A Novel Islanding Detection Technique for Distributed Generation (DG) Units in Power System

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Abstract

Distributed generation is a form of electric power privatization. Consumers install their own power station to supply the local loads and/or share in the utility loads. Many protective problems have been developed due to the existence of these distributed generations. However, a protective strategy should be developed to protect the system and the generator itself from different hazards. One problem with such generators is an unwanted islanding phenomenon. This paper introduces a hybrid passive method for islanding detection to minimize the non-detective zone. This method based on composed of rate of change of frequency over power under each event and rate of change of DG reactive power under each event (ROCORP). Simulation results which are carried out on software PSCAD/EMTDC shows good performance of this method.

Keywords: Distributed Generation, rate of change of frequency over power (ROCORP), Active Power

## 1. Introduction

Since the society becomes increasingly concerned to save energy and preserve the environment, the interest toward the distributed generation systems, such as photovoltaic arrays and wind turbines, increases year after year. Other sources, such as micro-turbines and fuel cells, are also in development. But wind turbines and generally DGs will have affects in the network that one of these influences is an islanding phenomenon [1]. Islanding state occurs when one or many sources continue to feed power to a part of the grid that is disconnected from the main utility. Islanding situations can damage the grid itself or equipments connected to the grid and can even compromise the security of the maintenance personnel that service the grid. Therefore, according to IEEE1547 standard, islanding state should be identified and disconnected in 2 seconds [2]. There are quite a few different methods used to detect islanding. All methods have benefits and drawbacks. The methods have traditionally been divided into two subgroups; passive and active methods. In active methods, small disturbances are injected into the power system and its responses due to the injected disturbances are monitored. These methods change the balancing power between loads and generations, reduce the power quality of the power systems and are not suitable for wind farms with numerous wind turbines. Reactive power export error detection method [3], impedance measurement method [4], slip mode frequency shift algorithm (SMS) [5], active frequency drift (AFD) [6], active frequency drift with positive feedback (AFDPF) [6], automatic phase-shift (APS) [7] and adaptive logic phase shift (ALPS) [8] are a few examples of active islanding detection methods. Passive methods continuously monitor the system parameters such as voltage, frequency, harmonic distortion, etc. Based on

the system characteristics, one or more of these parameters may vary greatly when the system is islanded. The passive methods do not affect the waveform of the high voltage. This is beneficial since it does not give rise to power quality issues such as voltage dips. Setting a proper threshold can help to differentiate between an islanding and a grid connected condition [9]. Rate of change of output power of DG [10], rate of change of frequency [11], voltage unbalance and harmonic distortion [12] are a few examples of passive islanding detection methods. However passive methods are based on the measuring parameters of the power system and setting thresholds for the measured parameters. The main argue in passive methods is selecting suitable thresholds such that the islanding detection algorithm will not operate under noisy conditions. In this paper, a new method based on a combination of previous methods for diagnosing of an islanding state is proposed because it utilizes of passive methods of high speed that based on measuring and also avoids of wrong diagnosis of the islanding state that results in disconnection.

2. System under Study

The system studied for proposed method is shown in Figure 1. As depicted in this figure, DG has been shown by a wind turbine and self excited induction generator. The DG supplies power to the local loads denoted as L. The imbalanced power between the DG and L is adjusted by the main grid. A capacitor bank is located in the end of induction generator in order to power factor correction. A step-up transformer is located between DG unit with its local loads and utility grid.
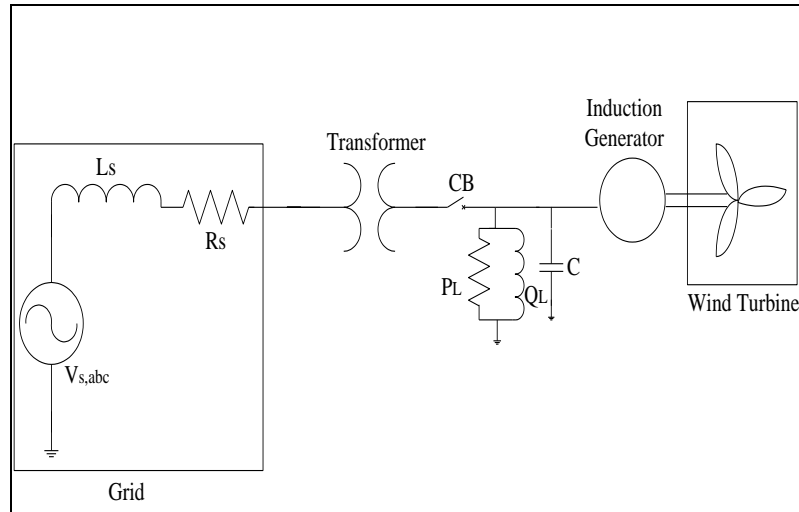
Figure 1. Studied Power System including DG and Power Grid

If the circuit breaker (CB) is open due to a grid fault, the DG and L will operate alone in an island (isolated) system. The system parameters are given in Table 1.

3. Proposed Hybrid Islanding Detection Strategy

One of the existing methods for islanding detection is rate of change of frequency of DG unit. This protection technique depends on the generator swing equation which defines the frequency rate of change as [13].

Table 1. Characteristic of Studied Power System

Parameter	Value	Units
Turbine Rated Power	660	KVA
R_s	1	Ω
L_s	1	mH
Rated Voltage of Local Load	0.4	KV
Nominal grid voltage	20	KV
Transformer Voltage Power	0.4/20	KV
Nominal grid frequency	50	HZ
Transformer Rated Power	660	KVA

$$\frac{\Delta f}{\Delta t} = \frac{f.\Delta P}{2HG} \tag{1}$$

Where:

ΔP : output power changing at the generator terminal

f : System frequency, in the condition of connecting to network

H : Inertia constant of DG units.

Rate of change of frequency (ROCOF) as control parameter is more stable than the voltage under grid connected conditions and therefore gives useful information about the nature of the connected network. ROCOF relay settings are based on the performance of independent DG and it should be set without network. The problem of this method is that in some cases such as switching in network, the system makes mistake and relay operates in a wrong way because decision making is extremely fast which in turn resulting in system disconnection. In rate of change of output power (ROCOP) method, the active output power of DG unit will be measured at any time and rate of change of output power will be calculated. The output power of the DG unit calculated with Eq. (2):

$$P_{DG} = |v_a||i_a|\cos(\theta_a) + |v_b||i_b|\cos(\theta_b) + |v_c||i_c|\cos(\theta_c) \tag{2}$$

Where v_a, v_b, v_c are sampling values of instantaneous three phase output voltage of the DG and i_a, i_b, i_c are sampling value of instantaneous three phase output current of the DG unit. The rate of change of output power calculated with derivative of this power. Islanding condition will be detected with this changing, if this value is more than threshold value. The problem of this method is that in some cases, such as switching, system mistaken and because decision making is extremely fast; relay operates and in a wrong way will result system disconnection. In this paper, a new method based on Rate of change of frequency over output power ($\frac{df}{dp}$) and rate of change of DG reactive power (ROCORP) to detect the islanding state is proposed. Figure 2, shows the flowchart of proposed method. At first, in the method, rate of change of DG reactive power ($\frac{dq}{dt}$) are measured and if the measured 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 of $(\frac{df}{dp})$ is examined and if the value also exceeds the threshold value, therefore the islanding state is diagnosed and disconnecting command will be exported.
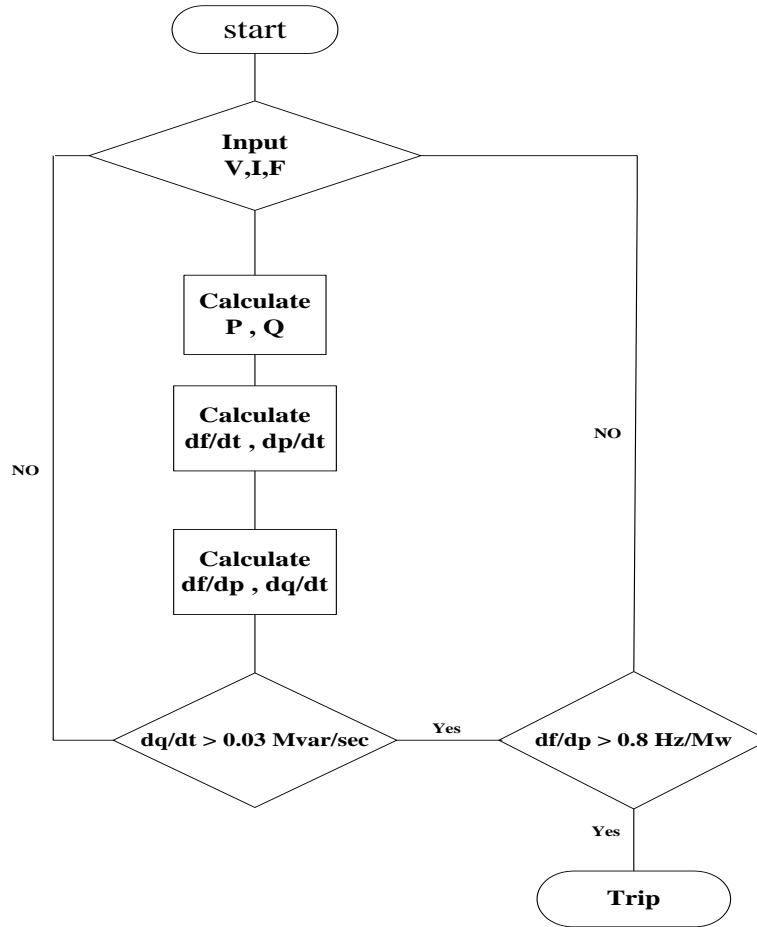
Figure 2. Flowchart of the Proposed Algorithm for Diagnosing Islanding Simulation Results

4. Simulation Results

Various events (islanding, capacitor switching and induction motor starting) have been simulated to show the effectiveness of the proposed methodology.
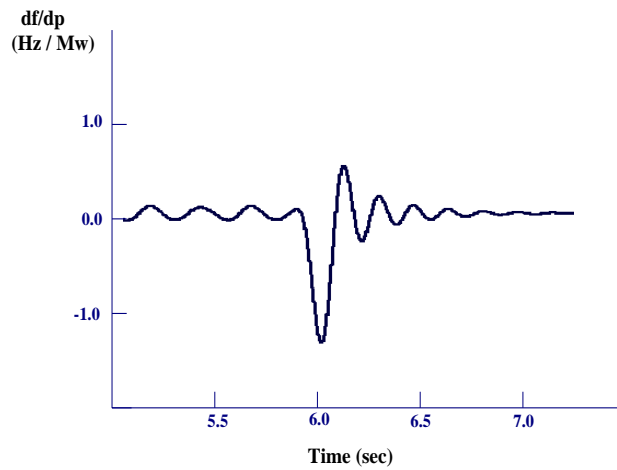
4.1 Islanding Condition

In this case, we set the load (values of resistant and inductance) in Figure 1 to nominal value given in Table 1. In simulations, an island was created by opening the switch CB. If for any reason this switch was opened, the DG become isolated from the main supply, and the DG was islanded. At $t = 6$ sec, CB is opened and DG together with local load is separated from utility grid and islanding occurs. Figure 3 depicts $\frac{dq}{dt}, \frac{df}{dp}$ and three phase load voltage,

respectively. From the Figure 3(a), it is obvious that in t = 6.02 sec $\frac{dq}{dt}$ rises fast and exceeds 0.003, in which the islanding condition is possible, hence $\frac{dq}{dt}$ changes should be examined.
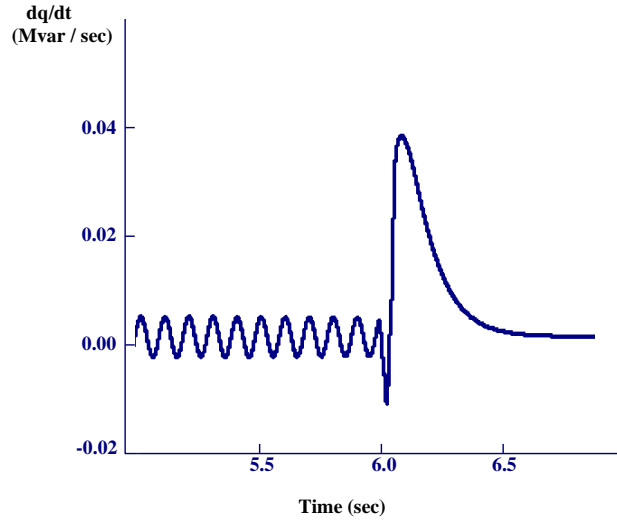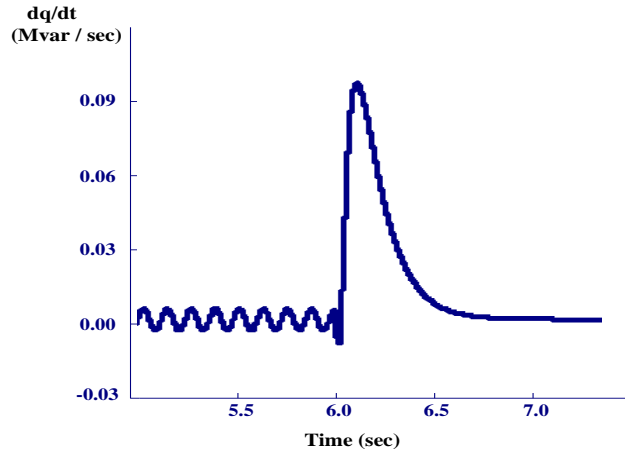

(a)

(b)

Figure 3. Islanding Conditions a) Rate of Change of DG Reactive Power ($\frac{dq}{dt}$), b) Rate of Change of Frequency over Output Power ($\frac{df}{dp}$)

Figure 3(b) shows ($\frac{df}{dp}$) signal. According to Figure 3(b), it is determined that the size of the $\frac{df}{dp}$ waveform in *t = 8.07 sec* has gone up to 0.8; therefore the islanding condition is detected at *t = 8.07 sec* and system should be disconnected and stopped production in this time.

4.2 Load Changing

In this case, the active and reactive power of local load is 300KW and 350KVAR respectively. Firstly CB is closed and the system is utilized in grid connected mode.
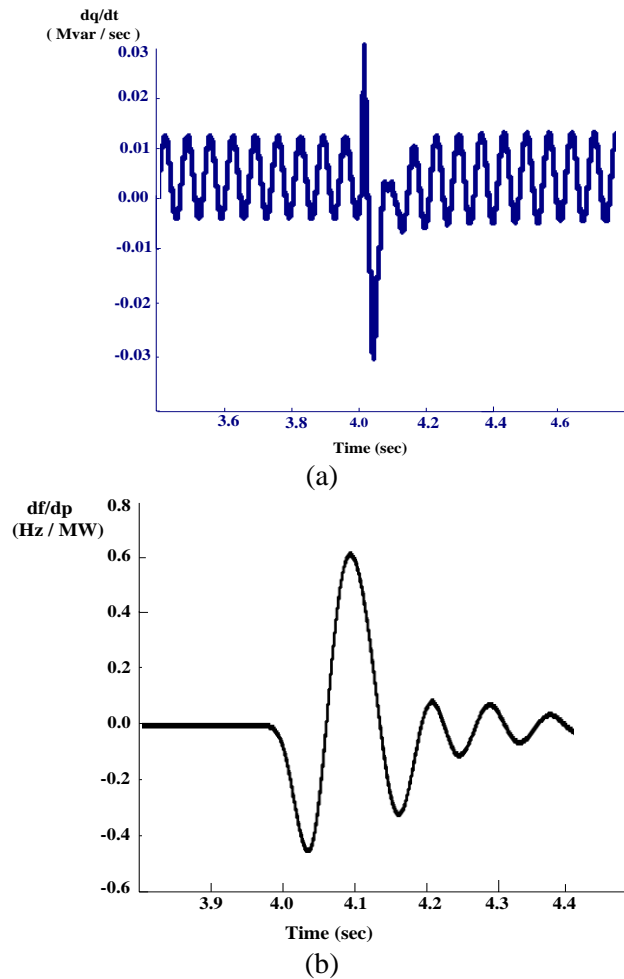

(a)
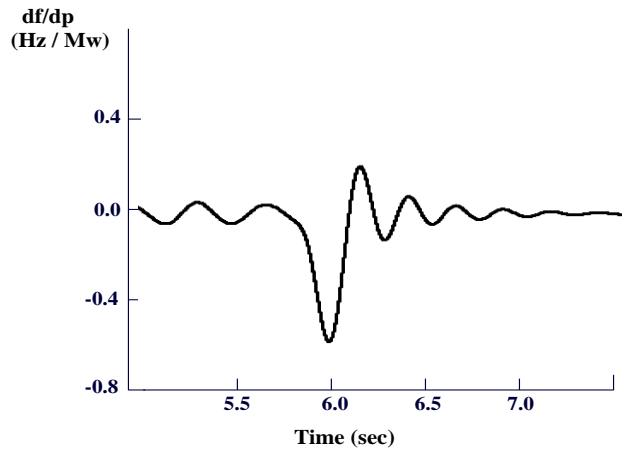
(b)

Figure 4. Load Changing a) Rate of Change of DG Reactive Power ($\frac{dq}{dt}$), b) Rate of Change of Frequency over Output Power ($\frac{df}{dp}$)

At $t = 6\ sec$, the CB is opened and the DG with local load is separated from the power grid and islanding condition occurs. Figure 4 depicts $\frac{dq}{dt}$ and $\frac{df}{dp}$, respectively. From the Figure 4, it is clear that the amount rate of change of frequency over power

under each event ($\frac{df}{dp}$) and rate of change of DG reactive power ($\frac{dq}{dt}$) do not exceed threshold.

4.3 Switching Capacitor Bank

Large capacitor bank switching in distribution power system initiates disturbances. In order to test the proposed algorithm, a large 0.45 Mvar capacitor bank is switched in t = 4 sec in a non-islanding case. The variation of $\frac{dq}{dt}$ and $\frac{df}{dp}$ are shown in Figure 5(a) and 5(b), respectively.

(a)

(b)

Figure 5. Switching Capacitor Bank a) Rate of Change of DG Reactive Power ($\frac{dq}{dt}$), b) Rate of Change of Frequency over Output Power ($\frac{df}{dp}$)

As seen in Figure 5(a), at *t = 4.03 sec* the value of $\frac{dq}{dt}$ changes exceeds threshold. In order to detection island condition rate of change of frequency over power also be studied, and

decided about islanding conditions. From the Figure 5(b), it is clear that the value of $(\frac{df}{dp})$ changes does not go beyond threshold. Hence, this state is detected properly and system does not act wrongly.

4.4 Inducting Motor Starting

In this section, the performance of algorithm is studied for induction motor starting to be shown that the proposed algorithm not mistaken in induction motor starting, and detect properly the islanding state from induction motor starting conditions. To study the reliability of the proposed algorithm, a 1 MW induction motor at *t = 5 sec* is switched and connected to the network.
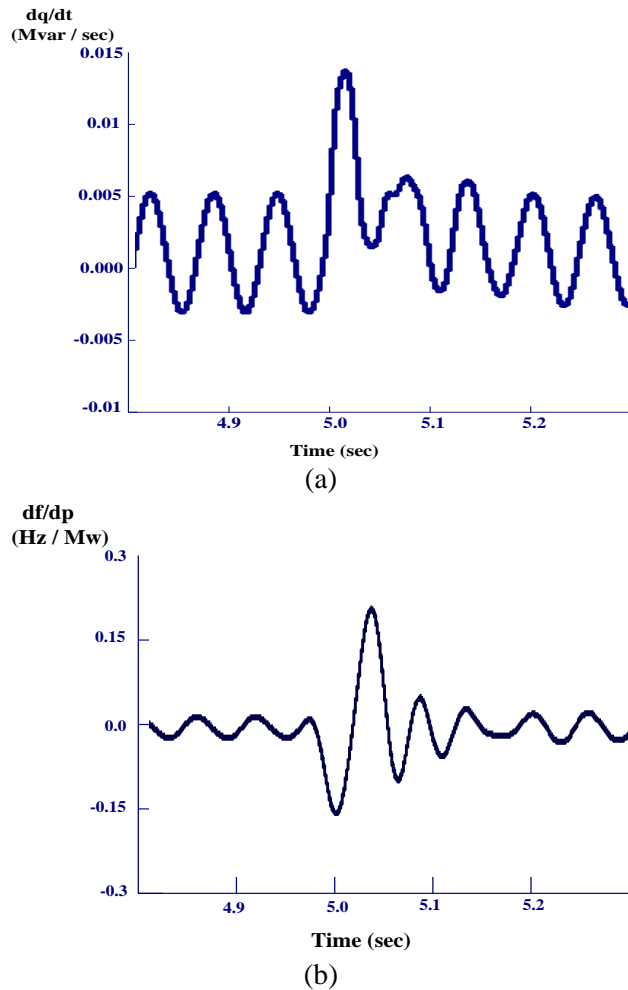

(a)

(b)

Figure 6. Inducting Motor Starting a) Rate of Change of DG Reactive Power ($\frac{dq}{dt}$), b) Rate of Change of Frequency over Output Power ($\frac{df}{dp}$)

From the Figure 6 is clear that the amount rate of change of frequency over power under each event ($\frac{df}{dp}$) and rate of change of DG reactive power ($\frac{dq}{dt}$) do not exceed threshold. So, this state is detected correctly and system will continue to work. This test shows good performance of proposed algorithm. Also, it should be noted that this algorithm shows as a condition of non-island.

5. Conclusions

In this paper, a new hybrid method to detect islanding condition for DGs was proposed. This method is essentially passive and decision making is based on the local measurement of signal. The capacitor bank switching and induction motor starting conditions were tested and shown the proposed algorithm distinguished correctly the islanding condition. The simulation results indicate the good performance of the proposed method while the previous methods have made mistake, this method can easily detect the conditions and make a proper decision to disconnect the system. Simulation result has been represented in PSCAD/EMTDC software and although the previous method performs it by error, this algorithm works properly.

References

[1] M. Karrari, W. Rosehart and O. P. Malik, "Nonlinear Modeling and Simulation of a Wind Generation Unit For Transient and Stability Analysis", Technical Report University of Calgary, (2003) March.

[2] H. Nikkhajoei and R. Iravani, "Steady-State Model and Power Flow Analysis of Electronically-Coupled Distributed Resource Units", IEEE Trans Power Deliv., vol. 22, no. 5, (2007), pp. 335-341.

[3] J. Warin and W. H. Allen, "Loss of mains protection", in Proc. ERA Conf. Circuit protection for industrial and commercial installation, London, U.K., (1990), pp. 431-435.

[4] P. O. Kane and B. Fox, "Loss of mains detection for embedded generation by system impedance monitoring", in Proc. 6th Int. Conf. Developments in power protection, (1997) March, pp. 95-98.

[5] G. A. Smith, P. A. Onions and D. G. Infield, "Predicting islanding operation of grid connected PV inverters", in Proc. IEE Electric Power Applications, vol. 147, (2000) January, pp. 1-6.

[6] A. M. E. Ropp, M. Begovic and A. Rohatgi, "Analysis and performance assessment of the active frequency drift method of islanding prevention", IEEE Trans Energy Converse., vol. 14, no. 3, (1999), pp. 810-816.

[7] J. Vinod, J. Zhihong and A. Kolwalkar, "Investigation of anti islanding protection of power converter based distributed generators using frequency domain analysis", IEEE Trans Power Electronics, vol. 19, no. 5, (2008), pp. 119-128.

[8] J. Yin, L. Chan and C. Diduch, "A new adaptive logic phase-shift algorithm for anti-islanding protections in inverter-based DG systems", in Proc. IEEE Power Electronics Specialists Conf., (2005), pp. 2482-2486.

[9] M. A. Refern, O. Usta and G. Fielding, "Protection against loss of utility grid supply for a dispersed storage and generation unit", IEEE Trans. Power Deliv., vol. 8, no. 3, (1993), pp. 948-954.

[10] M. A. Redfern, J. I. Barren and O. Usta, "A new microprocessor based islanding protection algorithm for dispersed storage and generation units", IEEE Trans. Power Del., vol. 10, no. 3, (1995), pp. 1249-1254.

[11] L. Yuping, Y. Xin, W. Jian and L. Xia, "An Intelligent Islanding Technique Considering Load Balance for Distribution System with DGs", in Proc. IEEE Power System Conf., (2006), pp. 567-573.

[12] J. Sung, K. Ho. Kwang, "An islanding detection method for distributed generations using voltage unbalance and total harmonic distortion of current", IEEE Trans. Power Del., vol. 19, no. 2, (2004), pp.745-752.

[13] M. Ezzt, M. I. Marei, M. Abdel-Rahman and M. M. Mansur, "A hybrid strategy for distributed generators islanding detection", IEEE PES Power Africa Conference and Exposition Johannesburg, South Africa, (2007) July, pp. 16-20.

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