IJCRT.ORG ISSN : 2320-2882

INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)
An International Open Access, Peer-reviewed, Refereed Journal

# Islanding Detection in Grid-Connected 100 KW Photovoltaic System Using Wavelet Transform

Ovais Nazir[1], Dr. Aziz Ahmad.[2]

P.G. Student, Dept. of Electrical and Electronics Engineering, Alfalah University Faridabad Haryana, India[1]

Professor Dept. of Electrical and Electronics Engineering, Alfalah University Faridabad Haryana, India[2]

**ABSTRACT***:*Islanding refers to the condition in which a distributed generator (DG) continues to power a location even though electrical grid power from the electric utility is no longer present. It should be detected as fast as possible in order to avoid the serious safety hazards and the damage of DG itself. In this paper, comparative study between wavelet transform (WT) and Total Harmonic Distortion (THD) on detection of islanding in a grid connected photovoltaic system is done. The negative sequence component of the voltage signal at Point of Common Coupling (PCC), a measure of unbalance in the system, is used in WT islanding detection. THD is calculated from the current signal at PCC. The energy content and standard deviation of WT are calculated in order to validate the graphical results. The results demonstrate the advantages of WT over THD in detection of islanding.

**KEYWORDS**: Distributed generation (DG), Photovoltaic (PV) system, Islanding, Wavelet transform (WT), Total Harmonic Distortion (THD).

.

## I.INTRODUCTION

The energy demand is skyrocketing day by day. In order to meet the expanded load demand, new methods should be included with addition of new transmission feeder and generation resources. In this context, DGs using renewable energy sources can be considered as an important alternative to enhance the total power generation [1]–[4]. This will also minimize the environmental pollution, especially greenhouse gas whose negative impact on climate has been already observable. DG can fulfil customer's demand in stand-alone as well as grid-connected mode as per situation requirements. When the power is surplus, it can be fed to the grid thereby increasing the reliability of power supply.

But there are many issues to be addressed with the DG connected to utility grid such as islanding of DG and PQ disturbances such as voltage sag, swell, notch, momentary interruptions, etc. Islanding will result to several negative effects on utility power system and the DG itself, such as the safety hazards to utility personnel who works on the event of islanding. Added, PQ related problems of electric service to the utility customers, and serious damages to the DG if utility power is wrongly restored [5]–[7]. As a matter of fact, both islanding and PQ disturbances must be properly and effectively detected to mitigate effects which may result into mal-operation and damage of equipments in the power system.

Several methods have been suggested in study of islanding detection [7]–[15]. These methods can be peripherally categorized into three groups: active, passive, and communication-based methods. Usually, active methods are based on injection of a small disturbance into the system. Then the system is analysed with the change in output parameters for islanding detection. Passive methods monitor the system parameters and a suitable threshold is selected for detection. In fact, the conflict exists in selection of most significant parameter to be measured. Also, selection of threshold for effective detection of the disturbances is a challenge. Active methods may inject unwanted harmonic content to the system whereas the passive methods suffer from large non-detection zone and selection of appropriate threshold at times.

The passive islanding detection techniques, those being adopted in [10], [11] are promising. But the voltage unbalance and total harmonic distortion techniques have their own disadvantages. In this paper, WT based islanding [8], [9] and disturbance detection is compared to THD based scheme at various loading conditions of PV, and the indices are tabulated along with suitable waveforms of measured signals.

This paper is organized as follows; Paradigms of the approaches for islanding is given in Section II. Then, the simulated results and discussions on performance of detection methods are described in Section III followed by tabulating the results and graphs in IV followed by conclusions drawn from the study in Section V.

## II.**ISLANDINGDETECTIONMETHODS**

This section presents a brief on the techniques that are used in the islanding detection. Mainly, this paper discusses two detection techniques: Detection using Wavelet Transform and THD. Energy of the signal is also calculated to confirm the islanding event. Important aspect of the signals under islanding is that they are non-stationary signals. It means information is often a combination of features that are localized in time and frequency. This speciality demands the use of analysis methods that are capable to handle signals in terms of their time-frequency localization. Wavelets localize the information in time-frequency plane which is suitable for the analysis of non-stationary signals. THD on the other hand gives an idea of amount of harmonics present in the system in ratio to the fundamental component of the signal. As the Islanding happens, the harmonic content rises considerably, will reflect on THD.

### i. Discrete wavelet transforms (DWT)

Wavelets localize the information in the time–frequency plane which is suitable for the analysis of non-stationary signals that is generated in an islanding situation. Wavelet analysis deals with expansion of functions in terms of a set of basic functions (wavelets) which are generated from another wavelet by operations of dilatations and translations. WT decomposes transients of the signal/function into a series of wavelet components. Each of these components corresponds to a time domain signal that covers a specific frequency band. Each frequency component is studied with a resolution matched to its scale. In this study, the voltage signals are used as the input signals of the wavelet analysis. Daubechies4 (dB4) mother wavelet, is employed since it has been demonstrated to perform well [9, 10]. Both approximation and details information related to fault voltages which are extracted from the original signal i.e. here the negative sequence voltage at PCC. To analyse the signal at different scales, filters of different cut-off frequencies are used. The signal is passed through a series of high pass filters (HPFs) to analyse the high frequencies. To analyse the low frequencies, it is passed through a series of low pass filters (LPFs). Hence the signal (S) is decomposed into two genres of components. One is approximation (C) and the other is detail (D). The approximation (C) is the high scale, low-frequency component of the signal. High-frequency components are the details (D) which has the low-scale. The decomposition process can be iterated, with help of successive approximations technique. Thus one signal is divided into many low-resolution components. This is collectively called the wavelet decomposition tree and is shown in Fig. 1. As decompositions are done on higher levels, lower frequency components are filtered out. Unlike the Fourier transform, WT provides a non-uniform division of the frequency domain (i.e., the wavelet transform uses short windows at high frequencies and long windows for low frequency components).

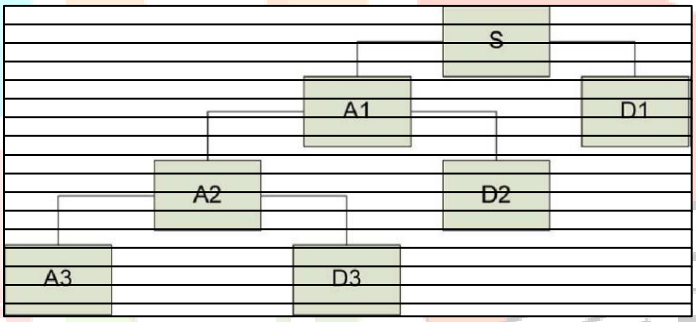

Fig. 1. Wavelet decomposition tree.

Given a function *v* (t), its continuous wavelet transform (CWT) can be calculated as:

$$\text{CWT}(v, x, y) = \frac{1}{\sqrt{a}} \int_{\infty}^{\infty} v(t)\Psi * \frac{(t-y)}{x} dt \qquad \text{………………………………………………………………………… (1)}$$

Where x and y are scaling (dilation) and translation (time shift) constants, respectively, and Ψ is the wavelet function. Wavelet transform of sampled waveform can be obtained by implementing the discrete wavelet transform as:

$$\text{DWT}(v, x, y) = \_\_ \sum v(k)\Psi * (\_\_\_\_\_\_)$$

Where the parameters x and y in Eq. (1) are replaced by x  and kx  , k and m being integer variables.

In a standard DWT, the coefficients are sampled from the CWT on a dyadic grid i.e. in the multiple of 2.

THD Variation of the Current

When islanding happens, the entire load has to be met by the DG. The changes in the loading of DG caused by loss of main power source will obviously result in variations on the harmonics content of the current. The total harmonic distortion of the current at the monitoring time t is defined as

$$\mathrm{THD_t} = \frac{\sqrt{\sum_2^H I_h^2}}{I}\; x\; 100$$

Where is the $I_h$rms of the harmonic components and is the $I_1$rms value of fundamental component of the current signal.

Parseval's theorem

The theorem states that the energy of a signal remains the same whether it is computed in a signal domain (time) or in a transform domain (frequency) [24]. Parseval's Theorem is mathematically framed as follows.

1

$$E = \_ \quad |v(t)|\, dt = |V[n]|$$

T

Where T and N are the time period and length of the signal respectively, and V[n] is the Fourier transform of the signal. The energy of the voltage signal taken from the PCC, is used as an index along with standard deviation (SD) taken from the WT. Both energy and SD gives the perfect localization of values in different scenarios like PQ issues or Islanding.

## III. SIMULATION RESULTS

This section presents the simulated results of detection of islanding events using the above discussed techniques, i.e., WT and THD in PV under islanding and grid connected. The PV system used in this paper is a 100-kW PV array is connected to a 25-kV grid via a DC-DC boost converter and a three-phase three-level Voltage Source Converter (VSC). Maximum Power Point Tracking (MPPT) is implemented in the boost converter by means of the Incremental Conductance technique [16]. It is simulated in MATLAB/SIMULINK environment with WAVELET TOOLBOX. For Islanding, the voltage signal at PCC is extracted and using a sequence analyser negative sequence component is separated from it. This negative sequence voltage is loaded in WAVELET TOOLBOX taking mother wavelet as Daubechies4 (dB4). SD is calculated for the coefficients of level 1 details of WT (d1). THD approach uses the current signal from the PCC. Following waveforms are simulated results of PV system at PCC for both grid connected and islanding modes. The local test loading is 50 kW + 100 kVAr. Islanding instant is 0.7 seconds. Total simulation time is 2 seconds.

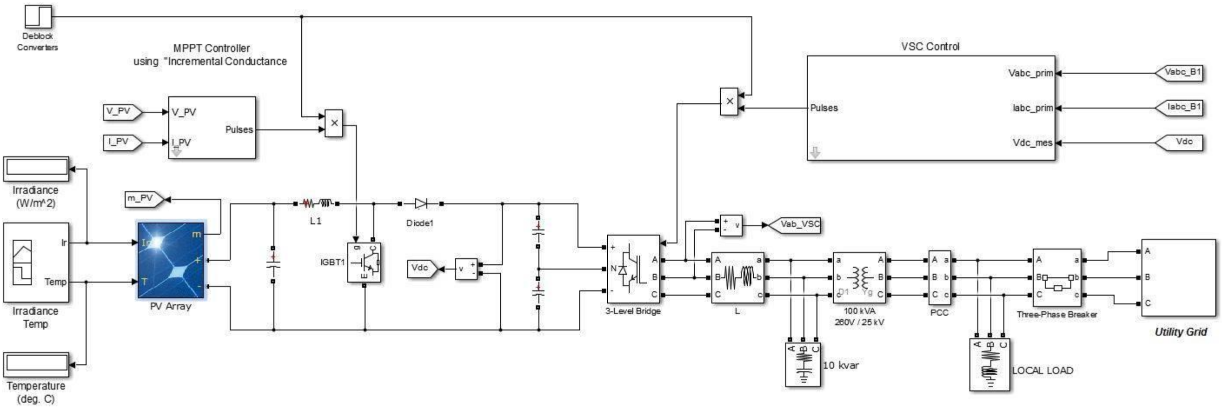

FIG. 2. SIMULATION DIAGRAM OF GRID CONNECTED PV SYSTEM

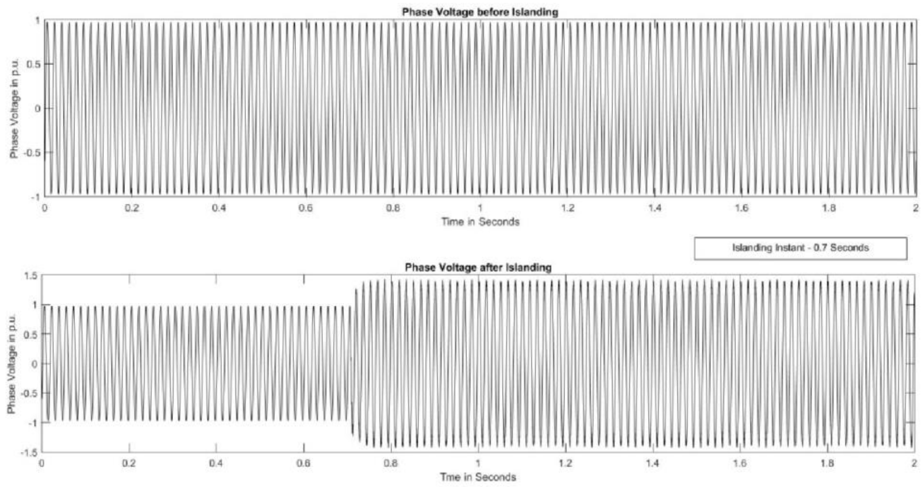

FIG. 3. PHASE VOLTAGE AT PCC BEFORE AND AFTER ISLANDING

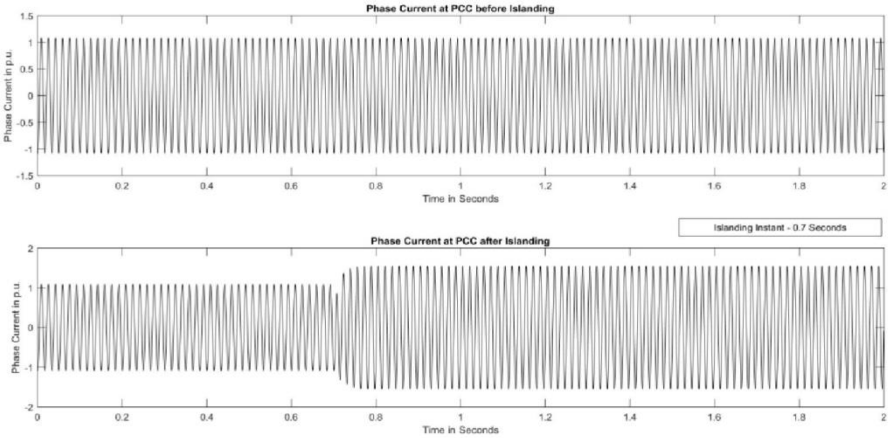

FIG.4. PHASE CURRENT AT PCC BEFORE AND AFTER ISLANDING

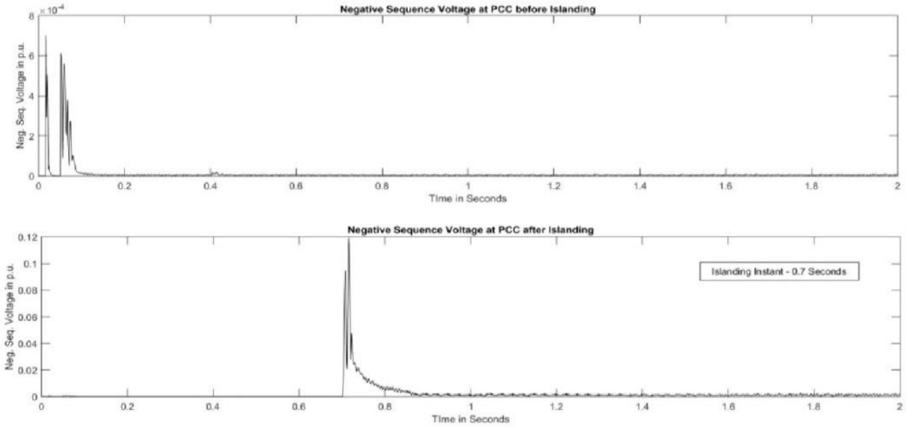

FIG. 5. NEGATIVE SEQUENCE VOLTAGE BEFORE AND AFTER ISLANDING

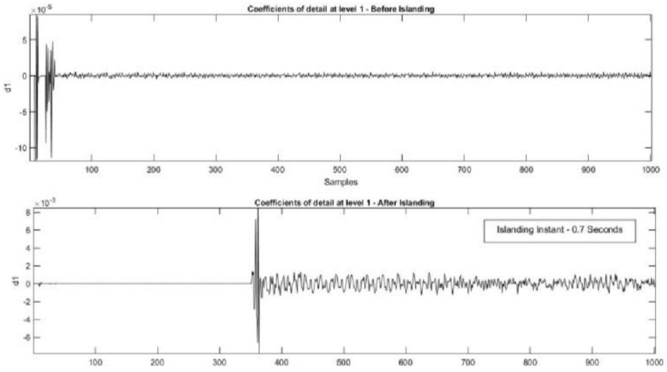

FIG. 6. COEFFICIENT OF DETAIL AT LEVEL 1 (D1) BEFORE AND AFTER ISLANDING

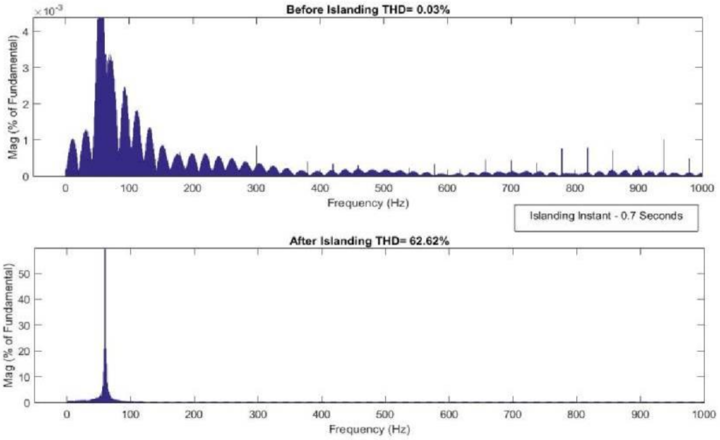

FIG. 7. THD OF PHASE CURRENT BEFORE AND AFTER ISLANDING

Table 1 shows the comparison of values during grid connected mode and islanding mode at the same test loading condition of 50 kW+100 kVAr.

| **MODE** | **THD** | **SD** | **ENERGY** |
|---|---|---|---|
| Grid Connected | 0.03% | $1.449 \times 10^{-5}$ | $4.5159 \times 10^{-6}$ |
| Islanding | 62.62% | $6.765 \times 10^{-4}$ | $1.253 \times 10^{-1}$ |

TABLE 1 INDEX BEFORE AND AFTER ISLANDING AT LOADING 50 KW + 100 KVAR

Table 2 shows the performance of the indices in various loading conditions of PV under Islanding. The loading variation is from 50% to 150% of the rated output of PV system.

| **LOADING** | **THD** | **SD** | **ENERGY** |
|---|---|---|---|
| 50 kW+100 kVAr | 62.62% | $6.765 \times 10^{-4}$ | $1.253 \times 10^{-1}$ |
| 70 kW + 100 kVAr | 48.60% | $5.137 \times 10^{-4}$ | $1.001 \times 10^{-1}$ |
| 90 kW + 100 kVAr | 47.84% | $4.798 \times 10^{-4}$ | $0.824 \times 10^{-1}$ |
| 100 kW + 100 kVAr | 47.45% | $5.025 \times 10^{-4}$ | $0.761 \times 10^{-1}$ |
| 110 kW + 100 kVAr | 54.41% | $5.644 \times 10^{-4}$ | $0.733 \times 10^{-1}$ |
| 130 kW + 100 kVAr | 50.11% | $6.258 \times 10^{-4}$ | $0.649 \times 10^{-1}$ |
| 150 kW + 100 kVAr | 47.99% | $4.360 \times 10^{-4}$ | $0.589 \times 10^{-1}$ |

TABLE 2 PERFORMANCES OF INDICES AT ISLANDING CONDITION DURING VARIOUS LOADS OF PV

## IV.CONCLUSION

From the simulation results in the previous section, some inferences can be made lucidly. Table 1 shows the effectiveness of the techniques that are adopted in this paper. The normal system gives the THD of only 0.03% which shoots to 62.62% after the event of islanding. Similarly SD and energy varies from $1.449 \times 10^{-5}$ to $6.765 \times 10^{-4}$ and $4.5159 \times 10^{-6}$ to $1.253 \times 10^{-1}$ respectively. Table 2 is the tabulation of the measurements of the same indices in various loading during islanding of PV. The following conclusions can be made from Table 2.

1. THD varies abruptly with loading.
2. SD and Energy are negligibly responsive to loading.
3. It is hard to fix a threshold for THD to compare and confirm the islanding event due to abrupt variations.
4. Threshold fixing is easy using SD and Energy since change in value of these indices is almost negligible.

Thus the WT based approach can detect islanding event effectively during various loading conditions outruns the THD based detection scheme. Loading of DG is not predictable at the event of islanding, then THD based approach can't be employed for accurate detection. Same time, the WT based scheme is immune to the loading changes on PV system and the detection scheme using WT can make use of this speciality.

## REFERENCES

[1] J. Jeon, S. Kim, C. Cho, and J. Ahn, "Development of a grid-connected Wind/PV/BESS hybrid distributed generation system," presented at the 19th Int. Conf. Elect. Distrib. (CIRED), Vienna, Austria, May 21–24, 2007.

[2] O. C. Onara, M. Uzunoglua, and M. S. Alama, "Modeling, control and simulation of an autonomous wind turbine/photovoltaic/fuel cell/ultracapacitor hybrid power system," *J. Power Sources*, vol. 185, no. 2, pp. 1273–1283, 2008.

[3] S. K. Kim, J. H. Jeon,C.H.Cho, J.B.Ahn, and S. H.Kwon, "Dynamic modeling and control of a grid-connected hybrid generation system with versatile power transfer," *IEEE Trans. Ind. Electron.*, vol. 55, no. 4, pp. 1677–1688, Apr. 2008.

[4] S. K. Kim, E. S. Kim, and J. B. Ahn, "Modeling and control of a grid-connected Wind/PV hybrid generation system," in *Proc. IEEEPES Transmiss. Distrib. Conf. Exhib.*, 2006, pp. 1202–1207.

[5] M. G. Bartlett and M. A. Redfern, "A review of techniques for the protection of distributed generation against loss of grid," presented at the UPEC, Belfast, U.K., Sep. 6–8, 2000.

[6] P. D. Hopewell, N. Jenkins, and A. D. Cross, "Loss-of-mains detection for small generators," *IEE Proc.—Elect. Power Appl.*, vol. 143, no. 3, pp. 225–230, 1996.

[7] H. Karimi, A. Yazdani, and R. Iravani, "Negative-sequence current injection for fast islanding detection of a distributed resource unit," *IEEETrans. Power Electron.*, vol. 23, no. 1, pp. 298–307, Jan. 2008.

[8] Islanding and Power Quality Disturbance Detection in Grid-Connected Hybrid Power System Using Wavelet and –Transform Prakash K. Ray, S, NandKishor, and Soumya R. Mohanty, IEEE transactions on smart grid, vol. 3, no. 3, september 2012

[9] Comparative Study of Advanced Signal Processing Techniques for Islanding Detection in a Hybrid Distributed Generation System , Soumya R. Mohanty, NandKishor, Prakash K. Ray, and João P. S. Catalão, IEEE transactions on sustainable energy, vol. 6, no. 1, january 2015

[10] S. Jang and K. Kim, "An islanding detection method for distributed generation algorithm using voltage unbalance and total harmonic distortion of current," *IEEE Trans. Power Del.*, vol. 19, no. 2, pp. 745–752, Apr. 2004

[11] Menon and M. H. Nehrir, "A hybrid islanding detection technique using voltage unbalance and frequency set point," *IEEE Trans. PowerSyst.*, vol. 22, no. 1, pp. 442–448, Feb. 2007.

[12] A.M.Massoud, K. H. Ahmed, S. J. Finney, and B.W.Williams, "Harmonic distortion-based island detection technique for inverter-based distributed generation," *IET Renewable Power Gen.*, vol. 3, no. 4, pp. 493–507, 2009.

[13] K. El-Arroud, G. Joos, I. Kamwa, and D. T. McGillis, "Intelligent based approach to islanding detection in distributed generation," *IEEETrans. Power Del.*, vol. 22, no. 2, pp. 828–835, Apr. 2007.

[14] G. K. Hung, C. C. Chang, and C. L. Chen, "Automatic phase-shift method for islanding detection of grid-connected photovoltaic inverters," *IEEE Trans. Energy Convers.*, vol. 18, no. 1, pp. 169–173, Mar. 2003.

[15] M. Liserre, A. Pigazo, A. Dell'Aquila, and V. M.Moreno, "An anti-islanding method for single-phase inverters based on a grid voltage sensorless control," *IEEE Trans. Ind. Electron.*, vol. 53, no. 5, pp. 1418–1426, Oct. 2006.

[16] Moacyr A. G. de Brito, Leonardo P. Sampaio, Luigi G. Jr., Guilherme A. e Melo, Carlos A. Canesin "Comparative Analysis of MPPT Techniques for PV Applications", 2011 International Conference on Clean Electrical Power (ICCEP).