A monitoring based Photovoltaic installation fault detection system for power loss optimization

Kalyan Srinivas A, Usharani Rout, Siv K Mishra

Abstract— with the global population swelling and industrialization on the rise in developing nations, humanity's hunger for energy has reached unprecedented levels. Every day, our species chews its way through more than a million terajoules of energy. That's roughly equivalent to what we would use if all 7.5 billion of us boiled 70 kettles of water an hour around the clock (according to BBC).

A PV system or solar power system is a power system designed to supply usable solar power by means of photovoltaics. Photovoltaic Systems are becoming increasingly popular, roof-top installations have never been as affordable and PV parks are also blooming. Unfortunately, as with all systems, problems can occur. These range from faulty cabling to Vandalism, but also more subtle issues such as breakdown of a single cell and ageing of the installation. The objective of this paper is to present a simple system that can be used to monitor and detect such issues and can optimize the losses. The proposed method requires electric power sensors to be added to an existing PV installation and temporary Mismatch fault clearing arrangements. The algorithm relies on a self-adaptive PV model that does not need the user to provide any input regarding model parameters. The PV model is continuously trained so as to reflect the installation status. A continuous monitoring of the produced PV power is performed and a comparison with the expected (i.e. modeled power) is carried out in order to detect discrepancies. In this work, the complete algorithm for fault detection is presented and validated on real data.

Index Terms— Cell Parameters, Internet of Things, Mismatch Faults, Monitoring System, Optimization, Photo Voltaic cell, Solar energy.

1 INTRODUCTION

The energy generation from sun helps to fulfill the energy requirement of the nation. The usual fuels like coal, wood wood etc have a limited reserve and they pollute the environment, resulting in global warming and green house gas effect. On the other hand, the renewable sources are non-polluting and available in abundance. The renewable sources consist of solar, wind, geothermal, biomass, hydro energy, tidal energy, wave etc. Therefore, energy from sun may be a good alternative for the future energy requirement, because the availability of sun in India is almost whole year except rainy season [1]. Sun has unlimited energy, its radiations produce solar energy through solar generation system. There are lot of research is going on in the area of solar generation to increase its efficiency, reliability, storage etc. Also lots of technologies changes taking place for better productions and planning of solar energy [2]. Hence, the developing country like India, solar energy generation is one of the best options to meet with the present demand of electricity. When solar power generation using PV panels increases, it is necessary to continuously monitor the health of solar distributed power generation system [3].

2 Fault Detection Systems

Fault detection, isolation, and recovery (FDIR) [4] is a subfield of control engineering which concerns itself with monitoring a system, identifying when a fault has occurred, and pinpointing the type of fault and its location.

2.1 Node MCU

NodeMCU is an open source IoT platform with Arduino core. It includes firmware which runs on the ESP8266 Wi-Fi SoC from Espressif Systems, and hardware which is based on the ESP-12 module. The term "NodeMCU" by default refers to the firmware rather than the dev kits. The firmware uses the Lua scripting language [5]. It is based on the eLua project, and built on the Espressif Non-OS SDK for ESP8266.

2.2 Photo Voltaic Cells

Photovoltaic solar panels absorb sunlight as a source of energy to generate electricity. A photovoltaic (PV) module is a packaged and connects assembly of typically 6x10 photovoltaic solar cells. Photovoltaic modules constitute the photovoltaic array of a photovoltaic system that generates and supplies solar electricity in commercial and residential applications [6].

2.3 Mismatch Faults

In general, there are three levels of faults developed in the PV systems: cell-, module- and string-levels [7]. The cell faults include mechanical cracks, corrosion by water permeation, and material degradation by ultraviolet or thermal stress. The module faults are related to open-circuits or short-circuit re-

sulting from the degeneration of the cells, cover or sealant materials. The PV string faults consist of open-circuits, short-circuits, mismatch between PV modules, and partial shading. Mismatch faults are generally caused by encapsulant degradation, anti-reflection coating deterioration, manufacturing defects and partial shading [8].

In a PV system, PV cells are connected in series to form a PV module, as shown in Fig. 1. A number of PV modules are then connected in series to form a PV string. Strings are further connected in parallel to form a PV array. This arrangement enables low DC voltage and current to be added up to a high output. For any solar power plants, the PV panels need to take up a large space, which is likely to cause some non-uniform illumination when shadows or leaves cover part of the PV modules. This effect is termed partial shading.

Providing a remedial MPPT technique to suppress the Mismatch, based on a temperature distribution analysis using a thermal camera. Currently, thermal cameras are a useful tool for PV array fault diagnosis [9].

3 PROPOSED SYSTEM FEATURE

In the proposed system, we used an embedded system gateway for interfacing solar PV PCU with host network. With the help of embedded system gateways, the data from the solar PV PCU will be transmitted to a remote server via the internet and hosted in a web page. In webpage with the help of server side scripting we hosted the data in cloud database and Analyze the data of solar PV PCU to determine whether the photovoltaic system in the remote location is working properly. The webpage will show the instant status of the PCU and stores all the parameters of the solar PV PCU in data logger. With the help of data logger monthly report of the solar PV PCU is generated and that can be analyzed by an authorized person from anywhere at any time [10].

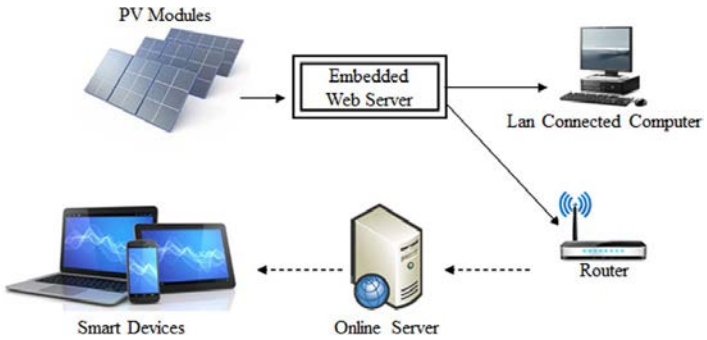

Fig.1 Block Diagram of Proposed Functionality

3.1 SYSTEM DESIGN AND IMPLEMENTATION

The Proposed system mainly consists of two blocks embedded system gateway and host network. In proposed system, Host network and embedded system gateway forms a core of IoT system. In host network we used a GPRS modem to connect Solar PV PCU to the Internet. In embedded system gateway we used Arduino UNO R3 Microcontroller module which is used to interconnect the solar PV PCU to the GPRS modem. Initially the Embedded system gateway initiates the connection of GPRS modem. When the connection is established embedded system gateway will start receiving the parameters from solar PV PCU using serial communication UART port. The data from the solar PV PCU is collected in the embedded system gateway and Transferred to GPRS modem using serial UART port. The GPRS modem will host the received data in authorized IP address of website via internet. The solar PV PCU data are sent to the web server and stored in the cloud. The data can be analyzed anywhere any time. The authorized person can monitor all the parameters through the internet via web-server.

3.2 SOFTWARE DESIGN

On the web page we used HTML (Hyper Text Mark-up Language) for front end design.HTML is a format that says a computer how to display a web page. The documents themselves are plain text files with special "tags" or codes that a web browser uses to interpret and display information on your computer. It is a text file containing small markup tags. The markup tags tell the Web browser how to display the page. An HTML file must have an htm or html file extension. Then we used CSS for defining the font family, font boldness, font size and the style of the text on the webpage. We implemented a bootstrap responsive design for changing the layout, size and pixels of the webpage according to the user end device like mobile, tablet and laptop.

We utilized jQuery for a plugin like meter and date picker in webpage. In webpage, we used Ajax for updating a webpage without reloading the page. The webpage is designed as dynamic and interactive webpage with the help of PHP (Hypertext preprocessing) server side scripting language. Cloud computing is the practice of using remote servers on the internet to manage, store and process data instead of using a personal computer. Cloud computing is the core of Internet of thing. In proposed design we implemented the cloud computing concept by using PHP, MySQL and JavaScript for getting data, storing in data base and manipulating stored data. Here we are storing the data in a MySQL database which runs under Apache server. The data stored in database can be manipulated using JavaScript.

3.3 IMPLEMENTATION SETUP

When the data received from solar PV PCU the connection between GPRS and Embedded system gate way are initialized. After initializing GPRS now the embedded system gateway collects the data from Solar PV PCU and stored in temporary buffers. In embedded system gateway we used Arduino UNO R3 software is written using the Arduino IDE using C++.

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When all the parameter received from the Solar PV System, then embedded system gateway starts to transmit the data to a GPRS module serially. Now the GPRS Module will host the data in remote server in specified time interval. Thus the GPRS modem has hosted all the parameter in the webpage via internet. In webpage received data are stores in a MySQL database which runs the apache server with the help of server side scripting language. Then the stored data in the database are processed and manipulated with help of Java scripting. Finally the parameters are displayed in a user end webpage. The following figure illustrates the operation of the IOT system for monitoring the solar PV PCU.

4 Observation

The thermal Image and the obtained parameters of the panel are mentioned below.

4.1 Electric Parameters of the PV Panel

Characteristics	Specification
Maximum power	26.70 W
Short circuit current	1.81 A
Open circuit voltage	20.78 V
Current at MPP	1.59 A
Voltage at MPP	16.79 V
Efficiency (cell)	12.61%
Efficiency (module)	10.68%

Table I. Parameters of the Panel on monitoring

4.2 Electric Parameters of the PV Panel

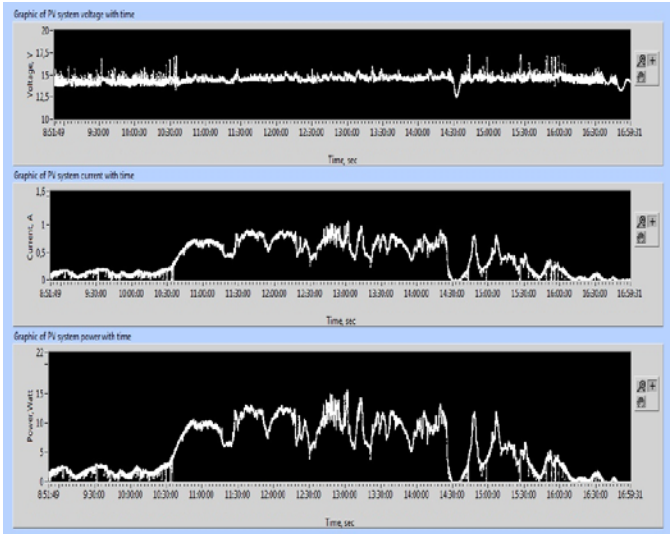

Fig. 2 Monitoring the current, voltage and power of PV system

4.2 Thermographic Image

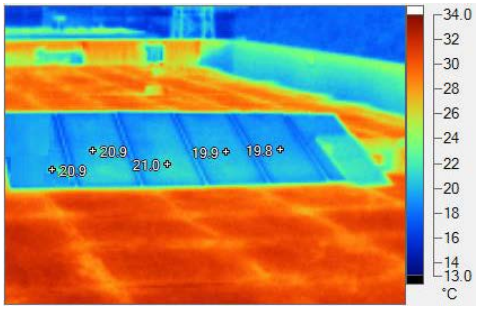

Fig 3.Thermographic Image

Various temperature spots can be observed from the Fig 3. Where, an obstacle is placed on the panel, knowingly to create the fault for educational purpose.

5 Estimation of Fault

The fault can be estimated by comparing the standard Table I, with the obtained table.

Characteristics	Standard	Monitored(Faulty)
Open circuit voltage	20.78 V	17.23 V
Short circuit Current	1.81 A	1.57 A
Voltage at MPP	14.32 V	12.43 V

Thus, on analysis of the parameters, it can be predicted that there occurred certain Mismatch Fault.

4.3 Assistance with MPPT Control

From the above analysis and experimental tests, the terminal Characteristics and operating conditions of the PV module are known. The temperature distribution can then be input to the MPPT algorithm under mismatch fault conditions. The maximum healthy section can be separated from fault PV arrays. The whole PV array can be first divided into two sections: healthy and unhealthy. In the healthy section, all the modules in all strings are deemed to be fault-free. That is, there is only a maximum power point in the section (local MPP). The global MPPT [11] is effective to locate the first local MPP, significantly reducing the search range. In the unhealthy section where one or more modules are subject to shading, the temperature distribution of the faulty PV modules is then analyzed by thermography. As a result, the global MPP operating range can be located directly without much searching effort.

5 Conclusion

Solar power is a cost-sensitive market. This work promotes its market acceptance by reducing the maintenance cost and improving the conversion efficiency of PV systems. The paper has presented a thermography-based temperature distribution analysis to analyze three different fault categories and the proposed methodology is validated by both simulation and experimental test results. The proposed technology will lower the capital and operational costs of PV plants as well as increase their energy efficiency.

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