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Islanding Detection and Frequency Circuit Measurement by Power Distribution Relation Depending on the Angle

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Abstract

This paper presents a new islanding detection method based on the difference of the power transfer angle between the distributed generation and local load. After islanding, current id and iq will be changed by adding the variation to d_q transformation block of current. This makes voltage and frequency disturbance and therefore islanding is recognized. Active islanding detection method usually has a negative effect on power quality .The great advantage of this method include small negative impact on power quality. Performance of the proposed method will be evaluated and simulation results will be presented.

Keywords: Component, Islanding detection, Active method, Power mismatch, Distributed generation.
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1. Introduction

The contribution of distributed generation is so important because of its effect on the power system. Recently, researchers have paid attention to use the distributed generation for supplying the local load. For this purpose, using the wind turbines, batteries and DC supply have become the focus of concern [1]. Electric power production lets the extra electric power to be fed to the network. The power production from distributed generation and renewable energies is growing because of many advantages. The connection of DG's to utility system has some protection issues such as islanding. Islanding detection of distributed generation causes this source in a system, to continue supplying part of the plant which is subtracted from it. This operation occurs when the distributed generation for some reasons is interrupted, but the distributed generation has consistently kept producing power [2, 4, 6]. The islanding situation imposes some considerable problems into power systems such as power quality problem, frequency/voltage deviation, overload condition and adverse effect on system's protection [7]. Therefore, islanding detection should be detected. Islanding happens in two ways i.e. intentional and unintentional. In addition, the recognition techniques of islanding are divided into two main groups including the local methods and remote technique.

The local methods are divided in two sets that are active and passive approaches. Communication methods are based on sending and receiving signals. The communication signals are defined between the network and the DG. Therefore, this method is better than the local method, but the implement and the usage of this method is so expensive and is totally uneconomical.

The local method based on the data received is defined as the DG. The passive method detects island by monitoring change of parameters such as frequency or voltage variation at the common coupling. This method is simple and low-cost to implement but if the power mismatch between load and DG is small, the deviation of parameters will not be large enough. As a result, this method can't detect islanding in reasonable time because it has large non-detection zone.

In the active method, small disturbance is added to power system to change in the system parameters. In fact, small disturbance cannot create considerable variation in voltage and frequency for the grid connected mode because the DG parameters are dictated by power system. When an island is formed, the small disturbance can create variation in parameters and therefore active methods have smaller non-detection zone than the passive algorithms [9]. However, they have unfavorable impacts on the power quality due to disturbance injection.

This paper presents new active method whose implementation does not require any considerable changes in inverter structure. In the presented method, the difference between the DG instantaneous and nominal voltage phase angle will be subtracted from the input angle of transformation block derived from the phase locked loop (PLL). In islanding mode voltage, phase angle will change so that the amplitude of this difference will be increased while instantaneous and nominal voltage phase angle are close to each other in grid-connected mode. Since, this value is inconsiderable, this method will not adverse effects on the power quality. In addition, detection time is reasonable.

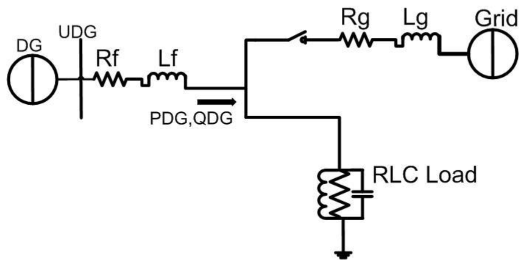

Fig. 1.System under study

Table.1.
Load and system parameters

System Parameters	
Frequency	60 HZ
Voltage (Line-Line)	480 V
DG output power	100 KW
DG input voltage	900 V
Grid resistance	0.02 Ω
Grid inductance	0.000307 Ω
R	2.304 Ω
L	0.00611 H
C	1151e-6 F
Quality factor	1

2. System Under Study and Control Scheme

Single-line diagram of the network consisting of an inverter DG, load and power system network is shown in Fig.1 and the related parameters are given in Table 1. The DG is modeled as a constant power source operating at power factor of 1 when it works above 10% of its capacity to supply the power system and loads in the highest capacity [10]. The load is modeled as three phases RLC.

In the grid connected mode, power system supplies the reactive power load demand. When DG operates in power factor of 1, reactive power demanded by the load will not be supplied. As a result, the island frequency is dictated by the resonance frequency. In the case that it is equal to the system nominal frequency, the frequency will not change significantly and the load resonance frequency is assumed to be near the system operational frequency [9]. In addition, the active power mismatch between RLC load and DG is small because a worse case must be considered in test. The load parameters are calculated as follows:

$$R=\frac{U^2}{P}\ ,\ C=\frac{PQ_f}{2\pi fU^2}\ ,\ L=\frac{U^2}{2\pi fQ_fP} \quad (1)$$

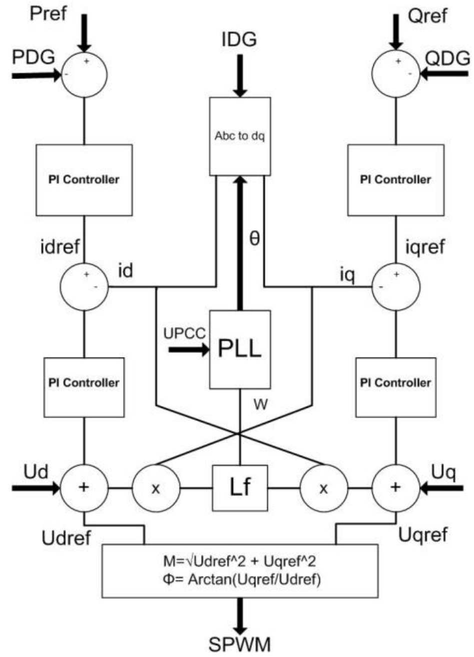

Fig. 2.DG controller scheme

The DG control block diagram is shown in Fig. 2. The inverter currents are controlled by a simple d-q synchronous reference frame. In transfer mode from abc to dq, instantaneous active and reactive power is calculated. Active and reactive powers are controlled by d-q currents. The DG is a constant power supply and its active and reactive powers will be controlled by the given reference value [11]. The proportional integral controller of power regulation produce I_{dref} and I_{qref}. The error of current reference and d-q current will be added to PI controller to create the voltage reference.

3. Proposed Method

The power exchange between the load and DG is defined as follows:

$$\Delta P = P_{LOAD} - P_{DG} \quad (2)$$

$$\Delta Q = Q_{LOAD} - Q_{DG} \quad (3)$$

In the grid connected mode, power system dictates the value of voltage and frequency. As a result, when the islanding is formed, active and reactive power for RLC load affect the value of voltage and frequency at common coupling point (PCC) as shown in (4):

$$P_L = \frac{U_{PCC}^2}{R_{LOAD}}, Q_L = U_{PCC}^2\left(\frac{1}{W_L} - W_c\right) \quad (4)$$

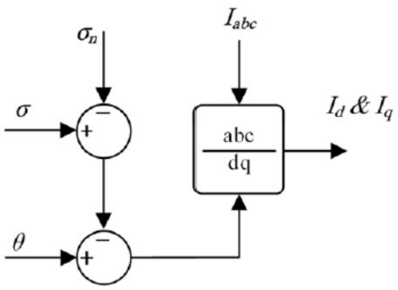

Fig. 3.Block of proposed method

The frequency will not change enough for islanding detection because the resonance frequency of RLC load is near to the system nominal frequency and DG acts close unity power factor. Therefore, if the power mismatch is not significant, the frequency and voltage variation will not change enough for islanding detection. According to the equations related to power transmission from DG to PCC, we have:

$$P_{DG} = \frac{U_{DG}U_{PCC}}{X_f}\sin(\delta_{DG} - \delta_{PCC}) \quad (5)$$

$$Q_{DG} = \frac{U_{PCC}(U_{DG}\cos\delta - U_{PCC})}{X_f} \quad (6)$$

Voltage phase angle δ of PCC is used as reference during the simulation. The parameter Q_{DG} almost is equal to zero because DG operates at the power factor of 1 and P_{DG} can be replaced by P_{ref} as shown in equation (7).

$$\tan\delta = \frac{X_f P_{DG}}{U_{PCC}^2}, \ \tan\delta_n = \frac{X_f P_{ref}}{U_{PCC}^2} \quad (7)$$

The nominal voltage phase angle is calculated by (7) for every DG connected to power system. Based on equation (7), the amount of $\delta_n$will be changed when islanding is created because power system is not able to exchange power with the island region in the case of islanding. In this method, the difference between the angle of the power transfer for the distributed generation and local load is added to controller scheme. In islanding condition, amplitude of this error will increase and I_d and I_q will change. Fig. 3 shows the way that we add a new block for the proposed method.

4. Result and Discussion

As mentioned, the amount of reactive power injected by DG is zero because assumption is that the system works with PF = 1 and the load is chosen in such a way that the power mismatch is minimum and the resonance frequency of the system is considered close to the base frequency. According to parameters in Table I, system simulation is performed. Parameters in the Table 1 are defined as assumption and compared with other modes. It is assumed that islanding accrued at t=1s.

To evaluate the performance of the proposed method in the diagnosis island, microgrid consider as follows:

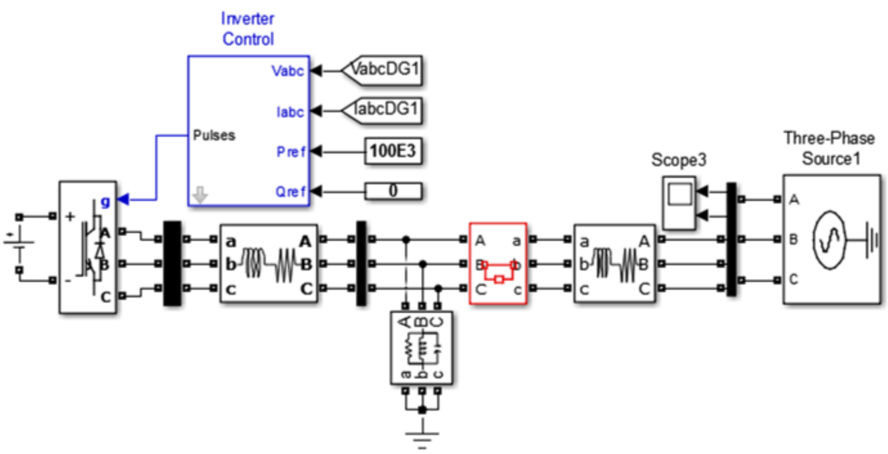

Fig. 4.Used case study

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Microgrid is disconnected from network at t=1s and it is reconnected at t=3s. The system under review with each two control methods is studied. The constant PQ control block is used first and the method with additional block in control system is then proposed. The goal is to identify the moment of the islanding under the different conditions. Fig. 5 shows the simulation results for first scenario.

It is obvious that system and DG cannot detect island using the first scenario due to small power mismatch. It is noted that the voltage and frequency variation is also insignificant. For more clarification, active/reactive power and voltage/current waveforms are obtained and shown in Figs. 6 and 7.

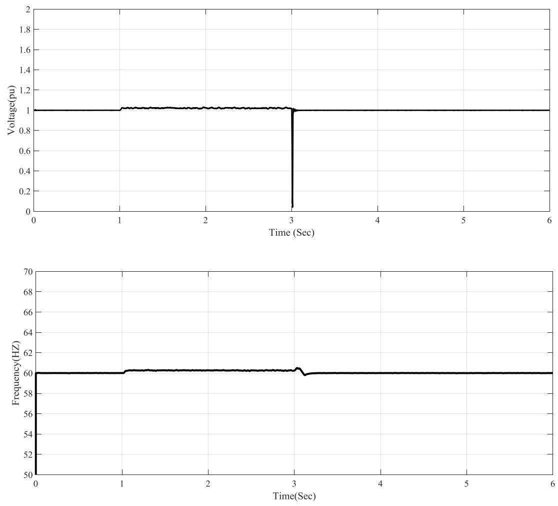


Fig. 5.Islanding detection with constant PQ controlled inverter

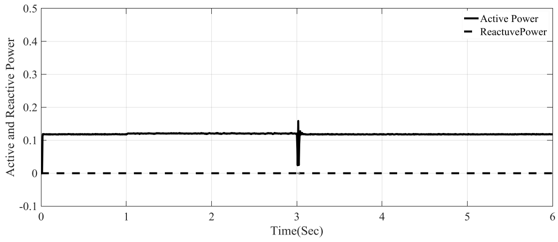
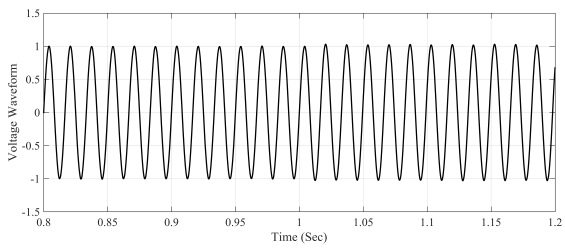


Fig. 6.Active and Reactive Power



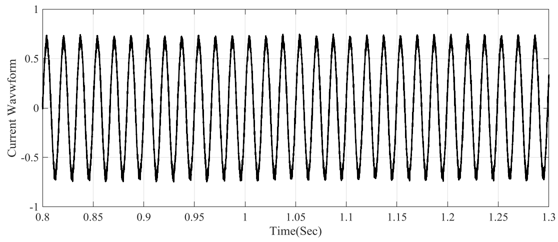


Fig. 7.Waveform of voltage and current

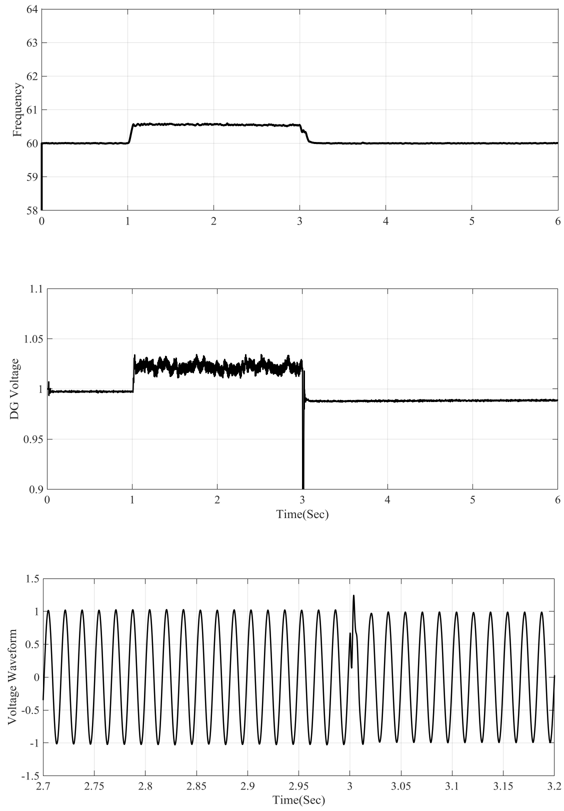


Fig. 8.Islanding detection with proposed method

For proposed scenario, the island happens at t=1 s and Fig. 8 shows the simulation results for this method. As seen, the island could be detected by proposed method when power mismatch is at minimum. In addition, the observed value for active and reactive power transfer between distributed generation and the grid confirmed the accuracy of islanding detection. This active islanding method is evaluated by different power mismatch. To create diverse power mismatch, various values for the load active and reactive power /inverter output ratio are considered which are given in Table II. Fig.10 demonstrates the simulation result for the cases mentioned in Table 2. As it can be seen, the voltage and frequency will change between t=1 to t=3 s when islanding occurs in different power mismatch scenarios according to Table 2.

The islanding detection method will not properly work if local load has a high quality factor. When load resonance frequency and the system nominal frequency are the same, a high value of quality factor may cause a fault in detection. For this reason, the proposed method must be tested for several of quality factor. Table III shows load parameters for all quality factors that have been tested. Fig. 11 demonstrates test method for different quality factors between 0.5 and 3. As seen from Fig. 11, different values of this parameter have no bad effect on detection. The PCC point is disconnected from network at t = 1 s and it is reconnected at t= 3 s.

Mostly load is modeled as constant power, as regards loads not necessarily be constant and during the hours of the day are changed so this model is not accurate. With the increase in non-linear and combination loads in power system using Constant power load model is not enough because loads change between the minimum and maximum value in a day. Many of the devices used are sensitive to the quality of Power, voltage and frequency; therefore this scenario has been tested by nonlinear load. As can be seen in Fig. 12 by this scenario island could be detected in reasonable time by variation in frequency and voltage.

Table.2.
Load Parameters

NO	***L***	***C***	***R***
Case1	0.00611	1151	2.304
Case2	0.00611	1151	1.843
Case3	0.00611	1151	4.605
Case4	0.00617	1151	2.304
Case5	0.00605	1151	2.304

Table.3.
Load and system parameters for different Q_f

Q_f	L	C	R
0.5	0.01222	575.6e-6	2.034
1	0.00611	1151e-6	2.034
1.77	0.003454	2037e-6	2.034
2.5	0.002445	2887e-6	2.034
3	0.0020387	3454e-6	2.034

Table.4.
Load and system parameters for different Q_f

Q_f	L	C	R
0.5	0.01222	575.6e-6	2.034
1	0.00611	1151e-6	2.034
1.77	0.003454	2037e-6	2.034
2.5	0.002445	2887e-6	2.034
3	0.0020387	3454e-6	2.034

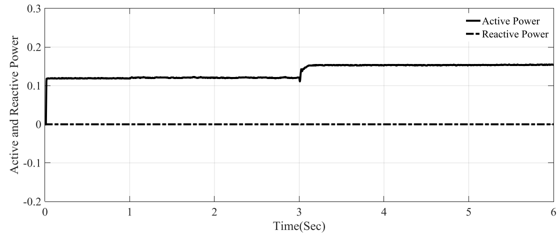


Fig. 9.Active and reactive power variation

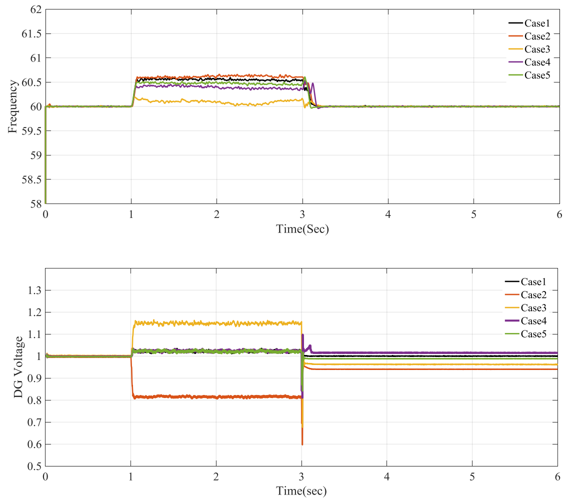


Fig. 10. Frequency and voltage variation during load switching

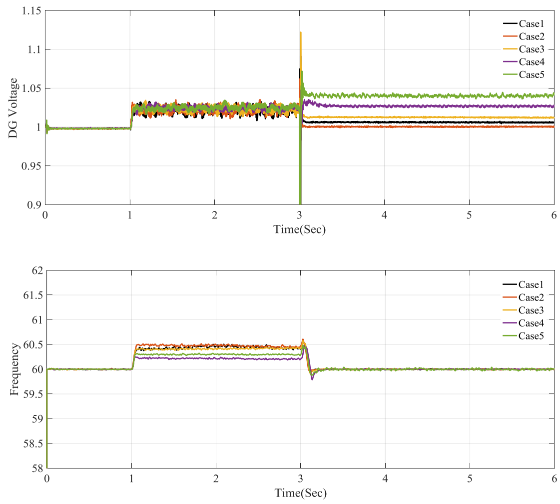
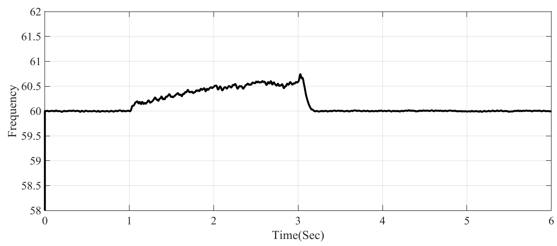


Fig. 11.Frequency and voltage variation for different value Q_f



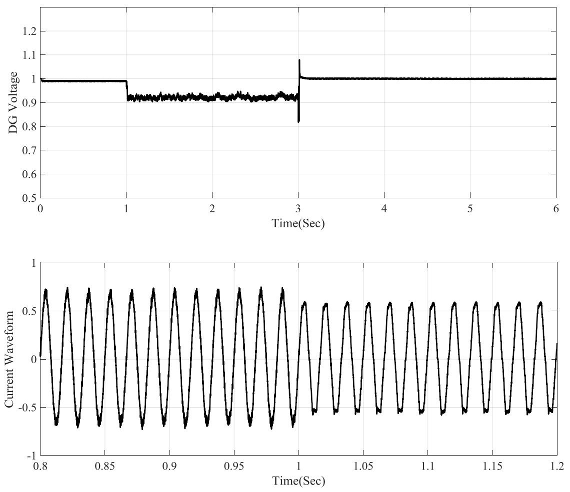


Fig. 12.Frequency and voltage variation by nonlinear load

5. Summary and Conclusion

In the proposed detection method, the difference angle of the power transfer between the distributed generation and local load will be subtracted from the input of angle of abc/dq transformation block derived from PLL block. In islanding condition, current I_d and I_q will be changed by adding the variation to d_q transformation block of current. This makes voltage and frequency disturbance and as a result the islanding is recognized. To evaluate the presented method under different conditions, various tests are provided. In addition, the simulations show that these conditions have no adverse effect on power system operation and detection process.

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