Industrial Engineering Journal
ISSN: 0970-2555
Volume : 54, Issue 5, No.4, May : 2025

OPTIMIZATION OF SOLAR PLANT WITH DESIGN OF MPPT SOLAR CHARGE CONTROLLER & IOT ALERT

Mr. Bhagwan S. Bodke, Assistant Professor, Department of Electronics and Telecommunication Engineering, Matoshri College of Engineering and Research Centre.
Dr. Devidas D. Dighe, Professor, Department of Electronics and Telecommunication Engineering, Matoshri College of Engineering and Research Centre.
Dr. Ravindra G. Dabhade, Associate Professor, Department of Electronics and Telecommunication Engineering, Matoshri College of Engineering and Research Centre.
Ms. Komal M. Avhad, PG Student, Department of Electrical Engineering, Matoshri College of Engineering and Research Centre, Nashik, Maharashtra, India-422105.

ABSTRACT

In the era of renewable energy, solar power stands as a pivotal solution for sustainable electricity generation. However, maintaining optimal efficiency and reliability of solar panels remains a challenge due to environmental influences and lack of real-time oversight. This paper proposes the design and development of a Smart Solar Monitoring and Maintenance Prediction System utilizing IoT and sensor technologies to enhance solar panel performance integrated with MPPT solar charge controller.

The system is built around the Atmega328 microcontroller, integrated with a 10W solar panel, voltage and current sensors, a sunlight intensity sensor, a dust sensor, and a vibration sensor. Real-time data is transmitted via an ESP8266-01 Wi-Fi module to the ThingSpeak cloud platform for remote monitoring and analysis. The key thing is the real-time detection of efficiency losses by comparing measured power output (Voltage × Current) with expected values, allowing the system to flag issues like shading, dirt accumulation, or electrical faults.

The dust sensor predicts cleaning schedules by monitoring atmospheric dust levels, while the vibration sensor detects abnormal physical disturbances or structural instabilities—alerting for potential damage or theft. The sunlight sensor aids in forecasting daily energy output, enabling efficient energy planning. The system operates independently using solar energy, powered through a low-cost Maximum Power Point Tracking (MPPT) charge controller and a 12V lead-acid battery, ensuring 24x7 monitoring. Designed to minimize manual inspections and enhance response time, this intelligent solution is scalable for both individual and large-scale solar installations. It offers a cost-effective, energy-efficient approach to real-time performance tracking, predictive maintenance, and secured solar energy management.

Keywords: Solar Panel Monitoring, IoT-based System, Predictive Maintenance, ThingSpeak Cloud, MPPT Charge Controller, Renewable Energy, Real-time Data and Remote Monitoring.

I. Introduction

Solar energy has been recognized as the most promising source of renewable energy all over the world. Solar energy possesses the potential to replace highly carbon intensive technology [1],[2]. As per the recent IEA declaration renewable is not a niche fuel any more it has become a mainstream fuel. Solar and wind is surpassing the other renewable energy sources, to be the largest share in renewable market. Many factors are affecting the solar panel performance. Some factors are proportional positively on the obtained electrical power, while other factors are affecting negatively [1]-[5]. Light intensity level represents an important parameter with respect to the effectiveness of the solar panel, the collected solar energy which converted to the electrical power is proportional with the instantaneous level of light intensity [5]-[7]. Dust density level is the other parameter which represents an obstacle between light beams and the front surface of the solar panel. The dust's particles deposits on the panel which will reduce the amount of radiation falling on the PV cells from the sun light [6]. In other word, increasing panel temperature value is leading to reduce the delivered power from the panel. Ambient

Industrial Engineering Journal
ISSN: 0970-2555
Volume : 54, Issue 5, No.4, May : 2025
humidity also affects negatively the panel performance. Since solar energy generation system is high a cost investment, it must be run at full efficiency.
In this paper, an automation is performed with the help of sensors to make sure that solar farm run at full efficiency and detect situation in case of any maintenance. IoT technique is used to visualization and alert. An MPPT solar charge controller is also used to increase the efficiency along with IoT system.

II. Objectives
The objective of this paper is to design and implement a solar panel monitoring and predictive maintenance system using IoT-based automation and MPPT Solar Charge Controller.
Objectives:
- To measure and monitor voltage, current, and power generation of each solar panel.
- To detect low-efficiency panels and alert for immediate maintenance.
- To predict cleaning schedules based on dust sensor data.
- To measure sunlight availability and estimate daily energy generation.
- To detect vibrations or movement in the panel structure indicating theft or damage.
- To display and log all parameters and alerts on a web interface using ThingSpeak.
- To use MPPT charge controller to maximize the amount of power extracted from solar panels.

III. Proposed System:
Figure1 Shows block diagram of proposed system. In this system IoT based system is used to monitor physical parameters as shown where as MPPT charge controller is designed to increase the power generation efficiency.

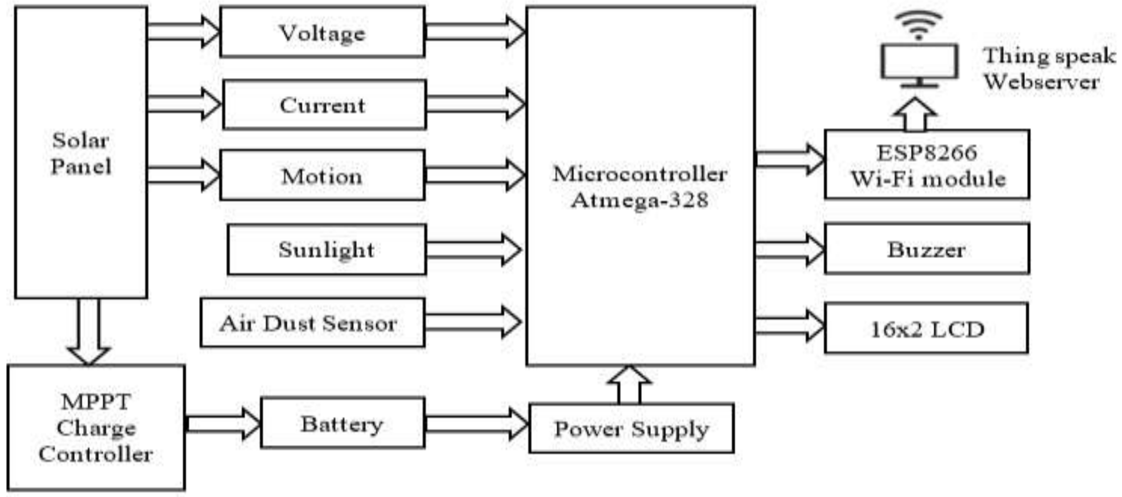

Figure 1 System Block Diagram

The working of the proposed system revolves around continuous data acquisition, intelligent analysis, and real-time communication through IoT. The system consists of both hardware and software components integrated to automate monitoring and alert mechanisms.

1.1 Power Monitoring:
The heart of the system is an Atmega328 microcontroller which collects data from various sensors. A voltage sensor and a current sensor are used to measure the output of the solar panel. The power generation is calculated by multiplying these two parameters ($P = V \times I$). This value is compared to a predefined ideal value based on panel specifications. If the real-time power output falls significantly below expected levels, the system flags the panel as underperforming, indicating a need for inspection or maintenance.

1.2 Dust and Sunlight Monitoring:

Industrial Engineering Journal
ISSN: 0970-2555
Volume : 54, Issue 5, No.4, May : 2025
A dust sensor measures particulate concentration in the air. Increased dust levels generally imply greater accumulation on the panel surface over time, reducing efficiency. The system logs this data and estimates the cleaning schedule based on dust density trends. Simultaneously, a sunlight sensor measures light intensity, which is used to estimate the expected power generation for the day. If the actual power is lower than predicted under sufficient sunlight, it may indicate soiling or electrical issues.

1.3 Vibration and Security Monitoring:

A vibration sensor is mounted on the solar panel structure to detect any mechanical movements or shocks. This can indicate strong winds, tampering, or physical damage. If abnormal vibrations are detected, the system triggers an alert to the webpage. This also acts as an anti-theft mechanism, as unauthorized movement of panels can be immediately reported.

1.4 IoT Data Transmission:

The system includes an ESP8266-01 Wi-Fi module which sends all sensor data to the ThingSpeak server. Users can view real-time data and alerts on a dedicated webpage. The webpage displays power generation trends, dust levels, predicted energy, maintenance alerts, and vibration status. This enables remote monitoring of solar panels from anywhere.

1.5 Power Supply and Sustainability:

The entire system is powered by a 10W solar panel connected to a 12V sealed lead-acid battery. A custom-designed MPPT charge controller ensures efficient energy harvesting and regulated charging of the battery. This allows uninterrupted operation of the monitoring system even in low sunlight conditions.

1.6 Display and Alerts:

A 16x2 LCD display is used locally to show key parameters such as voltage, current, power, and sunlight intensity. This provides quick on-site reference for technicians.

1.7 A MPPT Charge Controller:

MPPT charge controller is designed to maximize the amount of power extracted from solar panels and efficiently deliver it to battery. It helps in Optimizing Power Output, Efficient Voltage Conversion, Increased Energy Harvest etc.

Overall, this system integrates IoT sensor-based system with MPPT Charge Controller to enable intelligent monitoring and efficient energy conversion from solar panels. It ensures optimal performance, schedules timely maintenance, prevents damage, and improves overall energy management through data-driven decisions.

IV. Simulation Results

Figure 2 Shows simulation done using proteus software.

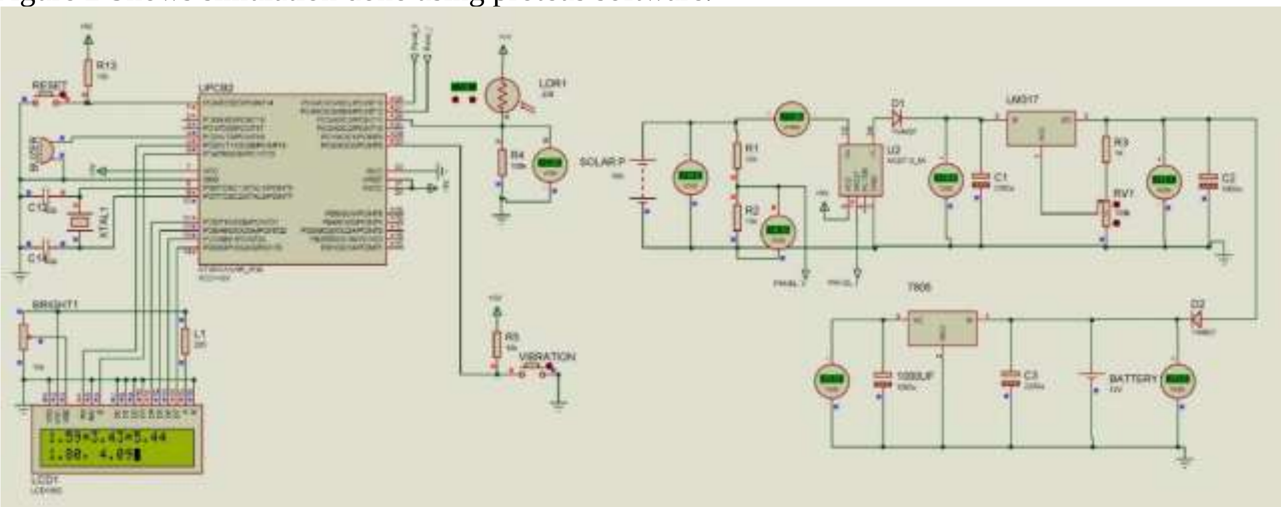

Fig.2 Simulation Diagram

V. Hardware Implementation

Figure 3 Shows implemented circuit.

Figure 3: Hardware Implementation

VI. Results

In figure 3, display showing the process to upload data on webpage, whereas result of webpage is shown in figure 4(a). In that calculated values from microcontroller are shown in numeric display whereas alert status are shown in lamp indicator form. When the motion detected, lamp indicator of motion alert field will turn on. This can be seen in figure 4(b).

Figure 4: a) Webpage results before fault occurs and b) Webpage results after fault occurs

VII. Applications

- Solar Farms – Monitor multiple panels for efficiency and maintenance.
- Residential Solar Systems – Enhance home solar system performance and reduce energy losses.
- Remote Solar Installations – Provide real-time monitoring where manual inspection is difficult.
- Educational Projects – Demonstrate IoT and renewable energy integration.
- Smart Cities – Integrate with other smart energy management solutions.

VIII. Advantages

- Real-time Monitoring: Allows continuous performance tracking.
- Maintenance Alerts: Reduces delay in servicing.
- Energy Prediction: Helps in daily power management.
- Theft Protection: Alerts for movement or tampering.
- Self-powered System: Operates using solar energy itself.
- IoT Integration: Enables remote access and control.
- Enhanced power efficiency using MPPT Controller.

IX. Conclusion

We believe that this system will be helpful in increasing the efficiency and maintenance alert for solar power plants. This will ultimately reduce the troubleshooting time and manpower needed for maintenance work. Also with the features of energy generation prediction and cleaning time prediction, it will be easy to manage things. Due to use of IoT, a remote monitoring is possible.
By considering all the situations and possibility, we decided the objectives for system and chosen components which are helping to achieve the desire target. Though, design of circuit is critical due to non-availability of some of module in Protius software. Whereas due to the use of Arduino development tools, reduce difficulties during programming & troubleshooting was reduced.

References

[1]B. Bodke, D. Dighe, R. Dabhade, K. Avhad, “A review of an IoT-enabled MPPT charge controller for solar PV”, Juni Kyat, Vol-15, Issue-04, No.04, April: 2025.
[2]Ahmad Amhani; Hussain A. Attia “Online multi-parameters electronic monitoring system for solar photovoltaic panel applications” International Conference on Electrical and Computing Technologies and Applications (ICECTA) 2017
[3]Soomin Lee; Sehyeong Lee; Laith Ellis; Anthony H Smith; Minsun Lee “Design of Solar Panels Efficiency Monitoring System” IEEE International Conference on Consumer Electronics - Asia (ICCE-Asia) 2020
[4]Pritam Pokhra, Rajeshwari, Raj Kumar Yadav, “A Project Report on automatic Sun Tracking Solar Panel Based on Open Loop Concept”, International Journal of Engineering and Applied Sciences (IJEAS), May 2020
[5]Babu K, Dinesh kumar P, Kamala priya S, Kathirvel P, “Solar Panel Cleaning Robot”, International Journal of Innovative Science and Research Technology, 2018
[6]K.G.Srinivasan, Dr.K.Vimaladevi, Dr.S.Chakravarthi,, “Solar Energy Monitoring System by IOT”, Special Issue Published in Int. Jnl. Of Advanced Networking & Applications (IJANA), 2018
[7]Purusothaman, SRR Dhiwaakar, et al. "Implementation of Anrduino-based multi-agent system for rural Indian microgrids." 2013 IEEE Innovative Smart Grid Technologies-Asia (ISGT Asia). IEEE, 2013.
[8]Kabalci, Ersan, Alper Gorgun, and Yasin Kabalci. "Design and implementation of a renewable energy monitoring system." Power Engineering, Energy and Electrical Drives (POWERENG), 2013 Fourth International Conference on. IEEE, 2013.
[9]D Saravanan; T Lingeshwaran, “Monitoring Of Solar Panel Based On IOT” IEEE International Conference on System, Computation, Automation and Networking (ICSCAN) 2019.
[10] Sakshi Lahabar, Ajinkya Barapatre, Lokesh Heda, “IOT - Powered Smart Photovoltaic Charge Controller” SSRG International Journal of Electrical and Electronics Engineering, Volume 10 Issue 1, 219-225, January 2023.
[11] Saeed H. Hanzaei, Saman A. Gorji, Mehran Ektesabi, “A Scheme-Based Review of MPPT Techniques with Respect to Input Variables Including Solar Irradiance and PV Arrays' Temperature”, IEEE Access, Oct.-2020.