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Monitoring system for photovoltaic plants: A review

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ABSTRACT

The Photovoltaic (PV) monitoring system collects and analyzes number of parameters being measured in a PV plant to monitor and/or evaluate its performance. In order to ensure the reliable and stable operation of any PV system, an effective monitoring system is essential. Moreover, the monitoring system keeps track on various electricity generation indices and fault occurrences. The cost and complexity of existing PV monitoring systems restricts their use to large scale PV plants. Over the past decade, different aspects of PV monitoring systems were reported in wide range of literature. In this paper, a comprehensive review of various PV monitoring systems is presented for the first time. This includes the detailed overview of all the major PV monitoring evaluation techniques in terms of their relative performances. Major aspects of PV monitoring systems which examines in this paper are: sensors and their working principles, controller used in data acquisition systems, data transmission methods, and data storage and analysis. The acquaintance of all these aspects are crucial for the development of effective, low cost, and viable PV monitoring systems for small and medium scale PV plants without compromising on the desired performance.

Contents

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1. Introduction

The energy demands of almost all the countries around the globe are on rise due to its large scale industrial expansions, increasing population, and continuous growth in energy consumption per capita. It should be noted that major portion of energy requirement is in form of electricity. On the other hand, use of fossil fuel based electricity generation came to saturation levels due to increased environmental concerns and limited resources. Thus, the gaps between the demand and generation in future are to be met by renewable energy sources (RES). In line with this objective, RES such as solar, wind, biomass, micro-hydro, and geothermal are being converted into electrical energy and delivered either to demand centers or utility grids [1–4]. The other motive behind promoting the dependency on renewable is to provide safe, clean and sustainable energy. In tropical countries, solar energy is deemed as the most reliable and viable options among all RES [5]. Owing to the developments in photovoltaic (PV) technologies and various financial subsidies being provided by the government bodies to electrical energy generation sector using PV technology has seen a rapid evolution during the past few decade. This is evident from the increase in cumulative installed PV capacity (MW) of countries participating in International Energy Agency- Photovoltaic Power Systems Programme (IEA-PVPS), from 103 MW in 1992–139795.2 MW in 2014 [6].

More recently, urban population and industrialists have shown their interests in PV energy generation in view of sustainable development. This will ultimately make the PV technology overcome their set back of lower power density by expanding its foot print to urban/populated areas. Therefore, a steep rises in PV systems/plants are expected in the years to come. At this verge, it is very much essential to develop the technologies, which keep track on PV energy production from a given PV plant and keep up its production in every possible dimension. The objective of such PV monitoring technologies is to predict/sense different undesirable situations, which may plunge the energy production levels from available solar irradiation [7]. The issues that are to be tackled to achieve the desired objective could be optimal control/design, climatic conditions, surrounding objects, and geographical locations etc. It was reported that the annual energy loss due to partial shading is about 10–20% [8]. 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 [9]. Consequently, it is necessary to develop techniques, which help in estimating the true potential (power) of RES 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 [10]. A comprehensive solution for all these problems is being termed as PV monitoring system, whose job is to maximize the operational reliability of PV system with minimum system costs.

The PV monitoring systems are aimed to provide/report information about the energy potential, energy extracted, operating temperature analysis of different of faults that might occur, and energy loss associated with them. The data being monitored can also be used for early detection/warning, evaluating the climatic changes etc. There has been a growing interest and importance in these issues. Due to which, significant expertise has been devoted in developing the effective, low cost, and viable PV monitoring systems for small and medium scale PV plants without compromising on the desired performance. Each monitoring system would comprise of several commercial products integrated within it. With the rapid increase in different commercial products based on various principles/concepts, it's very important to examine the operation and characteristics of each of them. The selection of appropriate product for a particular climatic condition is vital for an effective PV monitoring system. Over the past decade, different aspects of PV monitoring systems were reported. This paper presents an overall review on PV monitoring systems covering all the important factors and components associated with it.

This paper is organized as follows: Section 2 provides an overview of PV monitoring system. Classification of PV based systems is given in Section 3. In Section 4, the different characteristics of monitoring system are discussed. While major instruments used in PV monitoring system has been reviewed in Section 5. In Section 6, various data acquisition systems used to handle the output data of sensors are presented. Section 7 different methods used for data transmission, storage and analysis have been reviewed and summarized, and Sections 8 and 9 addresses the major challenges and opportunities in PV monitoring systems. The results of analysis are discussed in Section 10. Major recommendations and suggestions have been presented in Section 11. Section 12 summarizes the conclusion of this work.

2. Overview of PV monitoring system

The general block diagram of PV monitoring system is shown Fig. 1. The PV monitoring systems can be broadly classified as ground based or space based monitoring systems. The former approach is more prevalent due to its quick response and accuracy in monitoring the PV system health. Thus, it provides a chance to enhance PV system performance by detecting the possible energy losses from changes in operating condition and/or faults, before they have a considerable effect on energy production and/or system health. Major components used in the ground based systems are sensors, which measure the variable in real-time in the monitoring system. In this aspect, space based systems could be economical due to the absence of sensors. The bottleneck for space based systems is their low accuracy in estimation and is greatly affected by the climatic conditions, which is clearly undesirable. Therefore, the scope of this PV monitoring systems review is confined to ground based systems.

Another important unit in a PV monitoring system is the signal conditioning unit. This unit performs signal amplification and