



Light Intensity Measurement And Energy Harvesting System

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Abstract: Light Intensity Measurement and Energy Harvesting System is developed to monitor environmental light conditions in real time while simultaneously harvesting solar energy for sustainable power generation. The system integrates a light intensity sensor with a Wi-Fi enabled microcontroller to measure and process ambient light levels in lux units. A solar panel is incorporated to capture renewable energy, which is regulated using a charge controller and stored in a rechargeable battery. The harvested energy can power low-power IoT devices, making the system self-sustaining and energy-efficient. The measured light intensity data is transmitted to the ThingSpeak cloud platform through Wi-Fi connectivity for real-time monitoring, graphical visualization, and analysis. ThingSpeak enables users to remotely access sensor data, observe variations in light intensity, and evaluate solar energy generation efficiency via web dashboards. The integration of IoT technology with renewable energy harvesting enhances system scalability, reliability, and intelligent decision-making capabilities. This work provides a cost-effective and eco-friendly solution suitable for smart agriculture, smart street lighting, solar tracking systems, environmental monitoring, and smart city applications. By combining real-time sensing, cloud-based analytics, and sustainable energy utilization, the proposed system contributes to modern green energy management and IoT-enabled automation technologies.

Keywords - Energy Harvesting, IoT and ThingSpeak Integration, Light Intensity Measurement, and System Advantages.

Introduction

The rapid advancement of Internet of Things (IoT) has transformed conventional monitoring systems into intelligent, interconnected platforms capable of real-time data acquisition, processing, and remote management. IoT technology enables physical devices embedded with sensors, microcontrollers, and communication modules to collect environmental data and transmit it to cloud-based servers for analysis and visualization [1]. This evolution has significantly contributed to smart energy management, environmental monitoring, and sustainable development initiatives. Light intensity plays a crucial role in various applications such as smart street lighting, agriculture, solar energy optimization, industrial automation, and smart home systems. Accurate measurement of ambient light helps in improving energy efficiency and system performance. At the same time, the growing demand for renewable energy sources has encouraged the adoption of solar energy harvesting systems, which convert sunlight into electrical energy for sustainable power generation. The proposed IoT-based Light Intensity Measurement and Energy Harvesting System integrates a LDR (Light Dependent Resistor) sensor with a Wi-Fi-enabled microcontroller to measure real-time light intensity levels. A solar panel is incorporated to harvest renewable energy, which is regulated through a charge controller and stored in a rechargeable battery. The harvested energy can power the sensing and communication modules, making the system energy-efficient and partially self-sustaining. For cloud-based monitoring and data analysis, the system utilizes the

ThingSpeak web server platform. ThingSpeak allows real-time data uploading, graphical visualization, storage, and remote access through dashboards. It also supports data analytics features that help in evaluating solar panel performance and analyzing light intensity variations over time. By combining IoT technology, renewable energy harvesting, and cloud computing, this system provides a scalable, cost-effective, and eco-friendly solution for intelligent energy monitoring. The project demonstrates how modern IoT frameworks can enhance automation, improve energy utilization, and contribute toward sustainable smart infrastructure development.

I. BACKGROUND THEORY

Light Intensity Measurement and Energy Harvesting System combines concepts from environmental sensing, renewable energy, and cloud-based IoT monitoring. Understanding the underlying theory involves four main aspects: light intensity measurement, energy harvesting, IoT and ThingSpeak integration, and system advantages.

2.1 Light Intensity Measurement

Light intensity measurement is a critical component of the IoT-based energy harvesting system, as it determines both environmental monitoring and the efficiency of solar energy conversion. Light intensity refers to the amount of visible light incident on a surface per unit area and is typically measured in lux (lx). Accurate measurement allows intelligent control of lighting systems, solar tracking, and energy optimization. The system uses sensors that detect ambient light and convert it into an electrical signal. LDR sensor's resistance decreases as light intensity increases. It suitable for precise measurements and applications requiring rapid detection of changes in light. The analog output of the sensor is read by the microcontroller's ADC pin. The microcontroller processes the signal to convert it into a digital value representing light intensity in lux. The processed data can trigger actions or be transmitted to the cloud server for remote monitoring. Optimizing solar panel output is Light intensity data helps determine solar energy availability and optimize charging schedules. Intelligent control can be used to adjust street lighting or indoor lighting based on ambient conditions. IoT integration is real-time measurements are sent to the ThingSpeak web server, where data is visualized and analyzed for trends, performance evaluation, and predictive decision-making. By accurately measuring light intensity, the system ensures that both energy harvesting and IoT monitoring are efficient, reliable, and sustainable, making it ideal for smart city and renewable energy applications.

2.2 Energy Harvesting

This work focuses on measuring light intensity, harvesting solar energy, and uploading real-time data to the ThingSpeak web server for monitoring and analysis. The main points to be taken into account are the measuring ambient light intensity, harvesting energy using a solar panel, uploading data to ThingSpeak cloud platform, and monitoring data remotely via dashboard. ThingSpeak is an IoT analytics platform from MathWorks that integrates real-time data visualization, MATLAB analytics, and cloud data storage APIs. The steps to using ThingSpeak are to create an account on ThingSpeak, create a new channel, fill in the blanks, copy the Write API Key, and use the API in user ESP8266 code to upload data. The working steps are the measuring light intensity when light increases, the resistance of the LDR decreases ESP8266 reads the analog value from the LDR converts the light intensity to lux units' energy harvesting solar panel generates voltage from sunlight connecting the ESP to Wi-Fi [2]. Figure 1, 2 and 3 show NodeMCU board, LDR sensor, and LCD (Liquid Crystal Display) display.

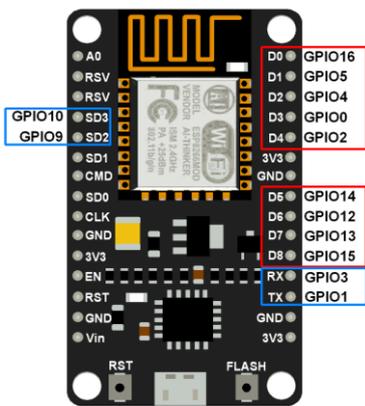


Fig. 1. NodeMCU

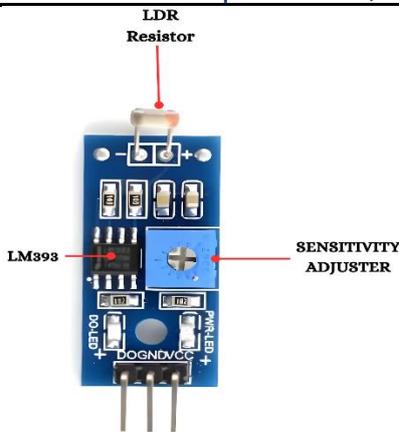


Fig. 2. LDR sensor



Fig. 3. Liquid crystal display

2.3 IoT and ThingSpeak Integration

This work express how the IoT device communicates with the ThingSpeak cloud, including data transmission, API usage, and cloud visualization. In terms of data flow, the LDR Sensor measures the light intensity, the ESP8266 processes the sensor data, the device connects to Wi-Fi, and sends the data to ThingSpeak via the HTTP API. ThingSpeak stores and visualizes the data in graphs. ThingSpeak is an IoT cloud platform developed by MathWorks that provides real-time data logging, MATLAB analysis, API-based communication, and cloud visualization. As for the communication protocol, the ESP module sends data using HTTP Protocol, Port 80, and REST API format.

2.4 System Advantages

This system integrates light sensing, renewable energy harvesting, and cloud-based monitoring using ThingSpeak. The main advantages of the system are that it uses solar energy as a power source, reduces dependence on grid electricity, is environmentally friendly and supports green technology, live data visualization in the cloud, access from anywhere via the internet, historical data storage and analysis, and data extraction for research and reports and is suitable for remote/off-grid locations. Precise environmental monitoring is a continuous measurement of light intensity, detection of day/night differences, and reliable digital data logging, useful for agriculture and smart lighting systems. Cost considerations include low-cost components (LDR sensor, NodeMCU board, and solar panel), no recurring electricity costs, minimal maintenance, and scalability for large deployments. In various applications, smart street lighting solar energy monitoring systems, greenhouse light monitoring environmental data collection, and remote research stations are particularly beneficial [3]. Figure 4, 5 and 6 show IoT, ThingSpeak web server, and LCD solar panel. Figure 7 and 8 show the block diagram and flowchart of the system.



Fig. 4. Internet of Things

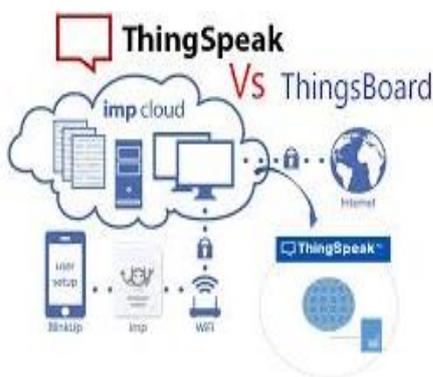


Fig. 5. ThingSpeak web server



Fig. 6. Solar panel

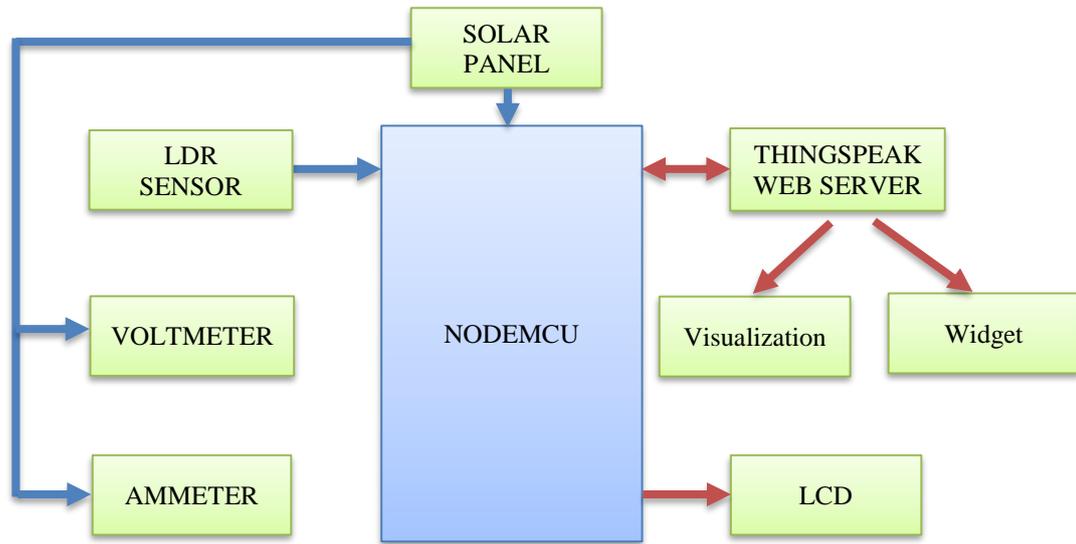


Fig. 7. Block diagram of the system

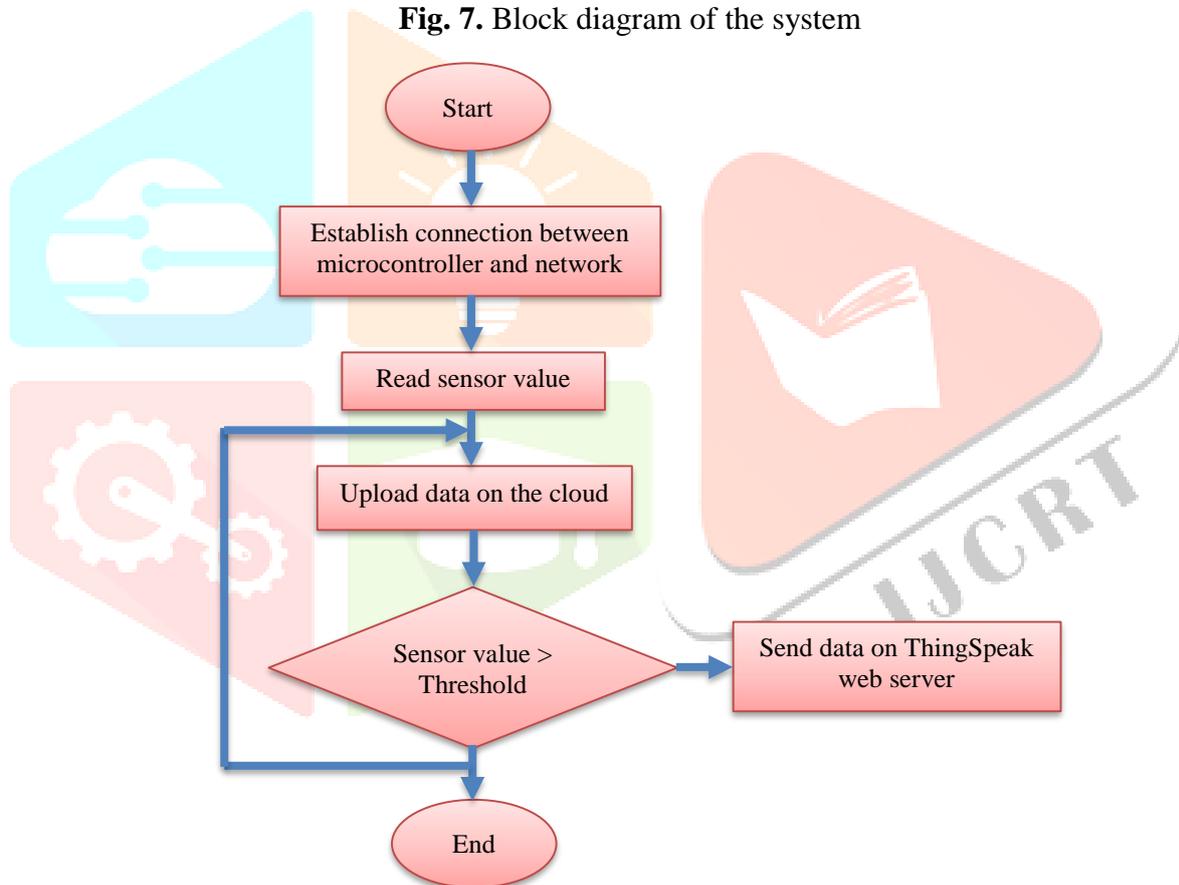


Fig. 8. Flowchart of the system

II. WORKING SYSTEM

A light intensity measurement and energy monitoring system works by integrating sensors, microcontrollers, communication modules, and cloud-based analytics to optimize energy monitoring. The LDR sensor measures the ambient light intensity. The microcontroller processes the sensor data and controls the connected devices. The communication module (Wi-Fi) sends the data to a cloud server. An ammeter and voltmeter are used to measure the current and voltage generated by the solar panel. The Cloud/Server (IoT Platforms such as Thingspeak web server) stores and processes the data for analysis. The light sensor continuously monitors the ambient light intensity. The sensor converts the light intensity into an electrical signal. The microcontroller processes the data and determines whether the light level is below or above a specified threshold. The processed data is sent to the cloud for storage and further analysis. The light intensity data is sent to the microcontroller and then sent to the cloud. The light intensity is compared with the data received from the solar panel. When the intensity is high, the panel is generating more energy. The ThingSpeak web server is not included in the Proteus software. Therefore, a suitable diagram has been drawn. Figure 9 and 10 show the circuit diagram and the completed system.

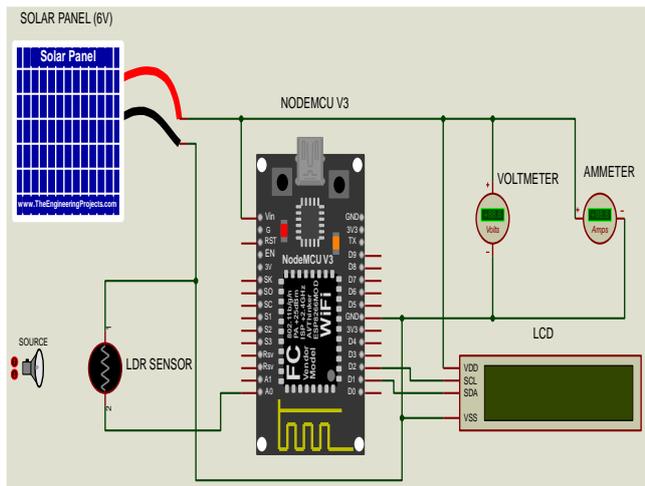


Fig. 9. Circuit diagram

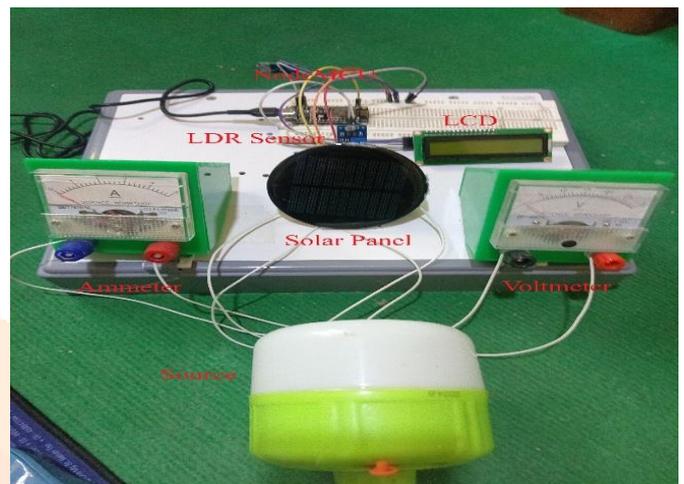


Fig. 10. Completed system

III. EXPERIMENTAL RESULTS

The LDR sensor was tested with various sources. Errors were found while testing the sensor. The sensor showed that the voltage on the solar panel fluctuated depending on the source used. When connecting to NodeMCU, had to connect it to the analog pin instead of the digital pin. As the tests continued, a slight sensor error was found. Light intensity was also measured at daily. In this measurement, the energy generated by the solar panel was also used in various ways. The solar panel was directly connected to a voltmeter and ammeter and the values were recorded. The obtained values were also calculated as power. Since used the ThingSpeak web server, it took a little while to complete the work due to the slow Wi-Fi connection. When connecting the LCD to the NodeMCU board, the text did not appear on the LCD screen, so had to reduce the version of the library file in the Arduino IDE and use various methods. Figure 11 and 12 show the displaying the sensor value on ThingSpeak web server and displaying the value of the light intensity. Figure 13 and 14 show the displaying the graph of light intensity and displaying the sensor value on LCD. Figure 15 and 16 show the light intensities and electrical power at difference time. Table 4.1 show the data of experimental results.

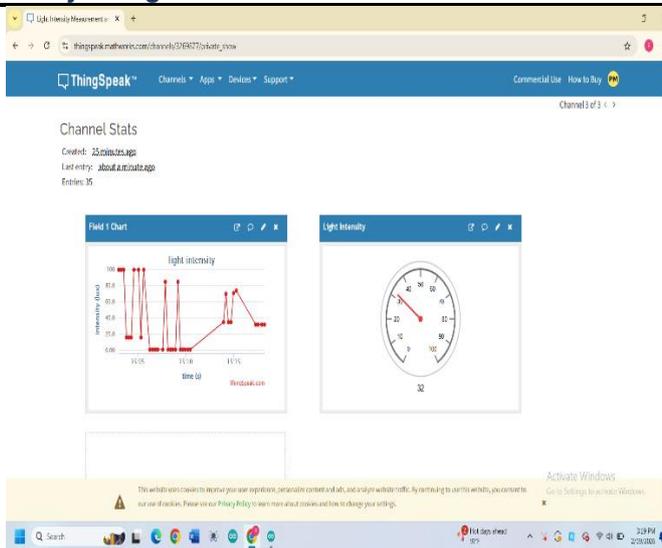


Fig. 11. Displaying the sensor value on ThingSpeak

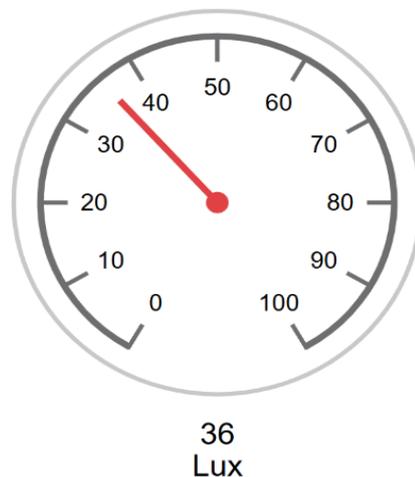


Fig. 12. Displaying the value of light intensity

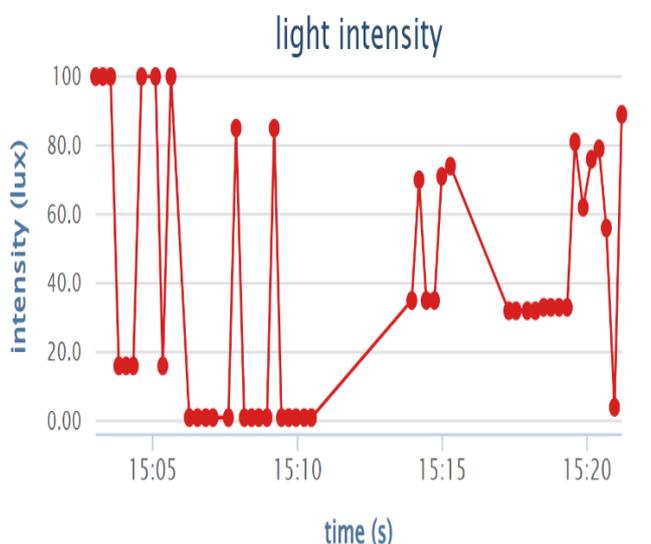


Fig. 13. Displaying the graph of light intensity



Fig. 14. Displaying the sensor value on LCD

Table 4.1: Data of Experimental Results

Experimental No:	Light Intensity (lx)	Voltage (V)	Current (mA)	Power (mW)
9:00 AM	43	6.40	0.31	1.984
9:30 AM	56	6.42	0.31	1.990
10:00 AM	65	6.48	0.31	2.008
10:30 AM	70	6.58	0.32	2.106
11:00 AM	82	6.59	0.32	2.109
11:30 AM	85	6.60	0.33	2.178
12:00 AM	92	6.61	0.33	2.181
12:30 AM	96	6.63	0.34	2.254
13:00 PM	99	6.64	0.34	2.258
13:30 PM	86	6.57	0.33	2.168
14:00 PM	79	6.46	0.32	2.067
14:30 PM	62	6.41	0.31	1.987
15:00 PM	58	6.37	0.30	1.911
15:30 PM	49	6.27	0.29	1.818
16:00 PM	32	6.02	0.28	1.686

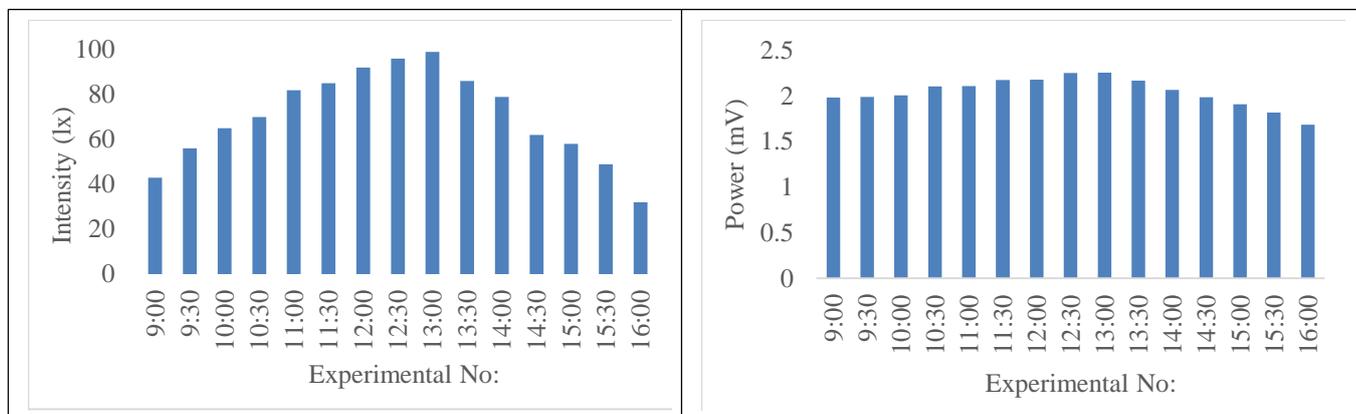


Fig. 15. Light intensities at difference time

Fig. 16. Electrical power at difference time

IV. CONCLUSION

Light Intensity Measurement and Energy Harvesting System successfully demonstrates how renewable energy, embedded systems, and cloud computing can be integrated into a smart and sustainable solution. The system effectively measures ambient light intensity using LDR sensors, processes the data through a microcontroller, and transmits real-time readings to the ThingSpeak cloud platform for visualization and analysis. At the same time, the integration of a solar energy harvesting module enables the system to operate with minimal external power dependency, making it energy-efficient and environmentally friendly. Key achievements of the research include to accurate real-time monitoring of light intensity, wireless data transmission to a cloud-based server, graphical visualization via ThingSpeak, sustainable operation through solar energy harvesting, low-cost and scalable IoT architecture. The work highlights the practical implementation of IoT in smart monitoring applications such as smart street lighting, agricultural field monitoring, greenhouse automation, and environmental sensing. By combining light intensity measurement with energy harvesting, the system reduces maintenance costs and enhances long-term deployment capability in remote areas. Finally, this system proves that IoT-enabled sensing systems powered by renewable energy sources can provide reliable, scalable, and sustainable solutions for modern smart applications. Future improvements may include integrating machine learning for predictive analysis, adding automated control systems (such as automatic light dimming), and expanding the system for large-scale smart city deployments.

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