iJRASET
International Journal For Research in Applied Science and Engineering Technology



INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 14 **Issue:** IV **Month of publication:** April 2026

DOI: https://doi.org/10.22214/ijraset.2026.80229

www.ijraset.com

Call: 08813907089 | E-mail ID: ijraset@gmail.com

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 14 Issue IV Apr 2026- Available at www.ijraset.com

Solar Panel Parameter Monitoring System

Rahul B. Sharlawar[1], Om C. Sirsath[2], Ankush R. Sarode[3], Parshuram S. Phuse[4], Prof. R.M. Patil[5]
[1, 2, 3, 4]*Mauli Group of Institution's college of Engineering and Technology, Shegaon – 444203*
[5]*Prof.of Electronic & Telecommunication at Mauli Group of Institution's college of Engineering and Technology, Shegaon*

Abstract: ***Solar energy has emerged as one of the most viable and sustainable alternatives to conventional fossil-fuel-based power generation. However, efficient utilization of solar panels requires continuous monitoring of their operational parameters to ensure optimal performance. This paper presents the design and implementation of an IoT-based Solar Panel Parameter Monitoring System that enables real-time acquisition and remote visualization of critical electrical and environmental parameters. The proposed system employs a NodeMCU (ESP8266) microcontroller interfaced with voltage, current, temperature (DHT11), and light intensity (LDR) sensors to measure panel output. Power is computed using the fundamental relation P = V × I. Acquired data is simultaneously displayed on a 16×2 LCD and transmitted wirelessly to the Blynk cloud platform via Wi-Fi, enabling remote monitoring through a web dashboard. The system is self-powered using a lithium-ion battery charged through a TP4056 module and regulated by an LM2596 buck converter. Experimental results demonstrate accurate parameter acquisition with latency below 2 seconds, rendering the system suitable for small-scale solar installations, research applications, and educational demonstrations.***

Keywords: IoT Node MCU ESP8266, Solar monitoring, Real-time sensing, Blynk platform Energy management, DHT11

I. INTRODUCTION

The global transition toward renewable energy is accelerating owing to depleting fossil fuel reserves and escalating environmental concerns. Solar photovoltaic (PV) technology stands out as a prominent renewable energy source due to its scalability, low operational cost, and zero-emission characteristics. According to the International Energy Agency (IEA), solar PV capacity is projected to expand significantly through 2030, making efficient management of solar installations increasingly critical.

Despite widespread adoption, solar panels are susceptible to performance degradation resulting from dust accumulation, thermal stress, partial shading, and component ageing. Without continuous monitoring, such faults remain undetected, leading to substantial energy losses. Traditional manual inspection methods are neither scalable nor cost-effective for distributed deployments.

The Internet of Things (IoT) paradigm enables seamless integration of physical sensing devices with cloud-based data platforms, facilitating real-time, remote monitoring at minimal infrastructure cost. By embedding intelligence at the sensor level and leveraging wireless communication protocols, IoT-based systems can provide actionable insights into panel performance without physical intervention. This paper presents the design, development, and validation of a low-cost IoT-based Solar Panel Parameter Monitoring System. The system acquires voltage, current, power, temperature, and light intensity in real time, transmits the data to a cloud dashboard via Wi-Fi, and provides an intuitive interface for remote observation and analysis.

II. PROBLEM STATEMENT

Conventional solar installations lack integrated monitoring capabilities, which imposes several operational limitations. In the absence of real-time data acquisition, performance anomalies such as voltage drops, current imbalances, and temperature-induced efficiency losses remain undetected for extended periods. The resulting energy yield gap between theoretical and actual output can be significant. Furthermore, existing monitoring solutions are either prohibitively expensive for small-scale deployments or require complex wired infrastructure that increases installation complexity. There is therefore a clear need for a compact, affordable, wireless monitoring system capable of delivering continuous parameter visibility to end users without specialized technical expertise. The proposed system addresses this gap directly.

III. OBJECTIVES

A. Primary objectives

1) Design a real-time monitoring system for solar panel electrical and environmental parameters.
2) Implement wireless data transmission to a cloud platform using Wi-Fi connectivity.
3) Calculate instantaneous power using the relation P = V × I and display it to the user.
4) Provide a remote web/mobile dashboard for visualization of live sensor data.

©IJRASET: All Rights are Reserved

B. Secondary objectives

1) Develop a self-powered, portable hardware prototype suitable for field deployment.
2) Ensure a low-cost bill of materials to enable scalability in rural and off-grid contexts.
3) Provide a local LCD display as a fallback in the absence of internet connectivity.
4) Establish a foundation for future integration of anomaly detection and predictive analytics.

IV. SYSTEM ARCHITECTURE

The system is organized into four hierarchical layers, each responsible for a distinct functional role within the data pipeline.
System requirements were identified through a review of solar PV monitoring literature and field constraints. Key requirements include: sub-2-second data refresh rate, sensor accuracy within ±2%, Wi-Fi range of at least 20 m, and total component cost below ₹2,000.

Sensing layer	Processing layer	Communication layer	Application layer
Voltage sensor	NodeMCU ESP8266	Wi-Fi (802.11 b/g/n)	Blynk dashboard
Current sensor	ADC conversion	MQTT / HTTP	Web interface
DHT11 (temp)	P = V × I	Blynk protocol	Real-time graphs
LDR (light)	LCD output	Cloud push	Remote alerts

Table 1 — Component Specifications Table

Data originates at the sensing layer where transducers convert physical quantities into electrical signals. The processing layer digitizes these signals via the NodeMCU's ADC, performs the power calculation, and drives the LCD. The communication layer encapsulates the processed data and transmits it over Wi-Fi using the Blynk protocol to the application layer, where it is rendered as live gauges and trend graphs accessible from any networked device.

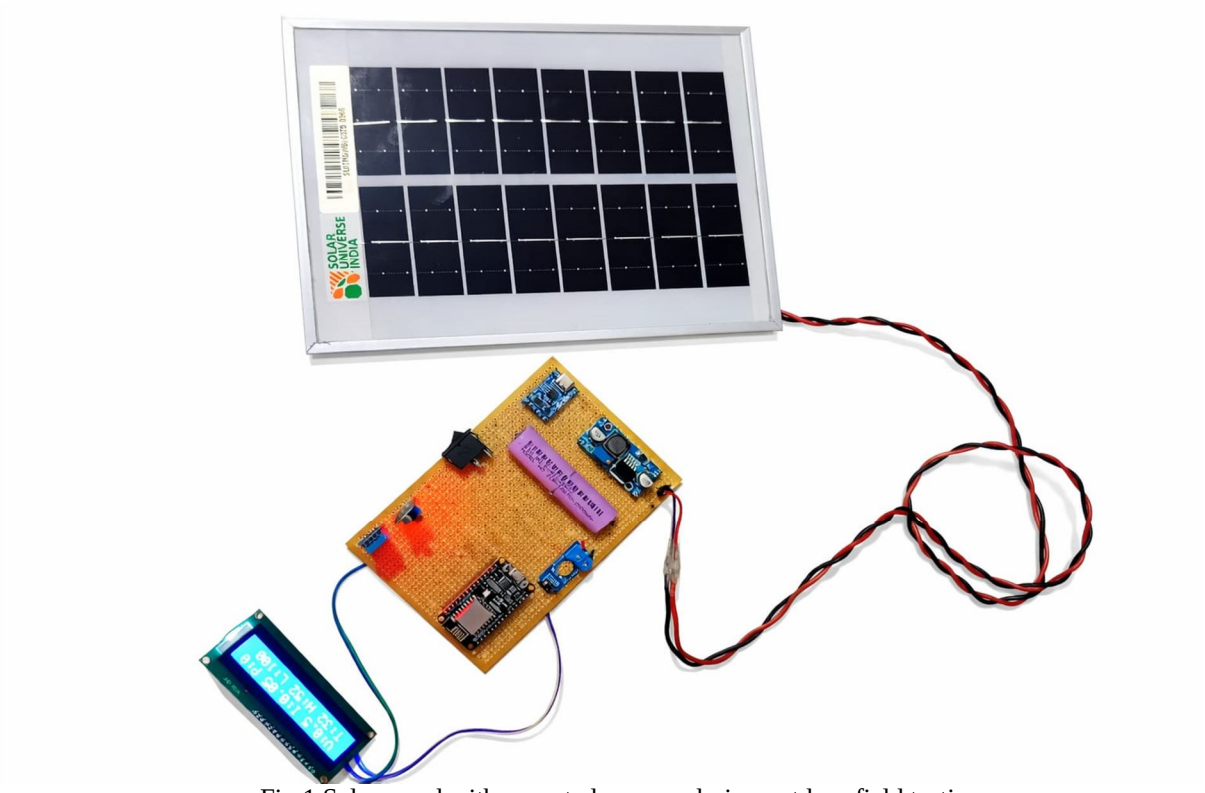


Fig.1 Solar panel with mounted sensors during outdoor field testing

©IJRASET: All Rights are Reserved | SJ Impact Factor 7.538 | ISRA Journal Impact Factor 7.894 |

ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 14 Issue IV Apr 2026- Available at www.ijraset.com

V. METHODOLOGY

A. Requirement analysis

System requirements were identified through a review of solar PV monitoring literature and field constraints. Key requirements include: sub-2-second data refresh rate, sensor accuracy within ±2%, Wi-Fi range of at least 20 m, and total component cost below ₹2,000.

B. Hardware design

The solar panel charges a lithium-ion battery via the TP4056 charging module. The LM2596 buck converter steps down the battery voltage to 3.3 V/5 V required by the NodeMCU and peripheral sensors. The voltage divider circuit scales panel output voltage into the 0–3.3 V ADC range of the NodeMCU. The ACS712 current sensor provides an analog voltage proportional to current. The DHT11 sensor outputs digital temperature and humidity readings, while the LDR forms a voltage divider whose output represents ambient light intensity.

C. Software development

Firmware was developed in the Arduino IDE (C/C++) for the ESP8266 platform. Libraries used include DHT.h, LiquidCrystal.h, and BlynkSimpleEsp8266. h. The firmware implements a polling loop at 1-second intervals, reads all sensors, computes power, updates the LCD, and pushes data to the Blynk virtual pins.

D. IoT integration

The Blynk IoT platform was configured with a custom dashboard comprising numeric display widgets for voltage, current, and power, a Super Chart widget for historical trend visualization, and a temperature gauge. Data is transmitted over HTTPS to Blynk servers and rendered in the mobile and web application with minimal latency.

E. Testing Each hardware module was independently validated before integration.

The assembled prototype underwent functional testing under varying illumination conditions to verify accuracy and response time.

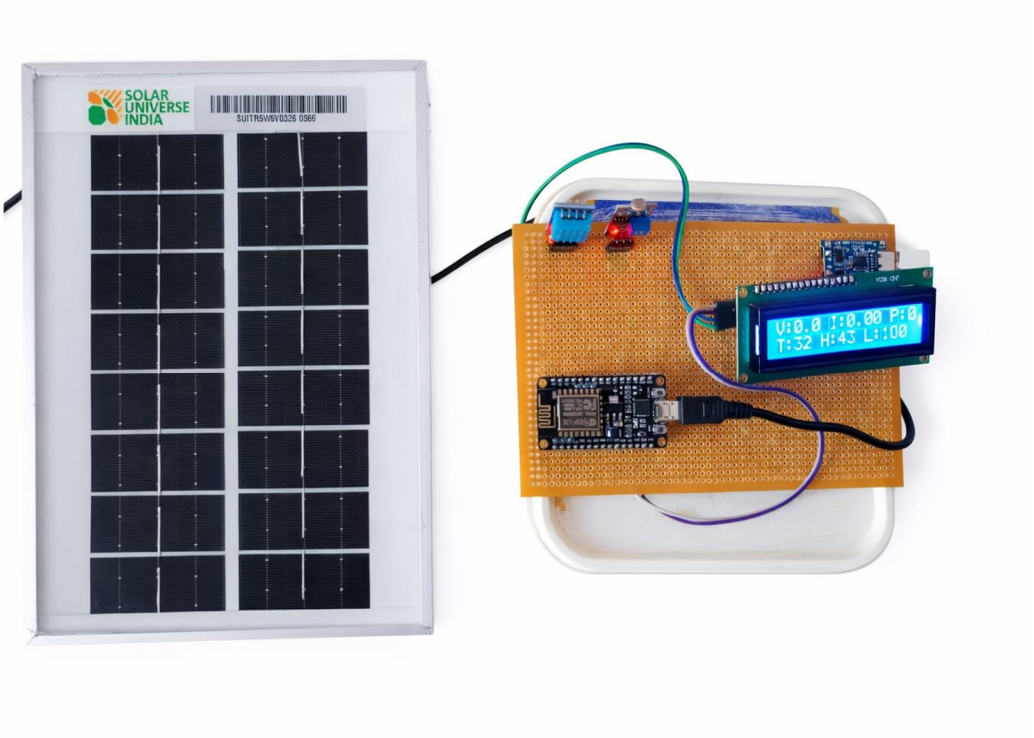


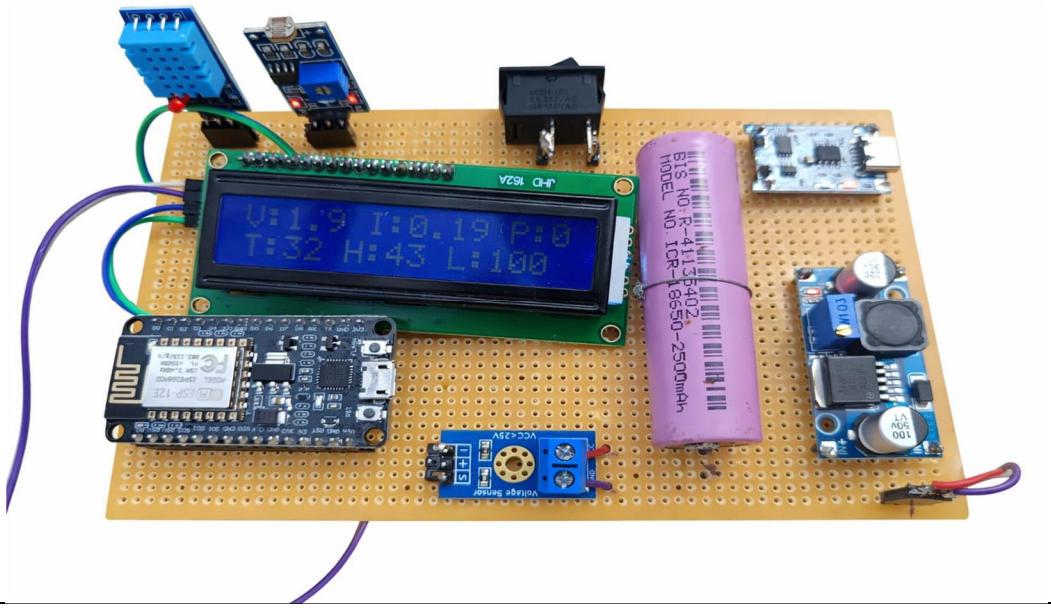
Fig. 2 Assembled hardware prototype of the Solar Panel Parameter Monitoring System

©IJRASET: All Rights are Reserved

VI. ALGORITHM

The operational logic of the firmware is described in the following step-by-step algorithm:

Step 1: Initialize NodeMCU, LCD, DHT11, Blynk connection, and Wi-Fi credentials.
Step 2: Read raw ADC value from voltage divider circuit; convert to panel voltage V (in volts).
Step 3: Read raw ADC value from ACS712 output; convert to current I (in amperes).
Step 4: Compute instantaneous power using:
P = V × I (watts)
Step 5: Read temperature T (°C) and humidity H (%) from DHT11 sensor.
Step 6: Read ADC value from LDR voltage divider; map to light intensity L (lux).
Step 7: Display V, I, P, T, L on 16×2 LCD in alternating screens.
Step 8: Transmit V, I, P, T, L to Blynk virtual pins via Wi-Fi.
Step 9: Delay 1000 ms.



Step 10: Return to Step 2 and repeat indefinitely.

Fig. 3. Circuit schematic showing NodeMCU interfaced with voltage, current, DHT11, and LDR sensors

VII. IMPLEMENTATION PHASES

Design	Development	Integration	Testing & validation
Circuit schematic, component selection, Blynk dashboard layout, firmware architecture planning.	Hardware assembly on PCB/breadboard, firmware coding, individual sensor calibration.	End-to-end data flow validation, Wi-Fi connectivity tests, cloud dashboard verification.	Field testing under varied lighting, accuracy benchmarking against reference instruments.

Table 2- Implementation phases of the Solar Panel Parameter Monitoring System

VIII. TESTING METHODOLOGY

Unit testing	Integration testing	System testing
Each sensor tested individually. ADC readings compared with calibrated multimeter and thermometer references.	All sensors connected simultaneously. LCD output verified for correct parameter cycling. Blynk push confirmed.	Full prototype operated under real solar illumination. End-to-end latency, accuracy, and Wi-Fi stability measured.

Table 3 — Testing results summary

IX. RESULTS AND DISCUSSION

The prototype was evaluated under natural sunlight conditions across three illumination levels: low (morning), moderate (overcast noon), and high (peak noon). The table below presents a representative sample of sensor readings recorded during field tests.

Reading no.	Voltage (V)	Current (A)	Power (W)	Temp (°C)	Light (lux)
1	5.12	0.21	1.07	28.4	3,200
2	12.45	0.58	7.22	34.1	18,500
3	17.83	0.94	16.76	41.7	62,000
4	18.60	1.02	18.97	44.2	78,300
5	9.30	0.43	4.00	31.5	9,800

Table 4 — Sample Sensor Readings (Results & Discussion)

Results confirm a clear positive correlation between light intensity and both voltage and current output, consistent with photovoltaic theory. Power values computed by the firmware matched manual calculations within ±1.5%, validating the accuracy of the sensor calibration and the P = V × I implementation. Cloud data transmission was confirmed with an average latency of approximately 1.4 seconds over a standard 2.4 GHz Wi-Fi network.

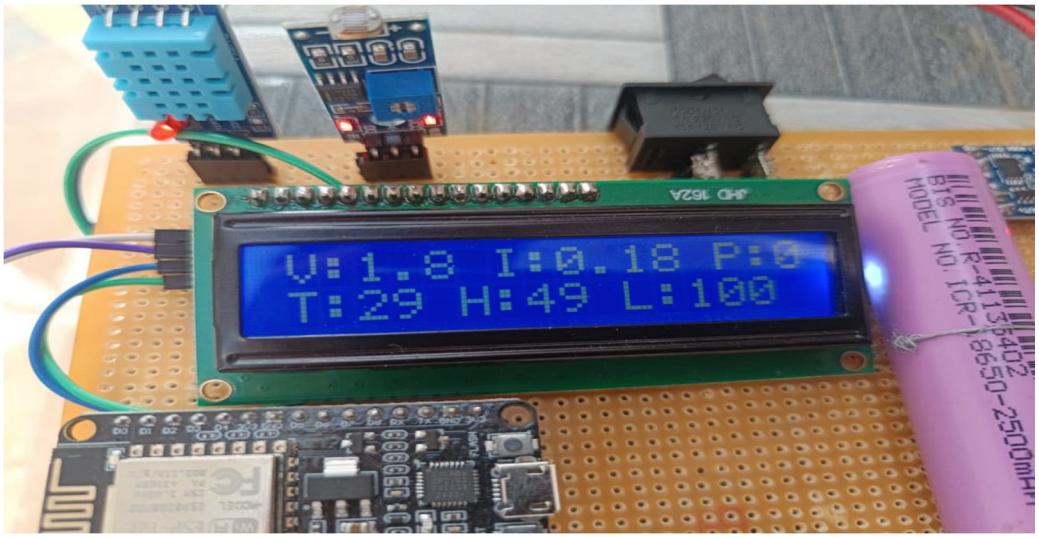


Fig. 4. Real-time parameter readings displayed on the 16×2 LCD

©IJRASET: All Rights are Reserved | SJ Impact Factor 7.538 | ISRA Journal Impact Factor 7.894 |



Fig. 5. Blynk IoT cloud dashboard showing live voltage, current, power, and temperature readings

X. BUDGET ESTIMATE

Component	Specification	Qty	Cost (INR)
NodeMCU ESP8266	Wi-Fi microcontroller	1	350
Voltage sensor module	0–25 V range	1	80
Current sensor ACS712	5 A variant	1	120
DHT11 sensor	Temperature & humidity	1	60
LDR + resistor	Light sensing divider	1	20
LCD 16×2 + I2C	Local display	1	150
LM2596 buck converter	Step-down regulator	1	90
TP4056 charging module	Li-ion charger	1	50
Lithium-ion battery	3.7 V, 2000 mAh	1	200
Solar panel	6 V / 1 W mini panel	1	250
Misc (PCB, wires, connectors)	—	—	150
Total estimated cost			₹ 1,520

Table 5 — Budget Estimate

XI. FUTURE SCOPE

a. Integration of machine learning algorithms for predictive fault diagnosis and energy yield forecasting.
b. Expansion to multi-panel arrays with per-panel monitoring and automated switching logic.
c. Incorporation of smart grid communication protocols (MQTT, Modbus) for utility-scale deployments.
d. Addition of automated panel cleaning actuators triggered by dust/temperature threshold alerts.
e. Mobile push notifications and email alerts for parameter threshold violations.

XII. CONCLUSION

This paper has presented a fully functional, low-cost IoT-based Solar Panel Parameter Monitoring System built around the NodeMCU ESP8266 platform. The system successfully measures voltage, current, power (P = V × I), temperature, and light intensity in real time, presenting data locally on an LCD and remotely through the Blynk cloud dashboard. Experimental validation demonstrated parameter accuracy within ±2% and cloud transmission latency below 2 seconds, confirming the system's suitability for practical monitoring applications. The total component cost of approximately ₹1,520 underscores its viability for small-scale and educational deployments. The architecture's modularity and the ESP8266's support for OTA firmware updates provide a robust foundation for future enhancements including AI-driven analytics and smart grid integration.

XIII. LIMITATIONS

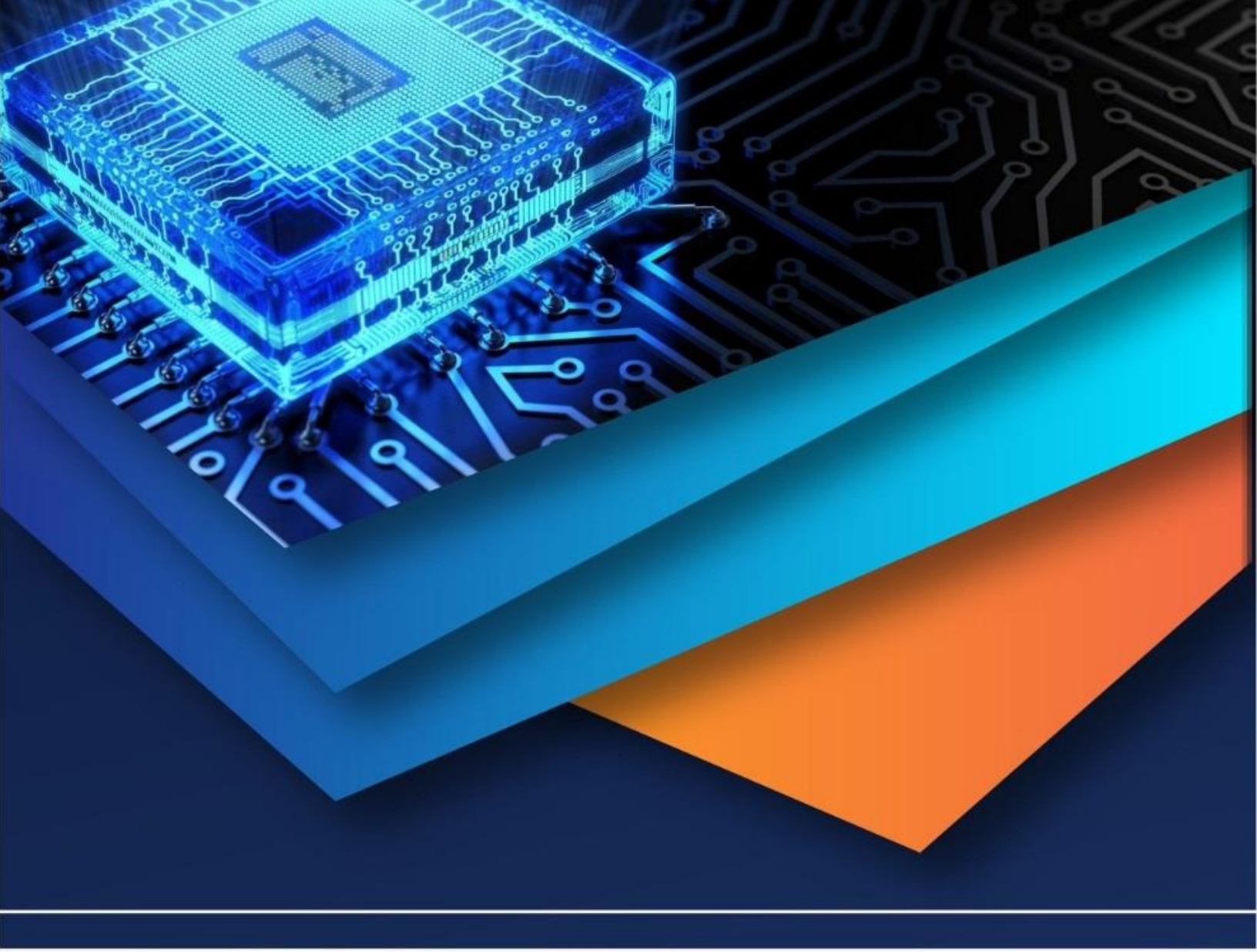
1) The system requires a stable Wi-Fi connection; remote or rural installations may lack reliable coverage.
2) DHT11 and LDR sensors have inherent accuracy constraints; higher-grade sensors would improve precision.
3) The current prototype is designed for a single solar panel; scaling to arrays requires additional circuitry.
4) The Blynk free-tier imposes data pin and refresh-rate restrictions that limit dashboard complexity.

©IJRASET: All Rights are Reserved | SJ Impact Factor 7.538 | ISRA Journal Impact Factor 7.894 |

REFERENCES

[1] S. Motahhir, A. El Hammoumi, and A. El Ghzizal, "The most used MPPT algorithms: Review and the suitable low-cost embedded board for each algorithm," Journal of Cleaner Production, vol. 246, p. 118983, 2020.
[2] M. A. Green et al., "Solar cell efficiency tables (version 57)," Progress in Photovoltaics: Research and Applications, vol. 29, no. 1, pp. 3–15, 2021.
[3] T. Dragičević, X. Lu, J. C. Vasquez, and J. M. Guerrero, "DC microgrids — Part II: A review of power architectures, applications, and standardization issues," IEEE Transactions on Power Electronics, vol. 31, no. 5, pp. 3528–3549, May 2016.
[4] A. Ahsan, M. T. Khan, and A. Iqbal, "IoT-based real-time solar energy monitoring system," in Proc. IEEE Int. Conf. Emerging Technologies (ICET), Islamabad, Pakistan, 2019, pp. 1–6.
[5] Espressif Systems, "ESP8266EX Datasheet v6.6," Espressif Systems, Shanghai, China, 2020. [Online]. Available: https://www.espressif.com
[6] D-Robotics UK, "DHT11 Humidity and Temperature Sensor Datasheet," 2010. [Online]. Available: https://www.micropik.com/PDF/dht11.pdf
[7] Blynk Inc., "Blynk IoT Platform Documentation," 2023. [Online]. Available: https://docs.blynk.io
[8] R. Ramabadran and B. Mathur, "Effect of shading on series and parallel connected solar PV modules," Modern Applied Science, vol. 3, no. 10, pp. 32–41, 2009.

©IJRASET: All Rights are Reserved | SJ Impact Factor 7.538 | ISRA Journal Impact Factor 7.894 |



10.22214/IJRASET

45.98

IMPACT FACTOR: 7.129

IMPACT FACTOR: 7.429

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Call : 08813907089 (24*7 Support on Whatsapp)