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Review

A comprehensive study on different types of faults and detection techniques for solar photovoltaic system

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ABSTRACT

Monitoring systems are essential to maintain optimal performance of photovoltaic (PV) systems. A critical aspect in such monitoring systems is the fault diagnosis technique being used. The role of a fault detection and diagnosis technique is to identify the causes affecting the real-time energy production and/or smooth functioning of PV systems. Over the past decade, various fault detection methods were reported in literature. Among all the fault detection techniques reported, some paid significant attention only on faults that occur in the PV system, some on faults on DC side of the PV system while the rest focused on AC side faults. For the first time, this paper provides a comprehensive review of popular fault detection techniques, addressing all major types of faults in PV systems. Detailed insights of PV fault detection techniques along with their relative performances are covered. A new fault detection technique is also proposed to identify the type and location (module level) of a fault. This review enables the reader to get acquaintance with major aspects/considerations in developing/choosing an effective yet viable fault detection technique for small and medium scale PV systems.

1. Introduction

Owing to the increase in industrial expansion and continuous growth in energy consumption, global energy demand per capita is on rise. This paved the way for intensive research of new, safe and sustainable green power technologies such as, solar, wind, hydro, tidal, biomass, and geothermal. The primary focus of renewable energy technologies research is to convert renewable resources into electrical energy in order to feed the utility grid or consumer loads. Among all the renewable energy sources (RES), solar energy generation is recognized as the best way to extract energy from the environment (Madeti and Singh, 2017a,b). Global installed PV capacity at the end of 2016 was reported as 310 GWp (Moreno-Garcia et al., 2016). However, as they are installed in outdoor environment, continuous exposure to harsh environmental conditions (sun beam, rainfall, etc.) may reduce the optimal performance of system. A monitoring study was conducted on a test PV system in Firth et al. (2010) and it was reported that the annual power loss due to various faults is about 18.9%. In addition to this, there will be a production loss associated with the occurrence of each of grid fault. All such issues pertaining to different domains have to be addressed by a single solution. Such an endeavor requires the complete knowledge of meteorological data (climatic conditions, which affects energy production) of the area where the system will be installed. Consequently, it is necessary to develop techniques, which help in estimating the true potential (power) of RES and for fault identification in the installed area in real-time. Moreover, continuous monitoring of PV system(s) health are very crucial to detect the causes, which hamper the desired performance. A comprehensive solution for all these problems is being termed as monitoring system along with fault diagnosis techniques, whose job is to maximize the operational reliability of PV system with minimum system costs and to detect the causes affecting the performance of the PV system.

A fault detection algorithm for PV system can provide an accurate estimation of electricity generation under normal operating condition and detection of faults present in the PV system. This would enable operator to take corrective actions, in order to prevent the PV system to under-perform for prolonged periods of time, which improve the performance of PV system by minimizing the power losses caused by the faults. Over the past decade, different aspects of fault detection techniques for PV system were reported. This paper presents an overall review of existing fault detection techniques in both DC and AC side of PV systems and also proposes a low-cost multisensor smart monitoring system (SMS) along with a fault detection procedure that is intended to detect various faults in PV system (modular level). A comparison of the present study with the other significant studies as suggested is also provided in Table 1.

This paper is organized as follows: Section 2 provides an overview of PV monitoring system with fault detection and diagnosis structure.

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Table 1
Highlights of some of relevant articles.

S. no.	Characteristics of previous monitoring system	Fault classification		Fault detection techniques		Cost analysis	Comments	Ref
		DC side	AC side	DC side	AC side			
1	–	✓	–	–	–	–	• Based on location and structure faults in DC side of PV system is classified • No algorithm provided for fault detection	Sabbaghpur Arani and Hejazi (2016)
2	✓	–	–	–	–	–	• Overview on pv monitoring system is provided • No faults classification and algorithm provided for fault detection	Madeti and Singh (2017a)
3	–	–	–	✓	–	–	• Proposed algorithm can only give the possible fault location and cannot identify the possible fault types	Chine et al. (2014)
4	–	✓	–	✓	–	–	• No faults classification on AC side and algorithm provided for fault detection	Sharma and Chandel (2013)
5	–	–	–	–	✓	–	• No algorithm provided for fault detection	Li et al. (2014)
6	✓	✓	✓	✓	✓	✓	• Overview on PV monitoring system, classification of possible faults in DC and AC side of PV systems and various fault detection techniques used are provided • Proposed algorithm can give the possible fault location and identify the possible fault types	Present study

Classification of faults in DC and AC side of PV system is given in Section 3. Sections 4, the different types of fault detection techniques are discussed. Section 5 and 6 addresses the fault detection techniques in DC and AC side of the PV systems. Proposed fault detection technique has been described in section 7. The results of different fault detection techniques are discussed in Section 8. Section 9 summarizes the conclusion of this work.

2. Overview of PV monitoring system with fault detection and diagnosis structure

The general block diagram of PV monitoring system with fault detection and diagnosis blocks is shown Fig. 1. It consists of PV array, DC/DC converter with maximum power point tracking (MPPT), grid connected inverter. There are two categories of PV monitoring systems, namely ground based and space based systems. The advantage of former approach is that it can respond very quickly and accurately monitor the health of PV system. Thus, it provides a chance to enhance the performance of PV system by detecting possible energy losses from changes in operating conditions and/or faults, before they have a considerable effect on energy production and/or system health. Sensors are used as major components in ground based system, which can measure the parameters in real-time. Though the space based systems are more economical due to absence of sensors. However, there accuracy is poor and they also get easily affected by the climatic conditions. Since, these problems are undesirable; therefore, a ground based PV monitoring system has been reported in this work.

Another important block is the fault detection and diagnosis block.

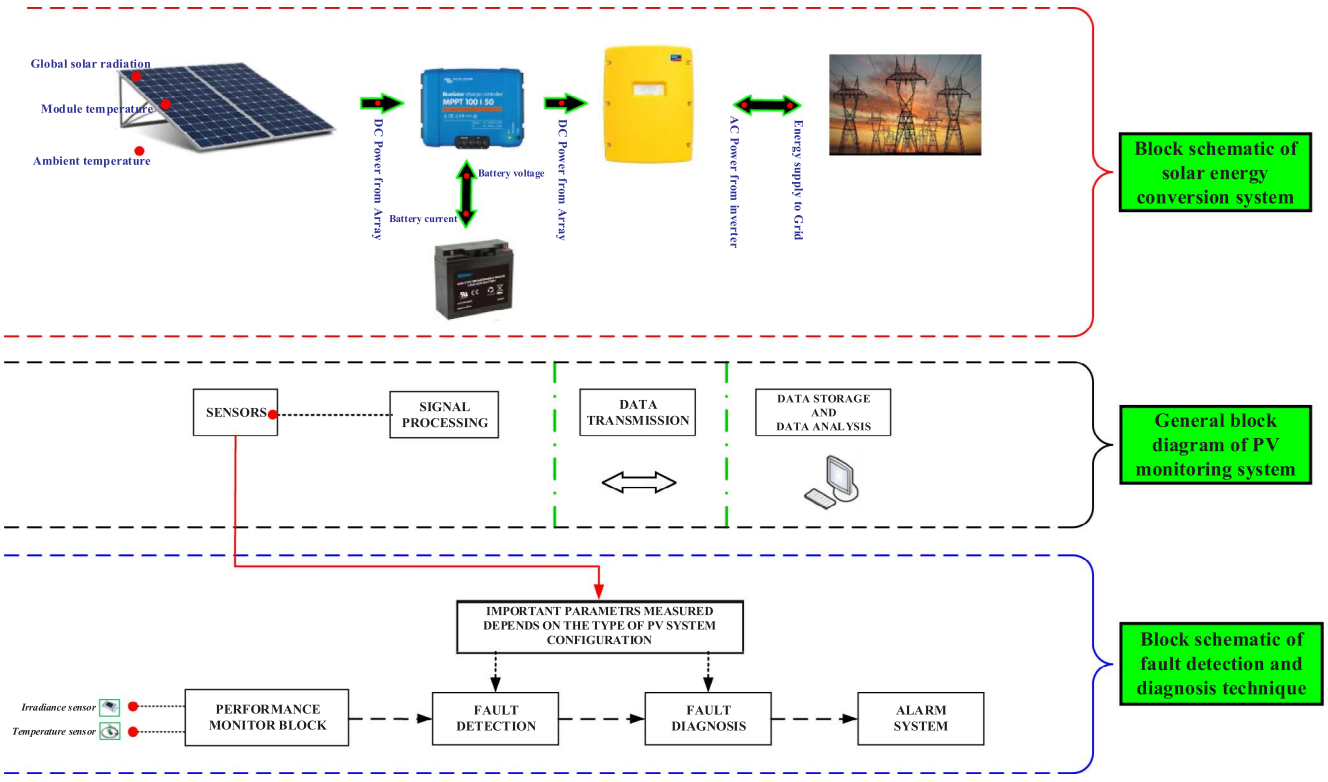

Fig. 1. General block diagram of PV monitoring system with fault detection and diagnosis blocks.