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A Reliable Strategy in Order to Islanding Detection Based on Combined Active and Passive Techniques

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***Abstract*—One of the serious concern of grid connected distributed resources is islanding problem. This condition should be prevented due to several reasons concerning such as personnel and equipment safety. This paper investigated a mixed passive and active islanding detection method using energy of rate of change of active power (EROCOAP) and disturbance applying through q-axis of dq-current controller. Reduction of Non detection Zone to as close as possible and keeping the output power quality unchanged in normal condition are main emphasis of the proposed scheme. In addition, this technique can also overcome the problem of setting the detection thresholds inherent in the existing techniques. In this study, we propose to use a hybrid active and passive method for islanding detection. At first, the energy of ROCOAP is calculated for settling time of case study system. If this value becomes higher than threshold value, disturbance is applied to q-axis of current controller. By frequency measurement islanding condition is detected. The simulations results, carried out by MATLAB/Simulink, shows that the proposed method has a small non detection zone. Also, this method is capable of detecting islanding accurately within the minimum standard time.**

***Index Terms*—islanding detection, active techniques, passive technique, NDZ**

I. INTRODUCTION

Nowadays, renewable energy resources play an increasingly important role in electricity production which, exhibit high energy efficiency, low environmental impacts, improve power quality and reduce planning costs of the distribution network [1]. These resources mostly are used of renewable energies for generating electric power includes solar power, wind power and fuel-cell power. In the future, many small capacity distributed generation power systems will be incorporated into the utility power system. In many situations, the power generated from these resources is transferred to the grid through utility interfaced converters [2]. However, the steady state and dynamic behavior of the DGs affect their connection on existing utility network giving rise to control, protection and power quality problems. One of the main issues that are to be considered when a DER is connected to the utility is islanding conditions [3]. Islanding is operation condition where a distributed generation is supplies their local loads when the utility is cut off due to power failure or maintenance of electrical equipment. This condition causes abnormal operation in the power system and also causes negative impacts on protection, operation, and management of distribution systems. Islanding control standards, such as, UL1741-2000, IEEE1547.1-2005 and IEEE929-2000 recommend disconnecting all distributed generators immediately after the formation of island [4].

Various islanding detection methods have been investigated in the technical literature which can be categorized in three major groups including passive, active and remote techniques [5]. Remote detection techniques are based on communication between the utility and the DGs. These schemes include transfer trip [6] and power line signaling [7]. Although, these techniques may have better reliability than active and passive techniques, they are expensive to implement and hence uneconomical.

Active techniques mainly are based on applying a disturbance into distribution systems and forcing the islanded system to become unstable [8]. The salient feature of these methods is their relatively small Non Detection Zone (NDZ). The main disadvantages of these techniques are power quality problems due to applying perturbation on the system and designing the complicated control circuit for the generation. Some active islanding detection approaches include sandia frequency and voltage shift [9] and [10], frequency shift and active frequency drift [11], current injection [12], high-frequency signal injection [13], phase-PLL perturbation [14], active frequency drift or frequency bias [15] and [16]. Many of these techniques are employed to inverter-based distributed generations.

Passive techniques depend on measuring certain system parameters and detect the islanding through data

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processing. Some other passive techniques [11], [16], [17] are rate of change of frequency, rate of change of generator power output, rate of change of phase angle derivation, and reference signal generator with a multi-level inverter.

This paper investigates a novel detection method based on combined active and passive methods. One of the well-known and frequently used passive methods is Rate of Change of Output Active Power (ROCOAP). The proposed method is used of energy of this signal and comparison of this parameter with threshold value. If they are higher than the threshold, an active technique is employed where the disturbance has been applied to q-axis of DG controller in order to confirm islanding phenomenon. NDZ reduction and unchanged keeping of output power quality are the main contribution of the proposed strategy. The simulations results of proposed strategy by MATLAB/Simulink show the performance of the proposed method with small non detection zone. Also, this method is capable of detecting islanding accurately within the minimum standard time.

II. System Description

Single line diagram of study system is shown in Fig. 1. The DG unit is a DC system which is connected to grid with a voltage source converter and transformer. The load of DG is a three-phase parallel RLC that is installed before the Circuit Breaker (CB). The parameters of system are given in Table I. In the grid-connected mode, the islanding condition occurs when CB is open. In this situation, by considering balanced condition for islanded system the transfer function of islanded system is given by (1) which is described in [4].

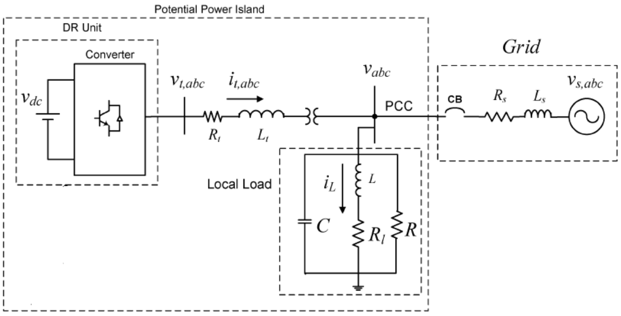

Figure 1. Schematic diagram of a grid-interfaced DG unit.

TABLE I. System, DG, and Load Parameters

DG Output Power	80kW
PWM carrier Frequency	2000Hz
Input Dc Voltage	800V
Voltage	380V
Rt	1.5mΩ
Lt	300μH
Nominal Grid Frequency	50HZ
Load Quality Factor	1.8
R	1.805Ω
L	3.192mH
C	3.174mF
Proportional Gain (Kp)	0.4
Integral Gain (Ki)	500

$$T(s) = \frac{5.116\text{e-}013\,s^3 + 1.05\text{e}006\,s^2 + 6.599\text{e}7\,s + 1.047\text{e}11}{s^4 + 242.4\,s^3 + 1.162\text{e}6\,s^2 + 8.133\text{e}7\,s + 1.047\text{e}11} \tag{1}$$

From of Fig. 2, the settling time is about 0.04 seconds. We consider 2 cycles of data for analysis to achieve reliable detection from the step response process.

In order to determine the performance of islanding detection method, non detection zone is one of the important characteristics. The NDZ is defined as an operating region where islanding conditions cannot be detected in a timely manner. In this region, power mismatch between production and consumption have a small value. Based on acceptable voltage range in distribution network (0.88 to 1.1pu) the voltage levels are equivalent to $\Delta V = -0.12$ pu and $\Delta V = 0.1$ pu, respectively. The calculated imbalance amounts [4] for our test network are 9.6kW and -8kW, respectively. Also, by considering the acceptable frequency range between 49.7 and 50.3Hz i.e.: $\Delta f = \pm 0.3$ Hz, the amounts of reactive power imbalances are 5.137 and -5.231 kVAr. The NDZ region for studied system is shown in Fig. 3.

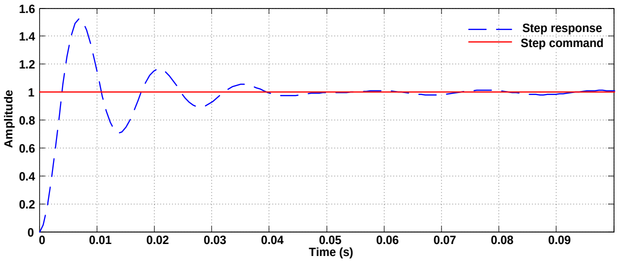

Figure 2. The step response of system in the islanding mode of study system.

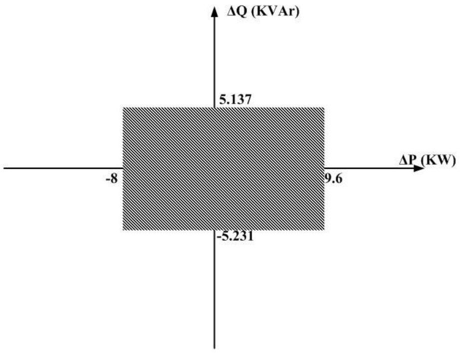

Figure 3. NDZ for the study test system.

III. Proposed Relay Algorithm

The proposed technique, which is based on learning the patterns of some of the sensitivities indices and applying the disturbance to system, is used for detection island events. At first, in order to determine the best parameters for islanding detection, the indices include all possible sensitive system parameters that could be affected by islanding and can be measured locally, are chosen. These parameters values are collected at the X matrix as follow:

$$\underline{X} = [\underline{X_1}, \underline{X_2}, \underline{X_3}, \ldots, \underline{X_n}] \tag{2}$$

In the proposed technique, the X matrix parameters are chosen as bellow:

$$X = \left[\Delta f / \Delta t \quad \Delta P / \Delta t \quad \Delta Q / \Delta t \quad THD_V \quad \Delta V_d / \Delta t \right] \quad (3)$$

The energy of each signals are calculated and the output is saved in E matrix as follows:

$$\underline{E_X} = \left[E_{\Delta f/\Delta t} \quad E_{\Delta P/\Delta t} \quad E_{\Delta Q/\Delta t} \quad E_{THDv} \quad E_{\Delta V_d/\Delta t} \right] \quad (4)$$

Prescribed events are simulated off-line in order to capture the essential features of the system behavior, which is comprises the proposed technique. These events can be categorized into switching actions under different network operating states. Some possible events are, Islanding condition in NDZ region, motor starting, capacitor bank switching, non-linear load switching. From the aforementioned signals, which were analyzed by mentioned events, The ROCOAP signal is chosen as it has less overlapping in islanding and non-islanding conditions.

When CB is opened and islanding occurs, the energy of ROCOAP signal is changed instantly and islanding condition can be detected by comparison of this value with a threshold. However, this method is not reliable. Islanding and some other events, such as switching of motors and capacitor banks, may have similar effect on ROCOAP, thus the algorithm may take incorrect decision and interrupt the production of DG in a wrong way.

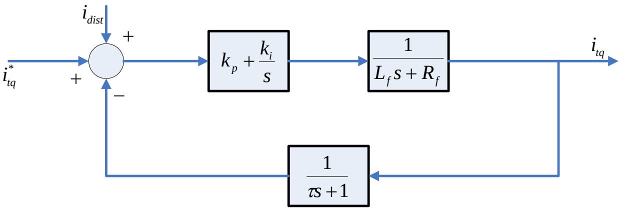

Figure 4. Disturbance applying of proposed strategy through q-axis.

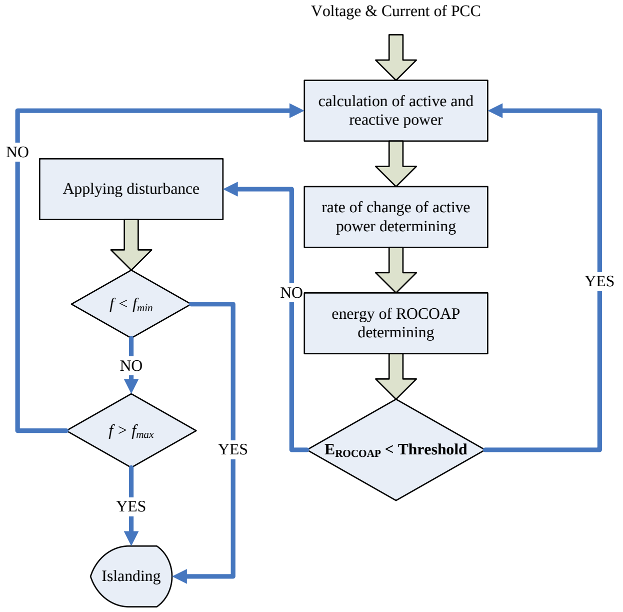

Figure 5. The proposed strategy algorithm.

Here, we propose a new algorithm that employs both energy of active power variation signal and current injection active method of islanding detection algorithm. The active injection current in control system is shown in Fig. 4. Fig. 5 shows flowchart of the proposed method. In the first step, the voltage and current signals of load voltage are measured for 0.04 sec and ROCOAP is calculated afterwards. The energy of this signal is calculated and if this energy is less than a threshold, it is assumed that islanding is not happened. But if ROCOAP exceeds the threshold value, islanding has been probably happened. Nevertheless, the method is not still reliable. In order to confirm that the islanding is happened, the Disturbance signal through q-axes of controller, which is shown in Fig. 5, is applied. If the frequency of system is changed and exceed from acceptable value, islanding is occurred, otherwise the disturbance signal is disconnected and the system continues its normal operation.

IV. SIMULATION RESULTS

In this section, the test system shown in Fig. 1 has been simulated by MATLAB/Simulink. The parameters of DG and load are presented in Table I. The proposed islanding detection method has been also tested for various conditions.

A. *Matched Reactive Power Test*

Performance of the proposed method is analyzed in islanding mode for the various loads which are given in the Table II. Design and selection of loads should be such that the imbalance of reactive power is equal to zero resulting in the situation which is more difficult to identify the island mood. Further, the load quality factor is equal to 1.8 which is the maximum recommended amount in standards.

TABLE II. VARIOUS LOADS FOR ISLANDING MODE TEST

Case	1	2	3	4	5	6
Power (kW)	74	76	78	82	84	86
R (Ω)	2.0	1.92	1.851	1.76	1.698	1.64

For all examined cases in Table I at the time t=1.0 sec Circuit Breaker (CB) opens and distributed generation along with local loads isolated from power grid and islanding mode is occurred. Instantaneous voltage waveform of the common coupling point for each cases reviewed in Table II are shown in Fig. 6. For each of these cases, the energy of rate of change of active power signal exceed from them threshold value. The disturbance signal is applied through q axes of dq current controller. After applying this disturbance, the frequency of system exceeds from acceptable value and islanding is detected.

The rate of change of active power and frequency of common coupling point voltage, for all cases studied in Table II are shown in Fig. 7 and Fig. 8 respectively. Finally, in Fig. 9 the output of detection method for all studied cases are shown.

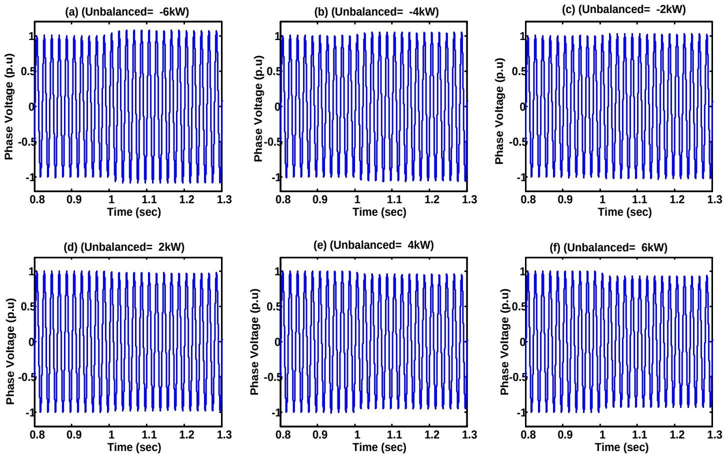

Figure 6. Instantaneous voltage waveform of the common coupling point for islanding mode.

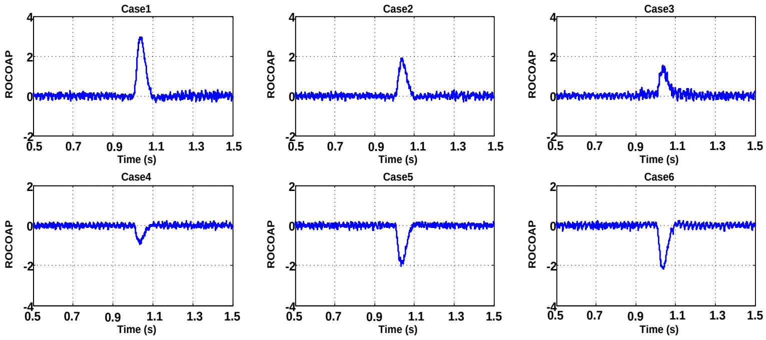

Figure 7. Rate of change of active power for islanding mode.

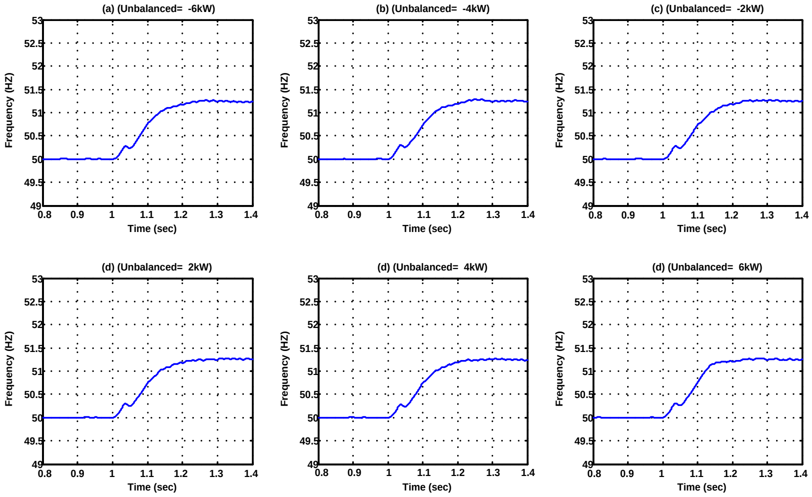

Figure 8. The frequency of common coupling point voltage for islanding mode.

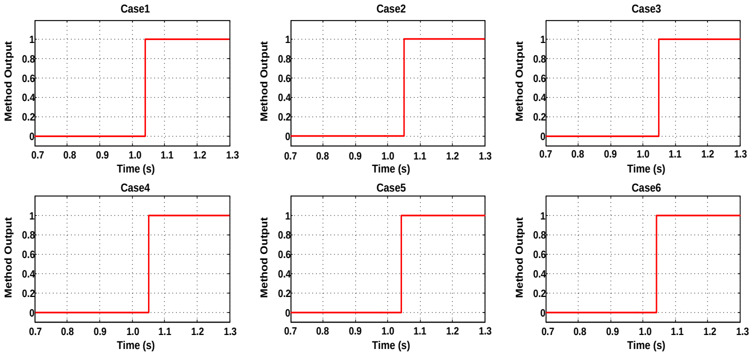

Figure 9. The output of detection method for islanding mode.

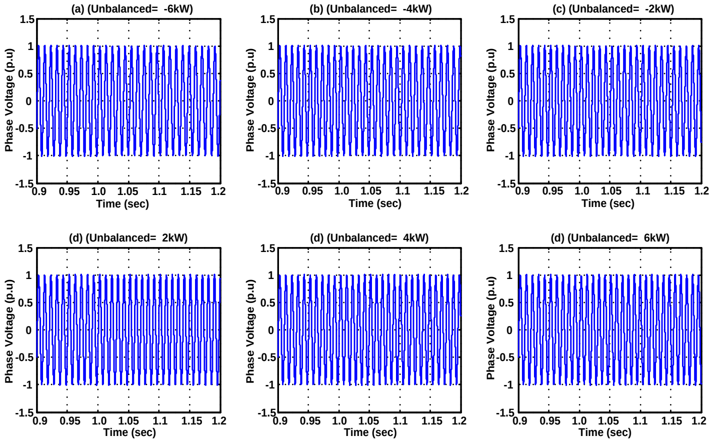

Figure 10. Instantaneous voltage waveform of the common coupling point for normal operation mode.

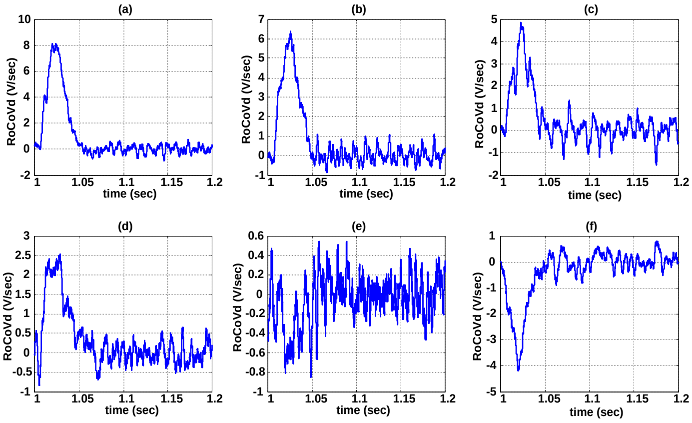

Figure 11. Rate of change of active power for normal operation mode.

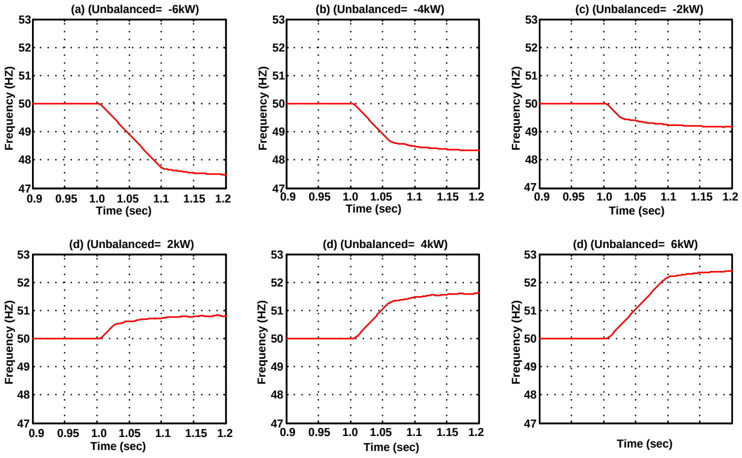

Figure 12. The frequency of common coupling point voltage for normal operation mode.

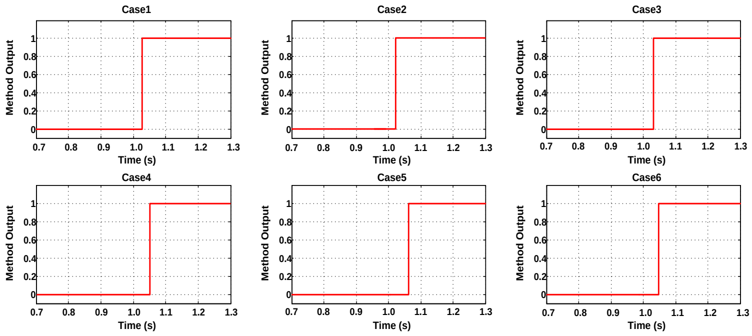

Figure 13. The output of detection method for normal operation mode.

B. *Matched Active Power Test*

Performance of the proposed method is analyzed in this operation mode for the various reactive power imbalance conditions, which are given in the Table III.

TABLE III. VARIOUS LOADS FOR NORMAL OPERATIONAL TEST

Case	1	2	3	4	5	6
ΔQ (kVAr)	-6	-4	-2	2	4	6

For all examined cases in Table III at the time t=1.0s Circuit Breaker (CB) opens and distributed generation along with local loads isolated from power grid and islanding mode is occurred. Instantaneous voltage waveform of the common coupling point for each cases reviewed in Table III are shown in Fig. 10. Also, the rate of change of active power and the frequency of common coupling point voltage for all cases studied in Table III are shown in Fig. 11 and Fig. 12 respectively. Finally, in Fig. 13 the output of detection method for all studied cases are shown.

V. CONCLUSION

In this paper, a novel mixed active and passive technique for islanding detection of DG is proposed based on energy analysis and disturbance applying. The salient feature of the proposed scheme is to reduce the NDZ to as close as zero. Also, this technique could also overcome to the problem of setting the detection thresholds despite the existing techniques. This method includes two major stages: the first stage is a passive method and the second one is an active method. The first stage is based on energy of rate of change of output active power signal. These values are calculated and compared with a threshold. If this value is higher than the threshold, in the second stage as an active process, a disturbance is applied to q-axis of DG controller. After that, the frequency of output voltage is measured. If these parameters leave an allowable range, islanding has been happened and detected. Consequently, a decision has been taken for interrupting of DG. This method has some advantages over passive methods, as the algorithm is able to distinguish between islanding and other switching methods and interrupting the system correctly.

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