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RESEARCH ARTICLE

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Anti-Islanding Protection using AFD for Renewable energy systems

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Abstract

The advancement in new technology like fuel cells, wind turbines, and photovoltaic cells and new innovations in power electronics to satisfy customer demands for better power quality and reliability are forcing the power industry to shift to distributed generations (DGs). Hence DG has recently gained a lot of popularity in the power industry due to market deregulations and environmental concerns. Islanding take place when a portion of the distribution system becomes electrically isolated from the rest of the power system yet continues to be energized by DGs. The main problem of interconnecting a DG to power distribution system is islanding. Failure to trip islanded generators can lead to a number of problems to these generators and the connected loads. All DGs must be disconnected immediately after the occurrence of islanding. Typically, this disconnection should be occurred within 100 to 300 ms after the loss of the main supply. To achieve such a goal, each DG must be equipped with any islanding detection method. In this paper, active methods have been introduced to overcome this problem especially the method of Active Frequency Drift (AFD) as it can detect islanding easily and has a small Non-Detection Zone, but unfortunately it degrades the power quality of the system. MATLAB/SIMULINK is used to simulate the output response of AFD method.

KEYWORDS

AFD, Islanding detection ways, Non-detection zone, Renewable Energy, smart grid.

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1 | INTRODUCTION

DGs are working in parallel to with utility power grid to feed power to the load, the operation is known as a grid-connected mode [1]. In contrast, in case of utility failure, the DG unit continues to supply power to the remaining load, and the operation is known as the islanded mode [2].

This paper discusses this problem that occurs during the connection between a DG plant and the rest of the power grid system. This problem has been mentioned and discussed widely in the last few years. Islanding occurs when a portion of the distribution power system becomes electrically complete isolated from the rest of the power system, hence load is remains energized by DG connected to the isolated subsystem as shown in figure.1. The causes of islanding divided to intended and unintended. Intended islanding is performed due to the scheduled maintenance required for the main utility, whereas unintended islanding may occur at any time due to regular faults or other uncertainties in the power system [3]. Therefore, islanding detection is considered as an important problem so IEEE 1547 [4,5,6] describe DG interconnection, planned and unplanned power islanding, and other important operating considerations. Risks of unintended Islanding are:

1- Islanding may interfere with the automatic or manual re-establishment of normal service for the neighboring customers [7].

2- The frequency and voltage provided to the users in the islanded system can vary suddenly if the DGs do not provide regulation of frequency and voltage and do not have protection relaying to limit voltage and frequency excursions [8].

3- The DGs in the islanding mode could be damaged when the rest of network is reconnected to the supply system. This is because the generators are likely not in synchronization with the system at the instantantly of reconnection. Such out-of-phase reclosing.

4- Islanding may create hazards for utility grid line-workers or the public by causing a line to remain energized that may be assumed to be disconnected from all energy sources.

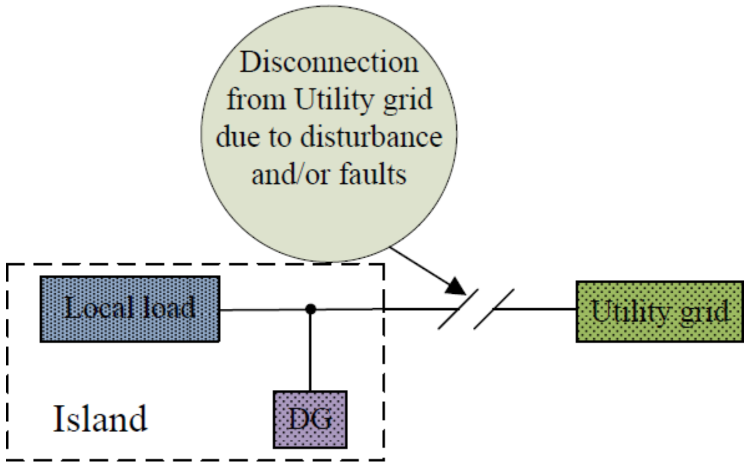

Figure 1 Schematic diagram to illustrate the concept of DG islanding [9].

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2 | NON-DETECTION ZONE (NDZ)

The effectiveness of the Islanding Detection Methods (IDM) is usually depends on the NDZ which relies mainly on the amount of local loads connected to the DG [10]. The closer the active power consumed by these loads is to the active power supplied by the DG, the higher the probability to form an islanding.

In the same way, as the resonant frequency of the local load approaches the local grid nominal frequency the potential formation of the islanding also increases. There are two kinds of representation methods up to now as follows: Power Mismatch Space Representation (PMSR), Load Parameter Space Representation (LPSR) [11].

PMSR uses the amount of active power flow (DP) and reactive power flow (DQ) to the grid. After islanding occurs, the islanding voltage and islanding frequency goes to the new operating point for the power balance between PV generation and local load consumption [12]. Under the local passive AIMs, the quantitative NDZ of PMSR can be analyzed as Eqs. (1) and (2) and this NDZ zone is described in figure 2.

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

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

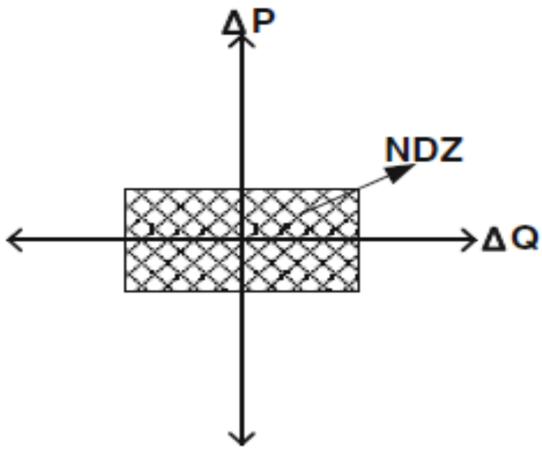

Figure 2 Representation of NDZ [13].

3 | ANTI-ISLANDING DETECTION METHODS

The taxonomy presented in Figure.3. Broadly classifies IDM methods as remote, passive and active methods.

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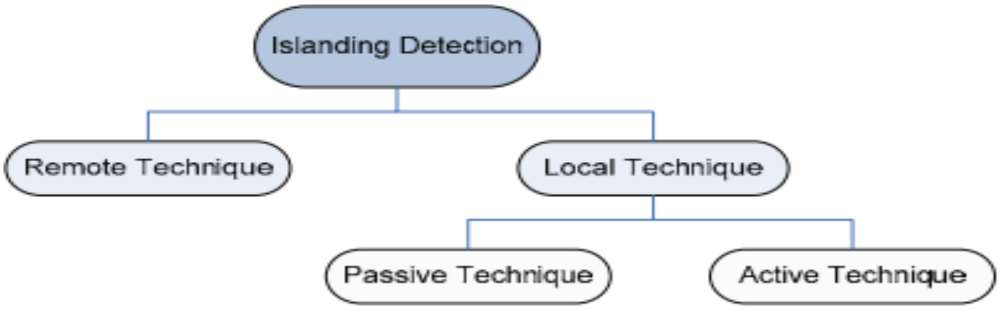

Figure 3 Representation of anti-islanding detection methods [16].

[redacted] REMOTE ANTI-ISLANDING METHODS

The remote methods are relies on the communication links between the utility power grid and DG sources. These methods have the high efficiency, have better reliability than local IdMs and have negligible NDZ [14].But it is costly, need a stiff infrastructure, updated improvement in communication, high computational burden [15]. Figure 4 shows a schematic of the remote islanding detection technique, where the main grid and DG unit share the information using a communication channel. Islanding detection is mainly based on the information collected and sent from transmitter from the applied media to the receiver at tripping switch. The common examples of remote IdMs include supervisory control and data acquisition (SCADA), power line communication (PLC), and transfer trip.

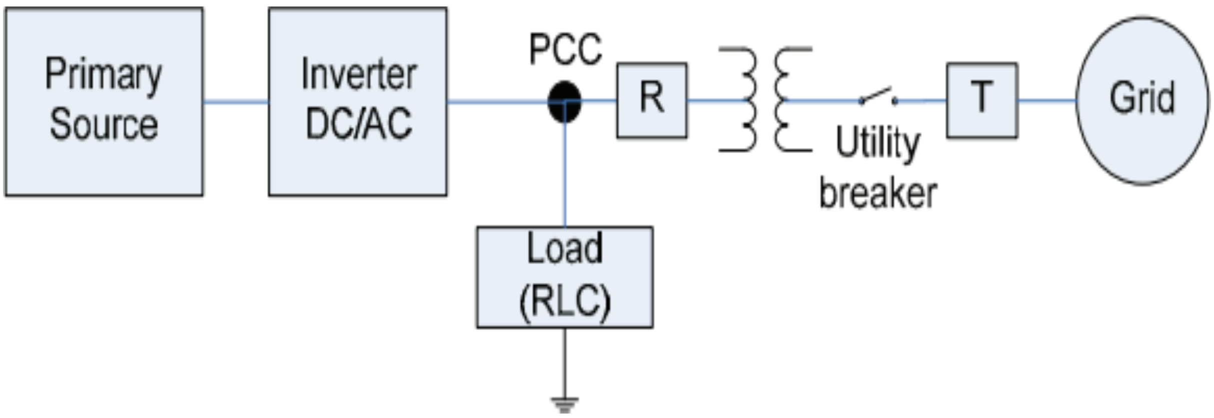

Figure 4 Representation of the concept of remote IDM [17].

[redacted] PASSIVE ANTI-ISLANDING METHODS

Passive Anti-Islanding Methods monitors the variation in system parameters such as frequency, voltage and current on the DG side at the Point of Common Coupling (PCC). In case of islanding, these parameters display variations which have been used to detect islanding. The methodology of choosing the limits of variation of these methods mainly depend on the IEEE standard 1547 [18] which is shown in table 1.

$$\Delta P = P_{DG} - P_{LOAD} \qquad (3)$$

Received: Added at production | Revised: Added at production | Accepted: Added at production
DOI: xxx/xxxx

$$\Delta Q = Q_{DG} - Q_{LOAD} \qquad (4)$$

Figure 5 presents a single line diagram of a grid-connected DG source. The real power (ΔP) and reactive power (ΔQ) delivered are represented by Eqs (3 and 4) respectively.
P_{DG} and Q_{DG} are the real and reactive power delivered by the DG source respectively. Similarly, Pload and Qload are the real and reactive power absorbed by the load.

Table 1 of IEEE 1547 standard for IDM

Parameters	**Standard**
Range of Voltage	88% ≤ V ≤ 110 %
Range of Frequency	49 HZ ≤ f ≤ 50 HZ
Maximum time for islanding detection	2 second
THD (%)	≤ 5 %

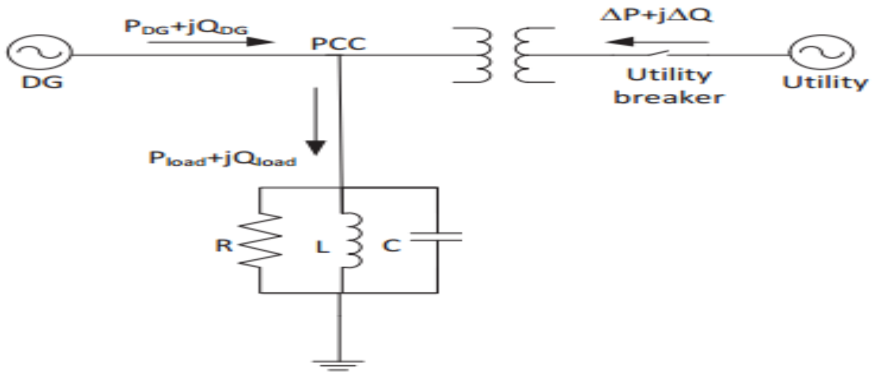

Figure 5 Representation single line diagram of a grid-connected DG source [19].

[redacted]ACTIVE ANTI-ISLANDING METHODS

Active methods introduce intentional disturbances to the rest of the circuit and then analyze the feedback to decide whether there is an islanding or not [22]. The way of detecting islanding for active techniques cooperate with the power system operation by injecting perturbations. The idea of an active detection method is that this small perturbation will result in a significant change in system parameters when the DG is islanded, whereas the change will be negligible when the DG is connected to the grid [23].

Received: Added at production | Revised: Added at production | Accepted: Added at production
DOI: xxx/xxxx

3.3.1 ACTIVE FREQUENCY DRIFT (AFD) TECHNIQUE

In this technique, some disturbances of the current signal are injected into the Point of Common Coupling (PCC) depending on voltage at point of common coupling V_{PCC} which follows the fundamentals of current of the inverter I_{inv} [24-27]. Hence, in the grid-connected mode, this distortion does not disturb the current and voltage. Therefore, the frequency of the system has the same frequency of the grid. In the other hand, the grid-disconnected mode (islanding condition) has distortion leads to a phase difference between the current and voltage. Hence, this difference leads to a drift in frequency that obligates the UF/OF relays to cutoff the DG from the rest of the circuit.As shown in Figure 6, it is a comparison between a waveform of distorted DG output current with undistorted sine waveform. The chopping factor C_f in equation (5) is used to calculate the intensity of the disturbance as in the following equation:

$$C_f = \frac{2t_z}{T} \qquad (5)$$

Where, T is the voltage period of the grid and t_z is the dead time. However, this technique can easily be implemented using a microprocessor. But unfortunately It affects the power quality [28, 29, 30, 31].

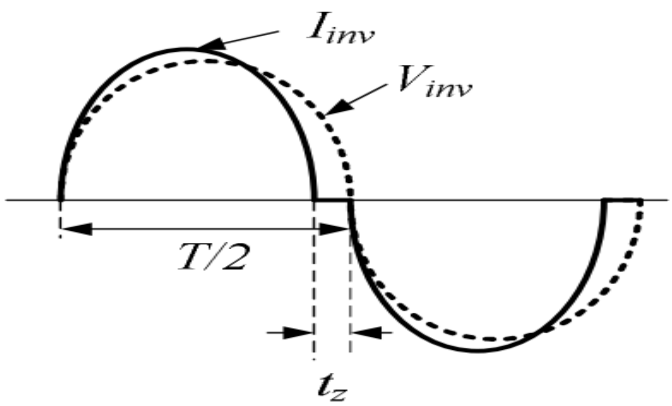

Figure 6 Waveform of AFD Technique [30].

4 | SIMULATION AND RESULT OF AFD

According to the previous description of AFD theoretical a 1 kW single-phase PV power generation system is established in Matlab/Simulink. This control was designed to monitor the F_{PCC} *and* V_{PCC}. The AFD controller will produce a signal to the inverter to stop supplying to the local load if voltage and frequency are out of the limits determined by IEEE 1547 [18]. The simulation module includes the inverter circuit connected to a utility grid control and AFD islanding Detection section at the PCC. The function of AFD controller module was achieved by using the s-function in Matlab/Simulink. The V_{PCC} and I_{Pv-inv} are in phase at the initial setting. The grid supply was set to be disconnected at t=0.1 s.

So the sequence of the AFD detection algorithm Firstly, the frequency data was taken and tested against the UFP/OFP threshold, if it is not in the threshold, the islanding occurred, else it is not islanding. If there is no islanding, a source with frequency modified by the C_f is then

Received: Added at production | Revised: Added at production | Accepted: Added at production
DOI: xxx/xxxx

injected into the inverter output current every half cycle and every full cycle to produce a t_z on the output current waveform. The value of the C_f will slightly increase every half cycle to drift the current frequency from voltage frequency until islanding is detected and a signal will be sent to stop the inverter from operating.

Figures 11-13 are the cases result for AFD controller which these cases were difficult to be detected by the passive IDM.

The results show that the AFD is capable of detecting islanding effectively with very small NDZ and a detection time within 0.06 s. The disturbance injection plays a significant role in performing islanding detection to meet the PV grid interconnection standard. The simulation results show the more disturbances injected the faster the islanding detection time but the higher the harmonic distortion.

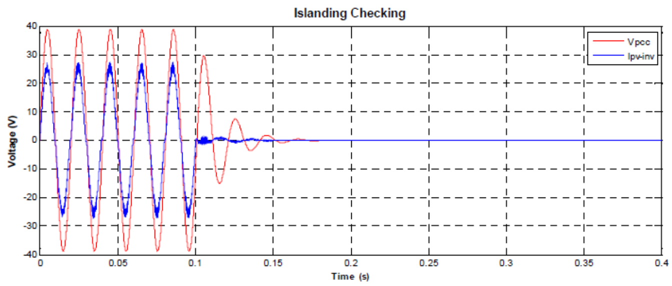

Figure 11 The simulation output of AFD for Frequency=49.4 Hz, Cf=0.049 Detection time, t=0.1006 s, VPCC stop at t=0.1594

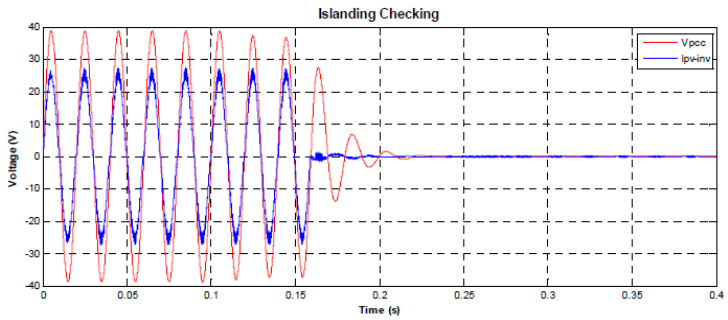

Figure 12 The simulation output of AFD for Frequency=50.0 Hz, Cf=0.05 Detection time, t=0.1591 s and load VPCC stop at t=0.2171 s

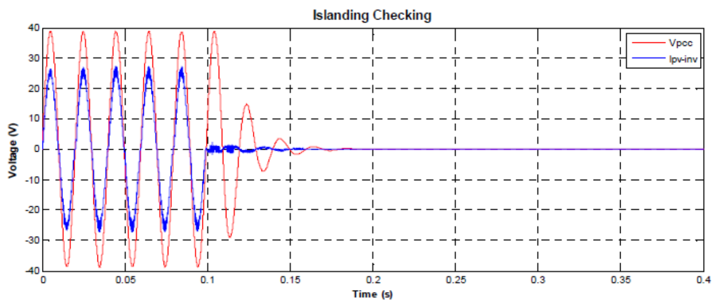

Figure 13 The simulation output of AFD for Frequency=50.4 Hz, Cf=0.0504 Detection time, t=0.1005 s and load VPCC stop at t=0.0.1672 s

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Despite, the active methods have small NDZ, but unfortunately it leads to decreasing power quality of the system. In addition to, these methods may change the magnitude of the output for the inverter either frequency or current. Although, there are some active methods can detect islanding without decreasing power quality, it will require using many controllers that will increase the complexity for the implementation and more expensive than the other local techniques [32,33 ,34 ,35 ,36 ,37 ,38 ,39 ,40]. AI detection techniques are explained in detail in the rest of this subsection.

5 | CONCLUSION

This paper presents anti-islanding detection techniques, which are remote, passive and active anti-islanding detection technique. The results shows that the passive detection technique isn't completing convenient as it has large non detection zones. On the other side, the active detection technique (AFD) can detect islanding faster and easier but it has bad effect on power quality. These techniques have been successfully simulated using MATLAB/Simulink package. Finally, the simulation results show that a hybrid anti-islanding detection technique or artificial intelligent are advised to be used for achieving higher detection efficiency as compared to any single detection techniques. The improvements include a narrower non-detected zone, faster response time and better power quality in terms of THD.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest regarding the publication of this article.

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