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Automatic Fault Monitoring and Maintenance of PV System

S.Kanthalakshmi, M.P.Anbarasi, S.Navaneethan

PSG College of Technology Coimbatore

E-mail: skl.eee@psgtech.ac.in

Abstract

An array of PV panels connected in series or parallel typically makes up a solar PV system. When a single photovoltaic panel fails, the electrical network breaks, lowering the net power production concurrently. As of now, no significant, cost effective approach is suggested for identification and isolation of faulty panel.This works aims to experimentally verify automatic identification of break/fault in an electrical network of solar PV system by means of the Internet of Things (IoT). Furthermore, preventive maintenance attribute based on dust level over the exposed area of PV panel is suggested as a means to ensure reliable functioning of the solar PV system.

Keywords: evergreen; *Solar PV System, Fault identification, preventive maintenance, reliable output*

1. INTRODUCTION

Solar energy has been identified as a potential solution to the present day energy issue due to its copious, renewable, and non-polluting nature. It is estimated that the electricity generated from the PV plants can contribute to 7% of world's electricity need by the year 2030, and this would increase to 25% by the year 2050. Photovoltaic (PV) technology has grown significantly in recent years owing to technological advances, material cost reductions, and government support for renewable energy generation. Annual installation of PV panels has increased as much as 78% in the recent years. Though the photovoltaic panels serve as good source of electricity, the major disadvantage associated with PV systems is that, they exhibit low efficiencies when compared to their cost. The conversion efficiency typically ranges from 12% to 20% and is further hampered by environmental factors such as contamination of the module, dimming of the module etc. Design of controller to extract maximum power becomes very significant for effective operation of solar plant.

Large-scale solar power plants have numerous solar panels in remote and open areas. With work on that scale, there is a great challenge of maintaining performance and reliability. Solar battery malfunctions manifest as non-linear current-voltage characteristics that affect output power. An online "high granularity" technique based on sensors installed on individual PV panels can yield better fault identification results. The intention of this proposed work is to design effective sensing circuitry that would measure the panel performance and perform isolation of panels in the event of fault occurrence. Ali Al-Dahoud et. al proposed solution for monitoring and troubleshooting Wireless Sensor Network (WSN) assisted solar panels based on node installation with appropriate sensors for the most common faults in 45 rooftop solar panels [1]. A study was conducted to design nodes with appropriate sensors, taking into account the node distribution simulation and prioritization of processing errors. Finally, WSN has been used in the design and adaptation of the graphical user interface for remote monitoring panels. To carry out the monitoring procedure and store the results as an Excel file, a user-friendly graphical user interface was created using the high-level Visual Basic language. Pierluigi Guerriero et. al. designed a novel sensor which measures the, quiescent voltage and short-circuit current and also the operating voltage and current of PV panels connected to a string in real time [2]. An efficient cutoff system prevents the sensor from disrupting with the string's activity during the measurement process and provides numerous benefits, including automatic

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identification of bypass events. Highlighting the possibility to detect faults in the solar module chain and pinpoint faulty panels is done.

Chao-Lin Kuo et. al. suggested the use of fractional order color ratio classifiers in microdistribution systems for a defect detection technique in photovoltaic (PV) energy conversion systems (PVECS) [3]. The output power reduction is used, in accordance with the electrical survey method, to monitor physical conditions resulting from modifications in the PV array circuit, such as open circuit faults, mismatch faults, bridging faults between two PV panels, and ground faults. A comparison is done between the measured power and also the estimated maximum power using the MPPT algorithm. To measure the output power drop between the measured power and the desired maximum power, the fractional dynamic error is calculated. After that, distinguish between the error event and the steady state using color ratio analysis. The use of a new, affordable IoT-based approach for remotely monitoring solar PV installations and assessing their performance was covered by Soham Adhya et al. [4]. Along with real-time monitoring, this can facilitate predictive maintenance, troubleshooting, and plant historical analysis. Akash Singh Chaudhary used a sensor and a thermal imaging camera to detect hot spots, solar panels' deposition and thermal degradation effects. [5]. Health monitoring system using soft computing techniques is developed and validated. Mayuri Ejgar et al. presented a system involved in real monitoring to identify different malfunctions and potential failures of these devices, as well as a number of techniques to identify anomalies in real-time. [6]. An anomaly is reported right away to the relevant service engineer so that prompt action can be taken as soon as it is discovered. This enhances the functionality and effectiveness of solar power plants.

2. System Overview

2.1 Solar Cell

A current source that generates a current proportionate to solar radiation is thought to be the perfect solar cell. Because of optical and electrical losses, the cell's actual behavior deviates from ideal, so its component needs an ideal current source (Villalva et al. 2009). A current source that generates current proportionate to incoming light can be used to represent light loss. Since the recombination current flows in the opposite direction from the current produced by the light, recombination is represented by a diode connected in parallel with a current source. Recombination in the space charge domain is typically ignored in the simple diode model, and the equivalent circuit of the solar cell is supplemented with just one diode. Figure 1 shows the solar cell equivalents represented by a series resistor, a shunt resistor, a diode, and a current source. Considering the cell's Ohmic losses, the shunt and series resistors are represented by Rs and Rsh, respectively. The shunt resistance is typically high in real-world scenarios and is easily ignored when doing analysis.

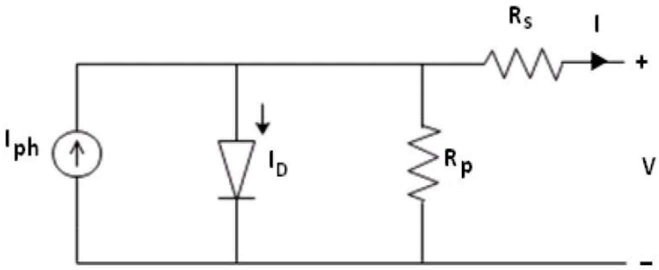

Fig. 1 Solar cell equivalent circuit

2.2 PV Panel

The panel output current represented by I_{pv} is given by

$$I_{pv} = N_p * I_{ph} - N_p * I_0 \left[\exp\{(q * (V_{pv} + I_{pv} R_s))/(N_s knT_a)\} - 1\right]$$

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where Vpv is the panel output voltage, Io is the saturation current, n is the diode, and Np and Ns are the numbers of parallel and series cells, respectively. Rs and Rsh are the shunt and series resistances, respectively, accounting for the ohmic losses of the cells. k- Boltzmann constant ($1.38 \times 10^{-3} JK^{-1}$) and T_a is actual temperature in Kelvin.

Fig. 2 displays the electrical properties of the 37W panel, specifically the Current Voltage (IV) and Power Voltage (PV) characteristics operating under Standard Test Conditions under uniform conditions.

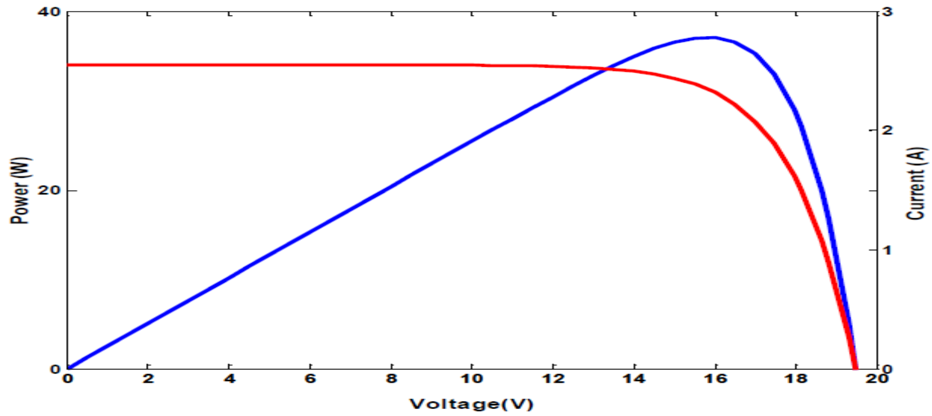

Fig. 2 Electrical Characteristic of solar panel

Similar to a solar cell, the output power from a solar panel reaches the maximum at a particular voltage and current. The maximum power point is located close to the knee of the IV curve. From the graphs, it is concluded that PV panels are nonlinear systems that change over time, and that MPPs change with changes in atmospheric conditions.

2.3 PV System

To achieve a desired current and voltage level, a solar power system comprises of multiple solar panels connected in series and parallel. It gets increasingly harder to keep an eye on the entire system for effective maintenance as the number of panels rises. Better results in terms of fault localization and yield reduction estimation can be obtained by using an approach based on measurements of individual solar panels: operating voltage and current, open circuit voltage (primarily temperature dependent), and short circuit current (proportional to luminance).

3. Proposed System

3.1 Monitoring mechanism

The proposed control method, which includes an isolation system, a power supply with a charging circuit, an energy storage device (ESD) and a DC/DC converter, a sensing circuit, and a communication module and microcontrollers block (MCU), is schematically diagrammed in Fig. 3. As seen in Fig. 3, switches and bypass elements (including panels and switches) are used to insulate a single PV panel when they are positioned parallel to the branch. In order to stop current from passing through the panel, a bypass diode acts as a substitute. To prevent evolution from being interrupted, provide the path to the current string. There are two components to the sensing circuit. The voltage measurement section, which is parallel to the panel and is implemented by a resistor divider, measures both the operating voltage and Voc of the panel (Vpanel). To measure the panel operating current and Isc, a current measurement section based on a shunt resistor can be connected in series or parallel with the panel.The communication module collects the information from the sensing circuit and passes on the information to microcontroller unit. The microcontroller unit processes the information and sends the data through IoT server.

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3.2 Automatic maintenance system: Fig. 4 illustrates the functional block diagram proposed for automatic maintenance system for PV panels. Solar panel is connected to LDR. The output of LDR varies with dust deposition over the panel. The LDR output is continuously compared with a threshold or reference voltage. When the output of LDR is less than the threshold voltage, wiper connected to the panel is activated through the motor drive. Ultrasonic sensors are used to detect the edges of the panel. Depending on the size of the panel, two thresholds, threshold 1 and threshold 2 are set. The output of ultrasonic sensor can be compared with these threshold values and motor actuation can be decided accordingly. The working of the automatic maintenance system is depicted in figure 5.

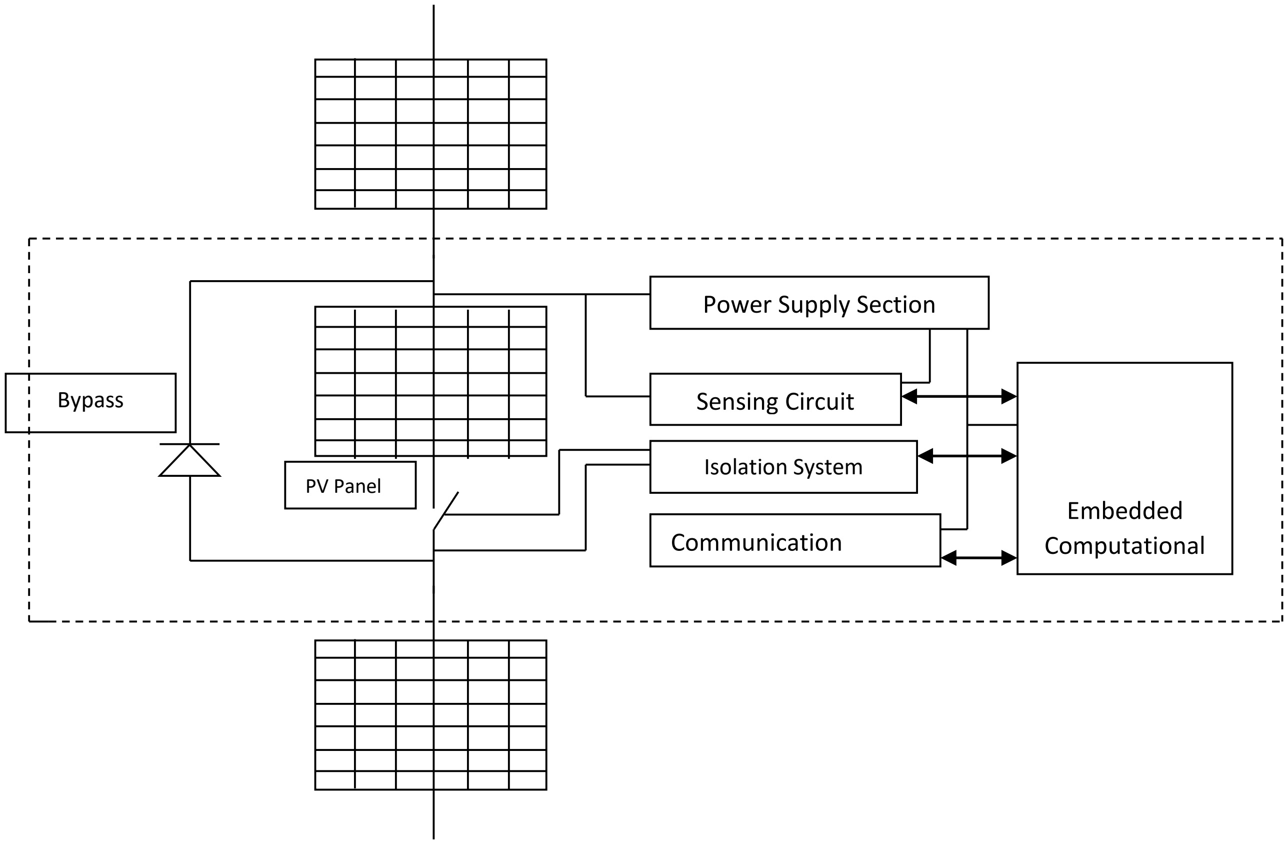

Fig. 3 Schematic Diagram of proposed monitoring system

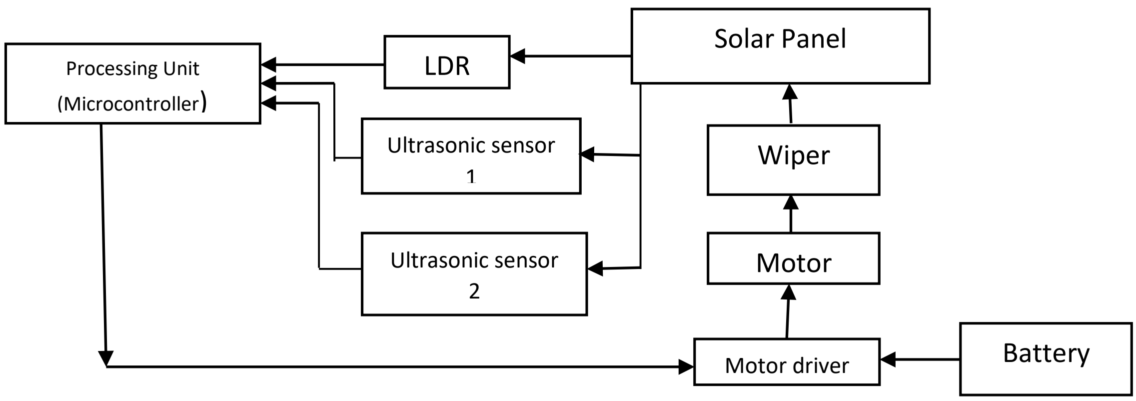

Fig 4 Functional Diagram of proposed automatic maintenance system.

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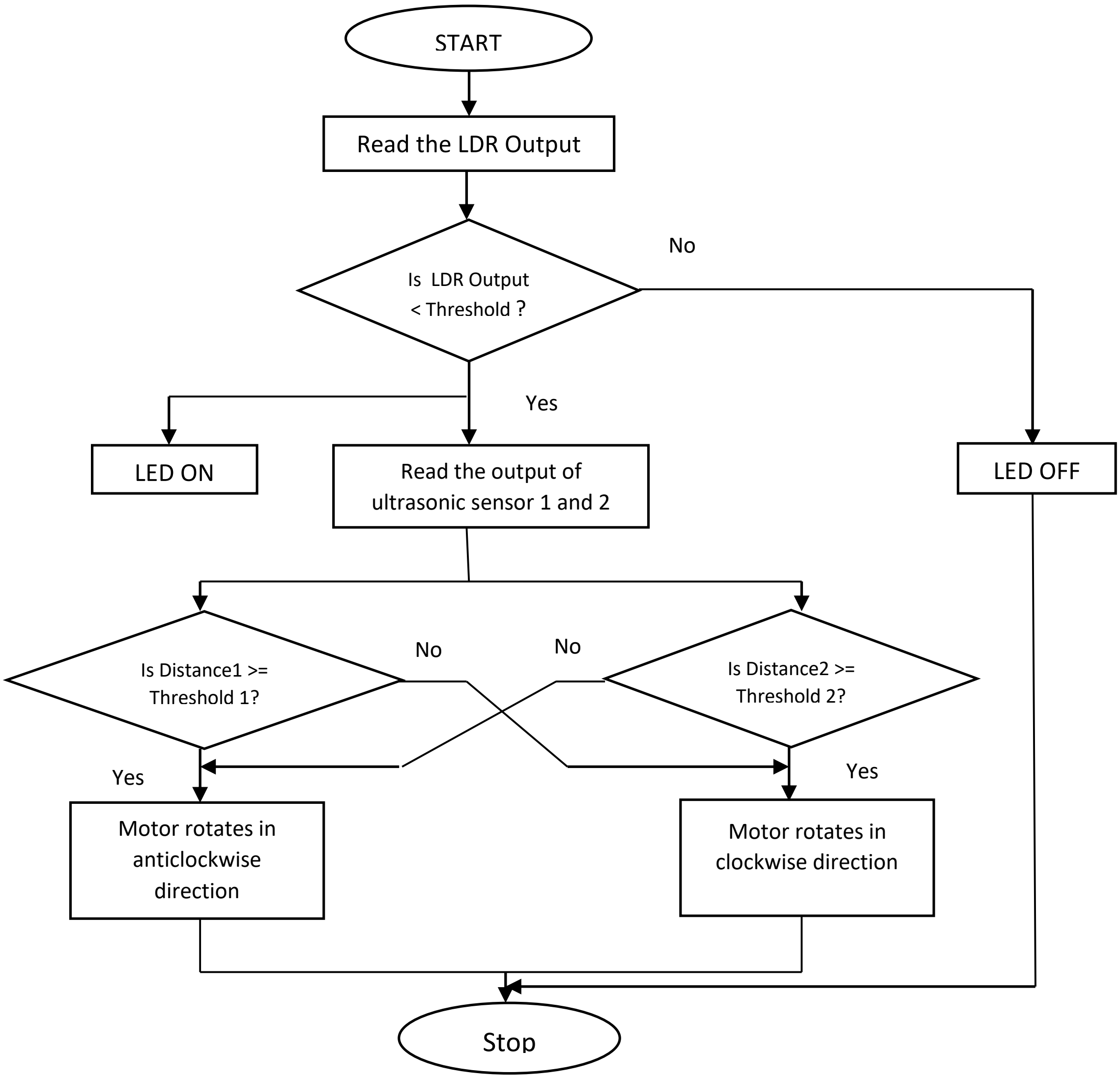
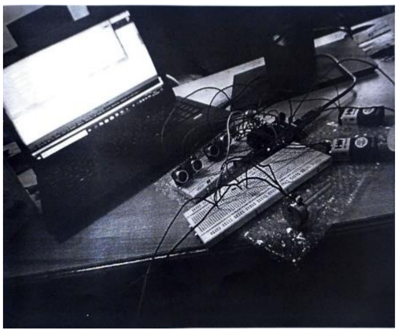


Fig. 5 Working of Automatic Maintenance System

4. Results and Discussion

Fig. 6 shows the proposed automatic fault monitoring system Here two ultrasonic sensors and a LDR are connected to the microcontroller. When the LDR output goes below the threshold value the LED glows. The same is depicted in fig. 7



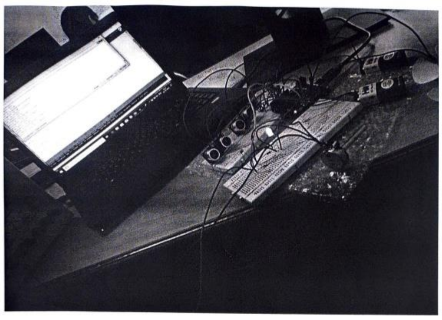


Fig. 6 Hardware setup of the proposed approach. Fig. 7 LED is ON when the LDR Output falls below the threshold

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Simultaneously as he LED glows, the ultrasonic sensor 1 and ultrasonic sensor 2 output values are read. Two threshold values (Threshold 1 and Threshold 2) are usually set which depends on the size of the installed solar panels. These threshold values are compared with the output of ultrasonic sensors 1 and 2 (distance 1 and distance 2) and depending on the condition satisfied the motor is made to rotate either in the clockwise or anticlockwise direction as shown in fig 8.

Fig 8. Motoi rotation as the threshold exceeds.

From the experimentation carried out it could be clearly demonstrated that the automatic maintenance of solar panel take place effectively.

5. Conclusion

Regular maintenance and equipment replacement are expensive. Modern maintenance practices have a major impact on productivity, leading to unplanned and often inefficient maintenance schedules. Downtime due to equipment failure also results in lost power generation and lost revenue. These challenges can be effectively addressed with IoT solutions that provide continuous remote monitoring and asset management. Tracking and analyzing sensor data helps to monitor the physical condition of plants and devices in real time. Predictive analytics proactively detect malfunctions, degradations and failures in devices such as PV modules.

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