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A Novel Algorithm Based on Combined of Passive Techniques in Order to Islanding Detection

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Abstract: Recently, the penetration of Distributed Generation (DG) at medium and low voltages in utility networks is increasing in developed countries and takes special place for them worldwide. Due to the DGs advantages, including using of Renewable Energy which not polluting environment and has endless nature, the application of DGs can potentially reduce the need for traditional system expansion, controlling a potentially huge number of DGs creates a daunting new challenge for operating and controlling the network safely and efficiently. One problem that encountered with it when using with DGs, is an unwanted Islanding phenomenon. In this paper, a novel technique in order to detecting islanding conditions has been present and the proposed method based on passive methods, its performance is much more appropriate than that of previous techniques. The simulation results performed in MATLAB, clearly show improved operation of this method.

Key words: Distributed Generation · Islanding · Switching · Passive Technique

INTRODUCTION

Distributed Generation (DG) with its various distributed resource technologies has many advantages when connected with the electric power system (EPS). Renewable distributed generation involves the interconnection of small-scale, on-site distributed energy resources (DERs) with the main power utility at distribution voltage level [1]. DERs mainly combined from renewable energy sources like solar PV, wind turbines, fuel cells, small-scale hydro, tidal and wave generators, micro-turbines, combined heat power (CHP) systems, etc.

Bulk of distributed generations in power system is from renewable energy. Depending on the distributed generations, their production can be AC or DC. But in all, most of these products are connected through electronic power converter to the network [2]. Most of inverters of DGs that produce DC voltage, usually operate with current control system in order to control the output power of DG. But DGs will have affects in the network. One of these effects has become an islanding phenomenon.

An essential requirement of the grid interconnected DG system is the capability of islanding detection [3]. Islanding state happens when one or more DGs without connecting to the network are connected and supplied local loads. In most cases this phenomenon can occur unwanted. The islanding operation of DG may cause potential hazards to line-maintenance personnel, equipment damage due to instability in user voltage and frequency and risk the DG in being damaged by out of phase reconnection to the grid. The majority of utilities require that DG should be disconnected from the grid as soon as the islanding occurs. Therefore, according to IEEE1547 standard, islanding state should be detected and disconnected in less than 2 seconds [4,5].

So far many methods to detect Islanding condition have been proposed. These methods can be classified in two broad categories of active and passive classifications [6]. In active techniques, disturbances are injected locally into the system and responses of these disturbances are used to detect islanding conditions. Including the active method we can point to the followings: Impedance measurement method [6], Sandia Frequency Shift (SFS) and Sandia Voltage Shift (SVS) [3], Frequency domain analysis [3], Changing voltage amplitude and reactive power method [7], the mid-harmonic method [8], Reactive power export error detection [9],

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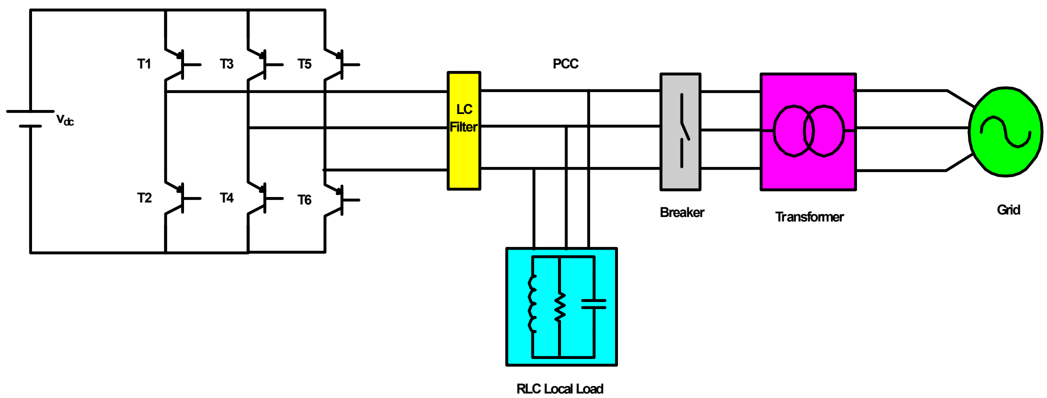

Fig. 1: Studied power system including DG and power grid

And the passive techniques make decisions based on the local measurements of voltage and current signals. Passive techniques include:

Under/over voltage and under/over frequency [3], Rate of change of frequency relay (df/dt) [10], Phase displacement monitoring [6], Output power speed changing [10] Comparison of rate of change of frequency (COROCOF) [11], Unbalanced voltage and Total current (or voltage) harmonic distortion (THD) [12].

One of the parameters that can be changed in islanding mode is Rate of Change of Frequency (ROCOF). in this paper one proposed algorithm has been proposed that can be detect the islanding condition based on this parameter of load voltage. But in order to detecting the islanding condition from other switching condition, Rate of Change of Phase Angle Difference (ROCOPAD) add to this algorithm an diction will be doing with ROCOF and ROCOPAD of local load voltage and current.

In order to sure of islanding condition, the threshold value of ROCOF will be taken low and ROCOPAD analysis after ROCOF checking. This algorithm based on quantity of ROCOF value and ROCOPAD value. The next sections deal with system studied, proposed algorithm, results analysis and conclusions.

Study System: In Figure (1), the study system in this paper that the proposed algorithm applied to this system, is shown. As illustrated, The DG unit is represented by a dc voltage source, a VSC that control with conventional dq-current controller, a series filter (L_f and C_f) and a step-up transformer. The local load is represented by a three-phase parallel RLC network at the PCC. A step-up transformer is located between DGs local loads and utility grid. The utility grid simulated with ideal source and R_s, L_s. connection between utility grid and DG is done with Circuit Breaker (CB). In order to convert the DC voltage to AC voltage, as can be seen, used of inverter with IGBT switches. The parameters of study system are given in Table 1.

Table 1: Characteristic of studied power system

Parameters	Value
V_{dc}	800V
L_f	2mH
C_f	0.022mF
Rated Voltage	380V
Grid Voltage	20kV
R_L	1.8 ohm
L_L	7.7mH
C_L	1.33mF
Transformer Ratio	20/0.38kV
Transformer Power	100KVA
Frequency	50HZ

When the CB as shown in the figure is closed, in this mode DG together with local load is connecting to power grids and power produced by DG is injected. But when the CB is opened, in this mode, islanding state occurs and DG along with a local load constitute an islanding state which creates an independent power grid in which just DG supplies loads demand power. In these conditions, that should a case be detected islanding mode and power production is entirely disconnected from the power grid and after reconnection it starts to produce power again.

To detection the islanding condition, a measurement system installed at the head of a local load and output of the mentioned system ended in a central processor in which measured signals are being processed and in the Islanding state a fast decision made and command for disconnecting system will be exported.

Proposed Algorithm: ROCOPAD algorithm uses synchronous transformation based phasor estimation of the retrieved instantaneous voltage and current signals [13]. The signal x(t) is represented as follows:

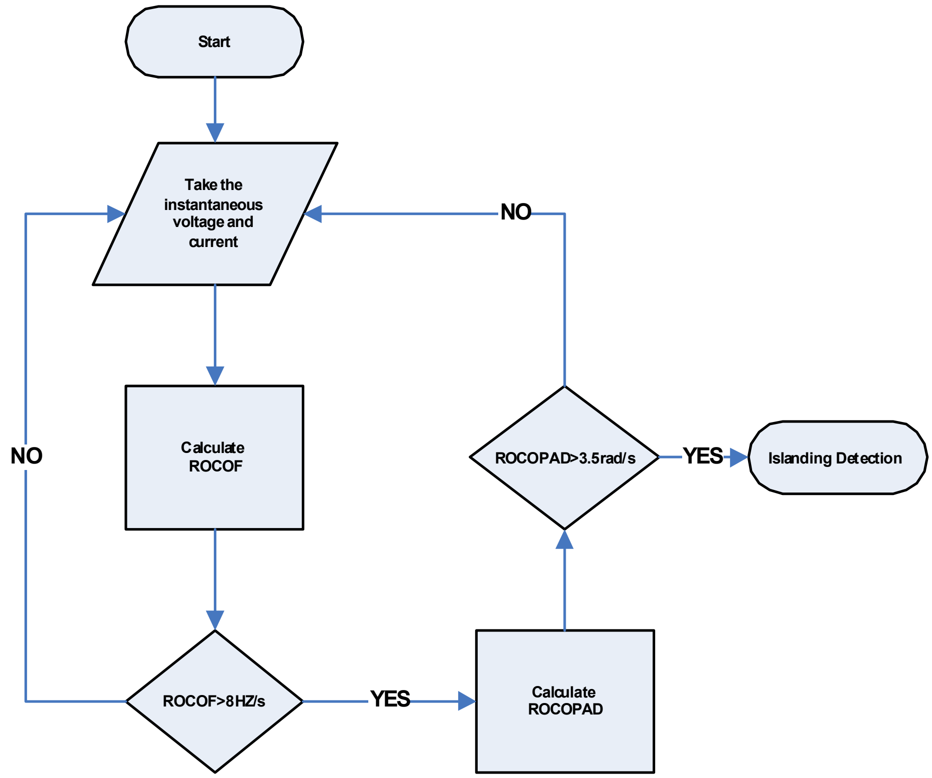

Fig. 2: Flowchart of the proposed algorithm in order to detection

$$X(t) = \sum_{n=1}^{\infty} X_{\max} \cos(n\omega_0 t + \theta_n) \quad (1)$$

Where, X_{max} is amplitude and θ_n is angle of signal $X(t)$. Under balanced conditions, each three-phase variable $x_{abc}(t)$of (1) can be transferred to a stationary $\alpha\beta$ reference frame system by applying the following *abc* to $\alpha\beta$ transformation:

$$x_{\alpha\beta} = x_a e^{j0} + x_b e^{j2\pi/3} + x_c e^{-j2\pi/3} \quad (2)$$

Where $x_{\alpha\beta} = x_a + jx_\beta$ in order to calculating dq parameters can be used of Eq(3):

$$x_d + jx_q = x_{\alpha\beta} e^{-j\theta} \quad (3)$$

where θ calculated by

$$\theta = \arctan \frac{x_\beta^{ref}}{x_\alpha^{ref}} \quad (4)$$

From the above d-q quantities, the amplitude and phase for first harmonic are calculated as follows:

$$X_1 = \frac{2}{3}\sqrt{\left(x_{d1}^2 + x_{q1}^2\right)} \quad (5)$$

$$\theta_1 = \arctan \frac{x_{q1}}{x_{d1}} \quad (6)$$

The ROCOPAD and ROCOF calculated as given in Eq (7) and (8) respectively:

$$ROCOPAD = \frac{\Delta\left(\theta_v - \theta_i\right)}{\Delta t} \quad (7)$$

$$ROCOF = \frac{\Delta f}{\Delta t} \quad (8)$$

Where θ_v calculate from v_a, v_b, v_c voltage of phase a and b and c respectively in volt. ù is the frequency of load voltage that measured by three phase PLL in MATLAB. Figure 2, depicted the proposed method's algorithm. At first, in the method, dq-component of voltage and current value will be calculated at any time, Then the value of ω will be calculated too with eq (8). If this value is less than the threshold value determined in this way continues working, but if its value exceeds the threshold value, in this case the value *ROCOF* will be analyzed. If the value of *RPCOPAD* exceeds from threshold value, this condition is islanding and DG unit must be interrupted but the value of *RPCOPAD* lesser than threshold value, system continuous it's working.

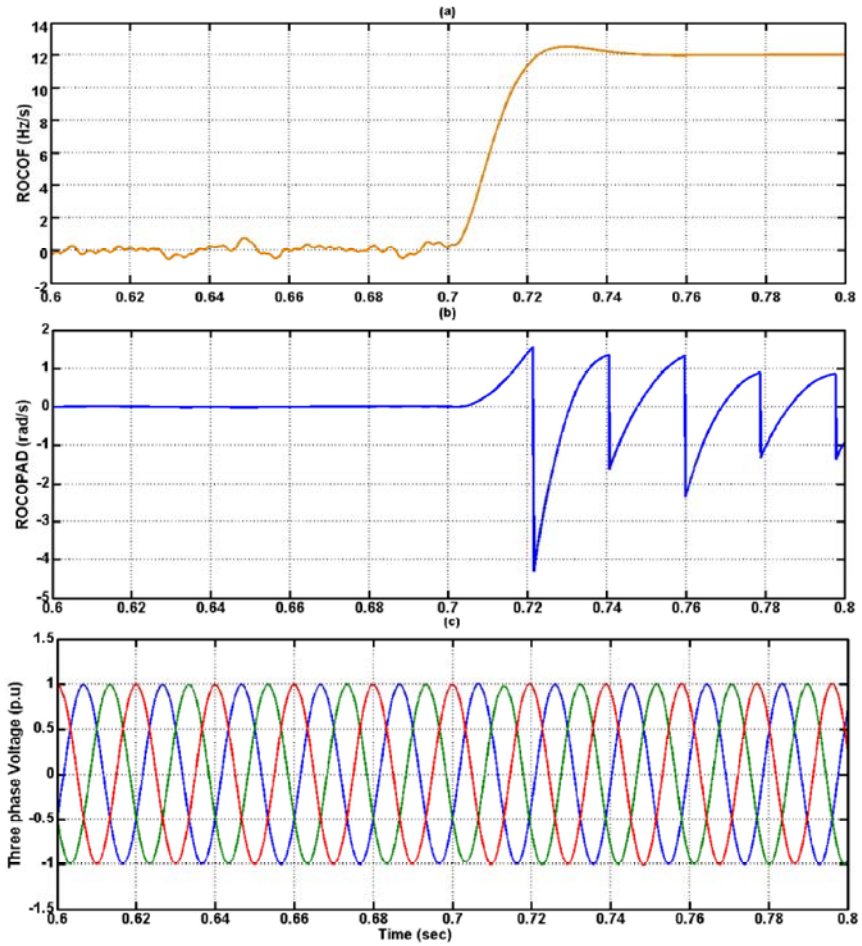

Fig. 3: The result of system in load condition 1 a) Rate of Change of Frequency b) rate of change of phase angle difference c) three phase voltage of local load in p.u

Simulation Result: In this section of the paper, the results of the proposed method to detection the islanding mode have carried out on different loads and the ability of proposed system for islanding detection have been shows.

Load Condition 1: In this case, the active and reactive power of local load is 80KW and Q_L=60KVAr and Q_c= 55KVAr respectively. At the first CB is closed and system utilized in grid connected mode. At t=0.7 sec, CB is opened and DG together with local load is separated from power grid and islanding condition occurs. Figure 3-a, shows rate of change of frequency. It is obvious from the figure that after islanding ROCOF value increased and at t=0.712 sec the value exceeded from 8HZ/sec. This case the probability of forming an island is take places but that is not sure..In order to be sure, the q-component of voltage is calculated and compared with threshold value, from Fig 3-b it is obvious that the ROCOPAD at t=0.722 sec exceeds from 3.5 rad/sec. Almost after 0.022 sec the ROCOPAD of load voltage is higher than its threshold value and islanding condition has been detected at t=0.722 sec. Fig 3-c shows instantaneous value of three phase load voltage in (p.u).

Load Condition 2: In second condition, the active and reactive power of inductance and capacitor considers P=70KW, Q_L=55KVAr and Q_c= 45KVAr respectively. At the grid connected mode CB is closed. At t=0.6 sec, CB is opened and islanding condition occurred again. Fig (4-a) shows the rate of change of frequency of load voltage. It is obvious from this figure that at t=0.615 seconds ROCOF rapidly increased and the value exceeded 8 HZ/sec. This case the probability of forming an island is take places too but that is not sure. In order to be sure, the ROCOPAD of DG unit is calculated and compared with threshold value, from Fig 4-b it is obvious that the amount of.ROCOPAD at t=0.623 sec exceeds from 3.5 rad/sec too. Almost after

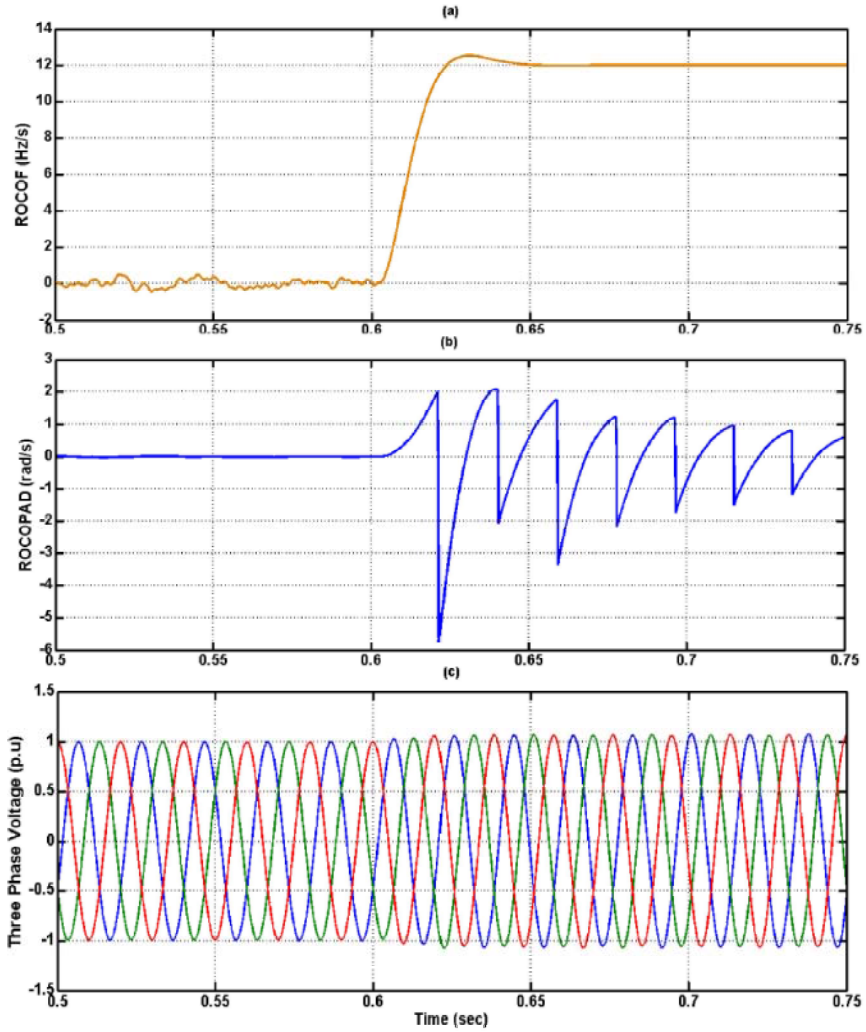

Fig. 4: The result of system in load condition 2 a) Rate of Change of Frequency b) rate of change of phase angle difference c) three phase voltage of local load in p.u

0.023 second the ROCOPAD value become higher than its threshold value and islanding condition has been detected at t=0.623 sec. Fig 4-c shows instantaneous value of three phase voltage of load voltage.

Switch of Capacitor Bank: In this section, the performance of algorithm is studied for capacitor bank switching in grid connected mode to be shown that the proposed algorithm not mistaken in capacitor bank switching and detection properly the islanding state from capacitor bank switching conditions. Initially the system works in a connecting to the network mode with load parameters that present in Table (1). At t = 0.8 sec a capacitor bank with 35KVAr reactive power switching and connect to system. Fig 5-a shows the rate of change of frequency of DG that at time t = 0.815 sec the value of ROCOF exceeds than threshold value (Fig 5-a). In order to be sure, the ROCOPAD of load is calculated and compared with threshold value again, from Fig 4-b it is obvious that the quantity of ROCOPAD don't exceeds from 3.5 rad/sec. Thus, the system doesn't interrupted and utilized power continuously.

Motor Starting: One of the other switching condition that algorithm may be mistake is motor starting. Initially the system works in a connecting to the network mode with nominal load. At t = 0.5 sec an induction motor with P = 20kw and Q=15kVAr is started to work. Fig (6-a) and (6-b) depicted the ROCOF and ROCOPAD value of load respectively. From Fig (6-a) the value of ROCOF doesn't exceeds from threshold value and system continues to its working and doesn't mistake.

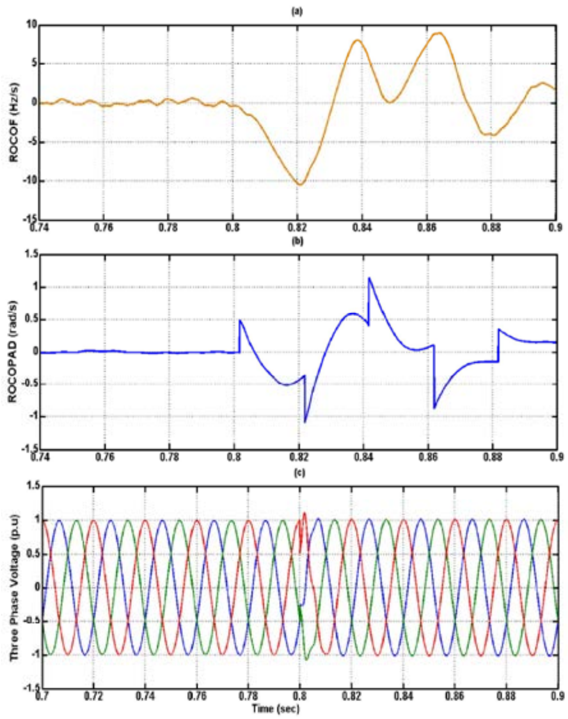

Fig. 5: The result of system in capacitor bank switching a) Rate of Change of Frequency b) rate of change of phase angle difference c) three phase voltage of local load in p.u

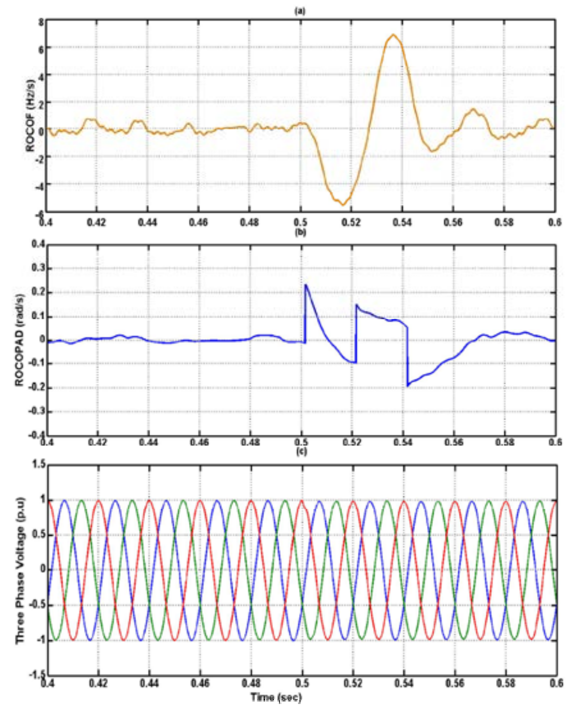

Fig. 6: The result of system in motor starting a) Rate of Change of Frequency b) rate of change of phase angle difference c) three phase voltage of local load in p.u

CONCLUSION

In this paper a new combination technique of passive methods in order to detecting of DGs islanding conditions was proposed. The results indicate that the performance of the proposed method is desirable because in other switching condition the proposed method don't has mistaken and this method easily detect Islanding conditions from other switching condition and making appropriate decision to disconnect the system. Simulation results are taken in MATLAB software and the results were shown for various loads were shown, this algorithm works well properly.

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