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Detection of Islanding in a Distribution System with DG Source and Interconnection with the Grid

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Abstract—*The crucial problem in distributed generation is unintentionally islanding. This detection phenomenon having a great importance. These detection methods are divided into active and passive islanding detection. These two methods are based on changing in parameters such as frequency, voltage and current harmonics. But these methods have some challenges such as reduction in power quality and large Non Detection Zone (NDZ). In this paper, the proposed method is change of a reactive power will be studied for islanding detection diagnosis.The studied system was considered by following the standard IEEE-1547 and UL-1741.The systemwas simulated using MATLAB/ SIMULINK.*

Keywords*: Distributed Generation (DG), Grid-connected, Islanding detection, Non Detection Zone, Reactive power*

1. INTRODUCTION

ISLANDING is an operating condition of the system that contains both load as well as local generation is isolated from the rest of the utility grid. One of the protection requirements for distributed generation (DG), mentioned by the IEEE Std. 929 and IEEE Std. 1547, is islanding detection [1], [2]. Unintentional islanding of DGs may result in power-quality problems, interference with grid protection devices, equipment damage, and even personnel safety hazards.

Islanding detection techniques are divided into local and remote techniques. The local techniques further classified into passive, active and hybrid techniques. Remote islanding detection techniques are based on communication between the grid and the DG like Supervisory Control and Data Acquisition (SCADA), Power Line Carrier Communication (PLCC). Even though they are more reliable but they are expensive to implement compare to local islanding detection techniques. Local islanding detection techniques are based on the measurement of parameters such as voltage, current, frequency. They are classified as passive, based on the monitoring of these parameters but it suffers with having large Non Detection Zone (NDZ).Hence it is not useful for highDG penetration. The active islanding detection techniques are based on intentionally introduce perturbations in the parameters voltage, frequency or output power and continues monitoring of these parameters to conform the islanding detection condition. Hybrid methods employs both the active and passive detection techniques.

2. DISTRIBUTED GENERATION

The distributed generation correlates the energy generation at distribution system near to the load centers less than 10 MW.

These distributed generation technologies categorized as renewable and nonrenewable. Renewable technologies includes

1. Solar, Photovoltaic or Thermal
2. Wind
3. Geothermal
4. Ocean.

Nonrenewable technologies includes

1. Internal Combustion Engine
2. Combined Cycle
3. Combustion Turbine
4. Micro-turbines
5. Fuel Cell.

The main function of the inverter for DG system can bestated as follows:

1. The main function of inverter is controlling the DG asa major source of active power.
2. Protection of DG and protection of network fromislanding.

The inverter can also produce power quality problems such as voltage distortion and harmonics.

3. PROPOSED SYSTEM ISLANDING DETECTION

The proposed system is shown in Fig. 1. It is consists of RLC load, DG source and inverter, power transformer, utilitybreaker. It also indicates the point of common coupling (PCC) at node “a”, which is the contact point of DG source to the utility grid. The power delivered by the grid to load is the difference between the power generated by the DG source to the power consumed by the load.

$$\Delta P + j\Delta Q = \left(\left(P_{pv} + jQ_{pv}\right) - \left(P_{load} + jQ_{load}\right)\right)$$

Where P_{load} andQ_{load} represent the active and reactive powers of the RLC loads at the grid-connected condition, respectively, $P_{pv}$and Q_{pv}represent the output active and reactive powers of the inverter in the DG side and ΔP and ΔQrepresent the active and reactive powers delivered by the grid.

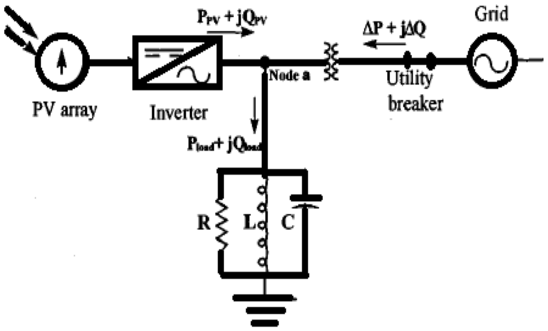

Fig. 1: (a) Grid connected system

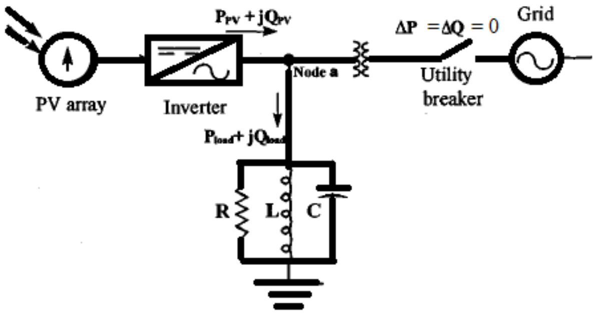

Fig. 1: (b) Isolated mode of the system

Under the ideal condition, when the utility breaker opens, the DG and the RLC load will resonate at nominal voltage and frequency and forms an island.

The active and reactive power of the three phase RLC load is given by

$$P_{load} = 3\frac{V_{PCC}^2}{R}$$

$$Q_{load} = 3\left(\frac{V_{PCC}^2}{2\pi f L} - V_{PCC}^2 2\pi f C\right)$$

whereV_{PCC}represents the voltage of PCC; $f$is the PCC frequency.

With the parameters of three phase RLC load the resonant frequency and quality factor is expressed as

$$f = \frac{1}{2\pi\sqrt{LC}}$$

$$Q_f = R\sqrt{\frac{C}{L}}$$

Mathematically, the RLC load can be represented as

$$R = \frac{V^2}{P}$$

$$L = \frac{V^2}{2\pi f\, Q_f P}$$

$$C = \frac{Q_f P}{2\pi f V^2}$$

Where

R Effective load resistance in Ohm;

L Effective load capacitance in Farad;

C Effective load inductance in Henry;

P Real power in W;

Q_fQuality factor;

f Grid frequency in Hz.

4. NONDETECTION ZONE OF UNDER/OVER VOLTAGEAND UNDER/OVER FREQUENCY

In practical situations, there will be power mismatch between the DG output and the RLC load. This mismatched load can be represented by$(R + \Delta R, L + \Delta L, C + \Delta C)$. Before the grid is disconnected, the power mismatch will be compensated by the grid.

When grid is disconnected, the voltage and frequency will be forced to new values of voltage and frequency. If the DG is controlled asa constant power in the system.

When the power mismatch is large enough, the values of voltage and frequency may be out of nominal ranges and under/over voltage/frequency protection will trip the circuit breaker present at the DG side to prevent continued island operation. The relationship between the power mismatch thresholds and voltage/frequency thresholds can be derived as below.

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

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

where V_{max}, V_{min}, f_{max}, f_{min} are under/over voltage and under/over frequency thresholds, respectively.

Non detection zone is shown in Fig. 2.In the NDZ the islanding detection is not possible.

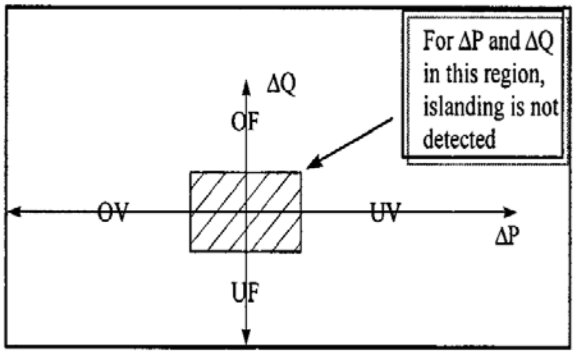

Fig. 2: Non Detection Zone

5. SYSTEM DESCRIPTION

The proposed system Simulink is shown in Fig. 5.The system parameters are taken from the reference paper [3].

The DG interface controller is the constant power control in which both voltage and current controller will takes place.

The outer control loop of DG interface controller is shown in Fig. 3.The outer controller is the constant voltage controller.

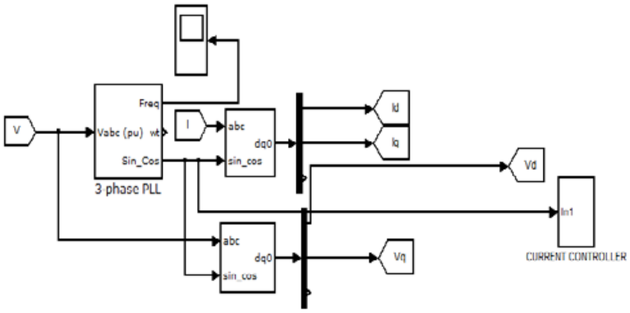

Fig. 3: Outer control loop of DG interface controller

The d-q transformations of the phase locked loop (PLL) is given below

$$V_d = \frac{2}{3}\left(V_a \sin(\omega t) + V_a \sin\left(\omega t - \frac{2\pi}{3}\right) + V_a \sin\left(\omega t - \frac{4\pi}{3}\right)\right)$$

$$V_q = \frac{2}{3}\left(V_a \cos(\omega t) + V_a \cos\left(\omega t - \frac{2\pi}{3}\right) + V_a \cos\left(\omega t - \frac{4\pi}{3}\right)\right)$$

$$V_0 = \frac{1}{3}(V_a + V_b + V_c)$$

The inner control loop of DG interface controller is shown in Fig. 4.The inner controller is the constant current controller.

The reference real power is taken as $P_{Ref} = 200$ kW and the reference reactive power is taken as $Q_{Ref} = 0$ kW.

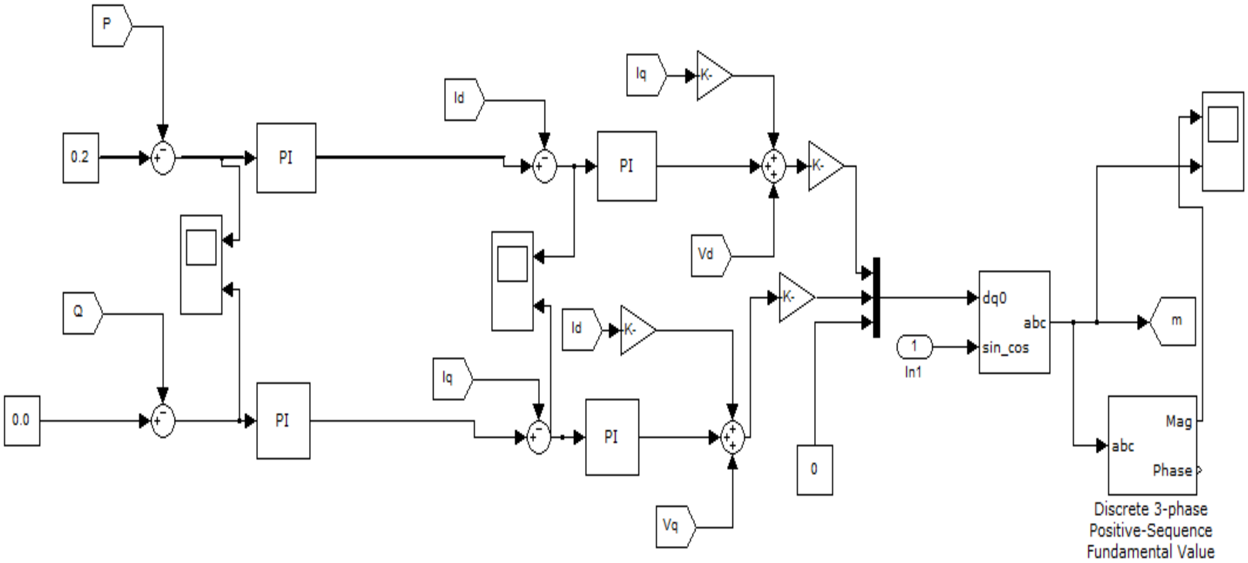

Fig. 4: Inner control loop of DG interface controller

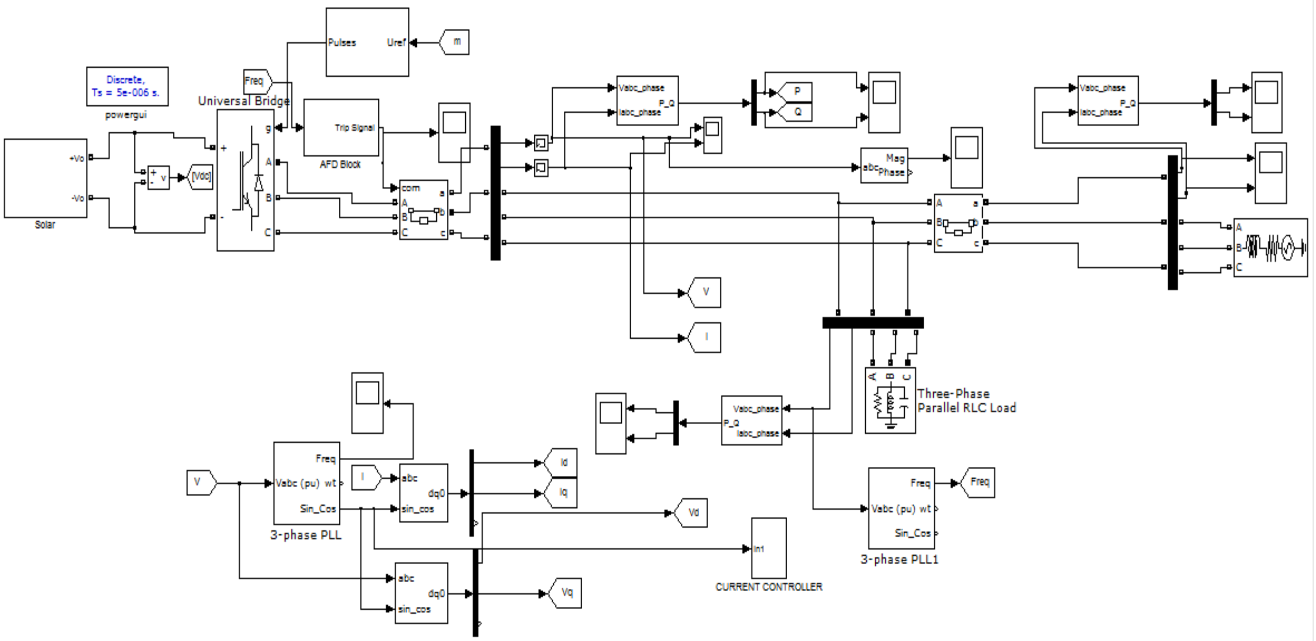

Fig. 5: Simulink diagram of the system

6. RESULTS

When the Grid is connected to the system the output of three phase voltage and current is stable but with the opening of CB at grid side, the system becomes isolated mode.

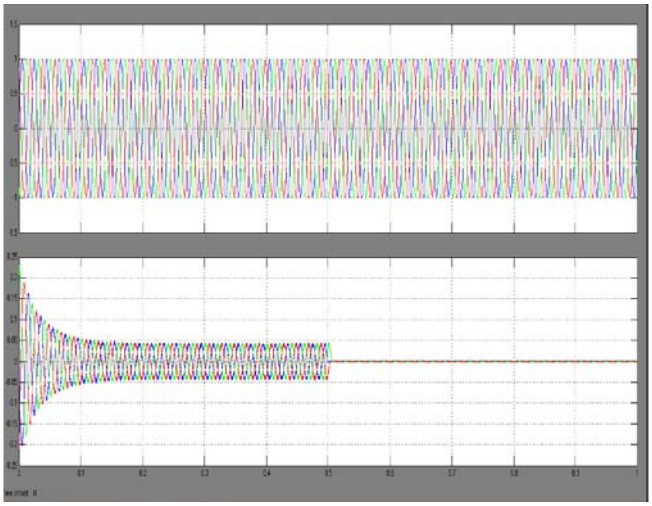

Fig. 6: Voltage and current at grid

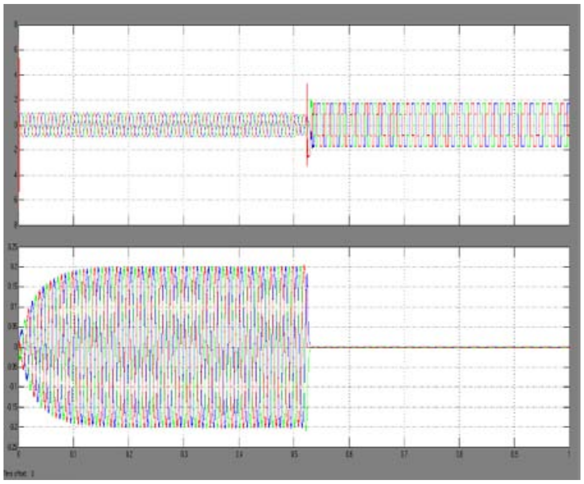

Fig. 7: Voltage and current at inverter

Whenever the Grid is disconnected at t=0.5 sec the the output of voltage and current was distorted and it settle after certain time.The output waveforms of voltage and current at grid,inverter and load is shown Fig. 6,7 and 8.The active and reactive power at PCC is shown in Fig. 9.

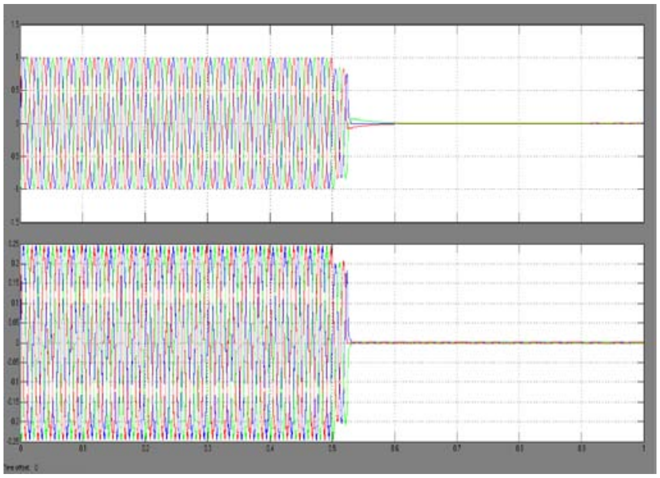

Fig. 8: Voltage and current at load

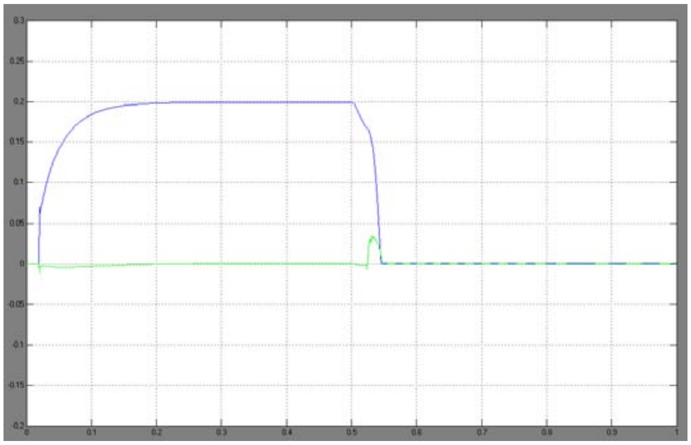

Fig. 9: Active and Reactive power at PCC

Due to the opening of CB at t=0.5 sec the frequency at PCC will change continuosly shown in Fig. 10.Due to the change in frequency the trip signal is generated and given to CB at DG side.

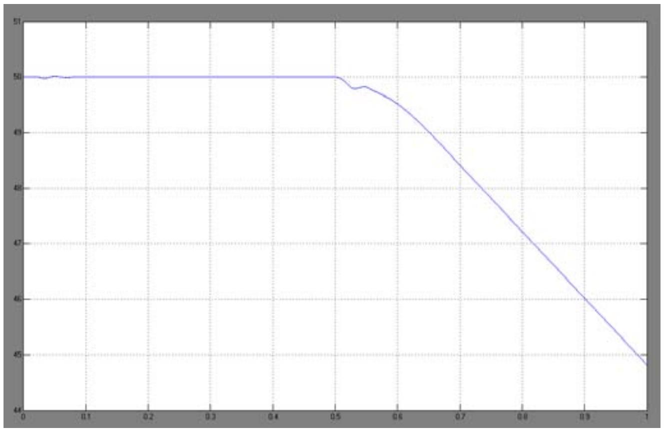

Fig. 10: Change in frequency at PCC

As per IEEE std,the DG is disconnected with in 0.02 sec from the rest of system and the trip signal provided to the CB at DG shown in Fig. 11.

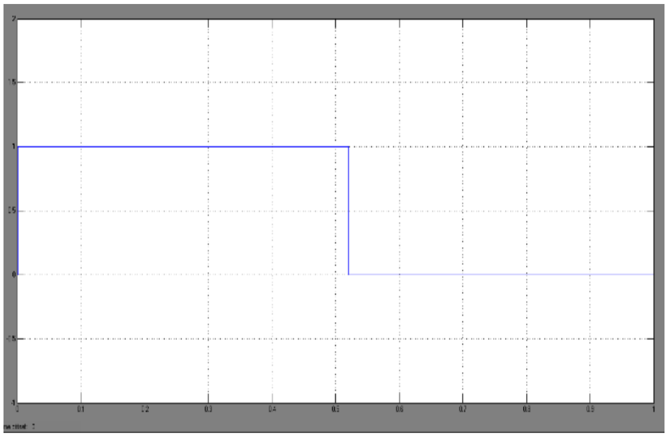

Fig. 11: Trip signal for CB at DG side

7. CONCLUSION

The change in real and reactive power at PCC is observed by disconnecting the grid for RLC load. This work will be carried out for the different loads and observe the change in real and reactive power for different load when islanding is formed. Those variations will be taken as reference for the islanding detection.

8. ACKNOWLEDGEMENT

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