Optik 168 (2018) 754–763

Contents lists available at ScienceDirect

Optik

journal homepage: www.elsevier.de/ijleo

Original research article

Modified wavelet transform based fault analysis in a solar photovoltaic system

Prakash K. Ray[a,*], Asit Mohanty[b], Basanta K. Panigrahi[c], Pravat K. Rout[c]

[a] Cambridge Centre for Advanced Research and Education in Singapore, CREATE Tower, 1 Create Way, 138602, Singapore
[b] Department of Electrical Engineering, CET, Bhubaneswar, 751003, India
[c] Dept. of Electrical Engineering, SOA University, Bhubaneswar, India

ARTICLE INFO

Article history:
Received 27 February 2018
Accepted 28 March 2018

Keywords:
Fault disturbances
Grid-connected solar PV system
Wavelet packet transform
Wavelet transform

ABSTRACT

Modified wavelet called wavelet packet transform (WPT) based approach is proposed in this paper for the detection of different disturbances occurring due to faults in grid-connected solar photovoltaic (SPV) power system. The detection performance of WPT is compared with that of wavelet transform under different operating scenarios. Further, performance indices such as energy and standard deviation (SD) are calculated to identify the faults from normal operating conditions. The qualitative and quantitative study suggests better detection performance of WPT over WT under different operating scenarios.

1. Introduction

Increasing demand of electric energy, non-availability of fossil fuels, increasing price of petroleum products and gases, power system restructuring and deregulations and increasing alarm for environmental pollution makes the paradigm to be shifted towards renewable energy [1]. Renewable energy recourses like solar photovoltaic (SPV) and wind energy are the most popular among them. Of course, SPV is probably the best choice if the input solar radiation is sufficient. The only problem with this power generation is its intermittent characteristics. Therefore SPV can be integrated with some storage options like battery, flywheel super capacitors etc. for stand-alone/isolated applications. Otherwise, it can also be operated in parallel with the conventional grid to support the uncertainties. As a result, the operation and control in modern power system is becoming a challenging task with large SPV penetrations. It is very important that when any fault occurs in power system, should be detected and classified as quick as possible in order to take the necessary protective action to improve the system stability and reliability [2].

Many techniques are proposed based on Fourier transform (FT), discrete Fourier transform (DFT), short-time Fourier transform (STFT) [3,4]. The first two provide only frequency information whereas the third one provides both time as well as frequency information. But, selection of fixed window in STFT may not be sometimes effective to detect critical non-stationary disturbances like three phase faults and short-circuits which are associated with transients. In recent years, WT [5–8] gained popularity because of its multi-resolution time-frequency analysis with adaptive window selection. This, of course provides better identification characteristics suitable for detections of all types of faults. But, the detection performance is suggested to be degraded under the presence of noise in test signal.

* Corresponding author.
E-mail address: prakash@iiit-bh.ac.in (P.K. Ray).

https://doi.org/10.1016/j.ijleo.2018.03.131
0030-4026/

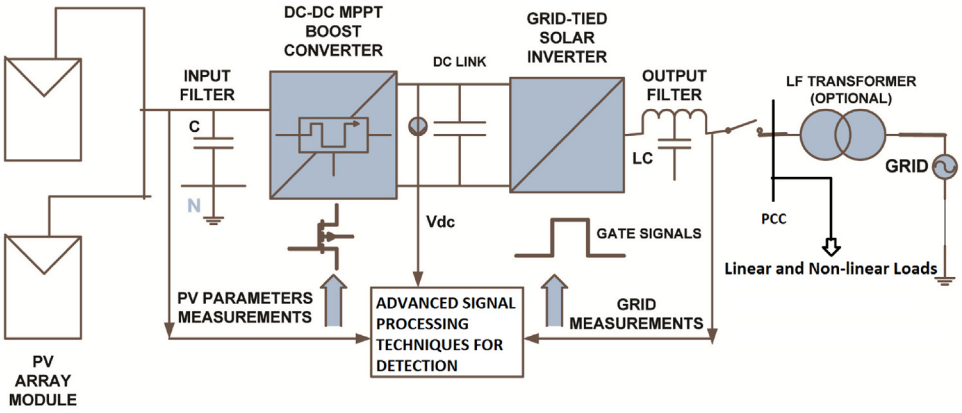

Fig. 1. Block-diagram of the grid-connected solar PV system.

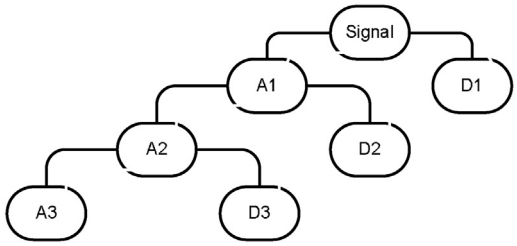

Fig. 2. Decomposition tree of wavelet transform.

Therefore in this paper, wavelet packet transform (WPT) [9–12] is proposed for fault detection. The performance of WPT is compared with that of WT under different operating scenarios. The better performance of WPT is analysed in all operating conditions because of the detailed filtering in WPT to find out all ranges of frequency contents in the signal. The degrading performance of WT is observed because of its inability to filter out the high frequency components only. The simulation study carried out in MATLAB is supported with determination of performance indices such as SD and energy in order to differentiate the normal operating cases from the fault operating conditions.

The paper is organised as follows; the configuration of grid-connected PV system is presented in Section 2, mathematical modelling of the detection and classification techniques is described in Section 3 followed by the descriptions of results in Section 4. Then, the conclusions derived from the detection and classification study is given in Section 5.

2. Configuration of grid-connected solar PV system

A solar PV system connected to grid is considered in the study whose configuration is shown in Fig. 1. The SPV system is integrated with the conventional grid through DC/DC and DC/AC interfacing converters.

The SPV system is connected to the utility grid through static transfer switch (STS) and the loads with linear and non-linear characteristics are connected at the point of common coupling (PCC) as shown in Fig. 1. The grid-connected SPV system is simulated in MATLAB/SIMULINK environment and the parameters of the models are presented in the Table A1 of Appendix A section [1,6].

3. Advanced signal processing and pattern recognition techniques

This section presents the mathematical modelling and descriptions of wavelet transform (WT) and wavelet packet transform (WPT) as detection techniques in the following sub-sections.

3.1. Discrete wavelet transforms (DWT)

The DWT is a advanced signal processing technique which decomposes the extracted signal at PCC into a range of varying frequencies and mother wavelets that helps in defining the time-frequency multi-resolution analysis (MRA). The voltage signal measured at PCC is decomposed into approximate (A) and detailed (D) coefficients representing the high scale, low-frequency and low-scale, high-frequency components respectively as shown in Fig. 2. Daubechies4 (db4) mother wavelet,