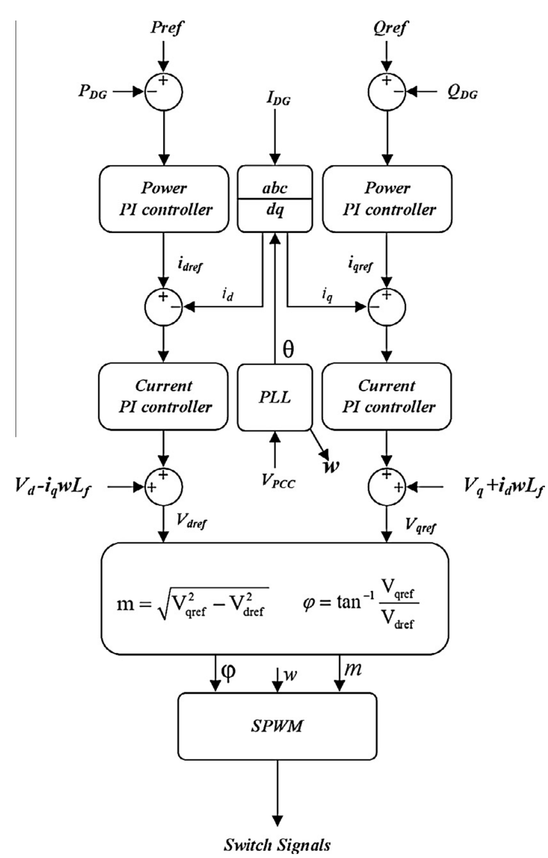

Fig. 2. The DG controller.