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Real-Time Monitoring of Photovoltaic Panel Using Node-RED

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Abstract: This research aims to design and implement an Internet of Things (IoT)-based monitoring system for Photovoltaic (PV) panels using Node-RED. The system can monitor critical parameters such as voltage, current, power, and the electrical energy produced by the PV panels in real-time. The data obtained from the PV panels is sent to a Node-RED server and visualized in the form of indicators and graphs on a dashboard. Statistical analysis calculates the daily average power and total energy produced. The results show that the proposed system can enhance monitoring efficiency and significantly benefit PV system maintenance and management. Users can quickly identify and address issues that may arise, such as panel performance degradation or system disruptions. Energy analysis and maintenance planning can be carried out by collecting historical data. This research supports the broader renewable energy development and provides an effective real-time PV system monitoring solution.

Keywords: Internet of Things, Node-RED, Monitoring, Photovoltaic, Real-Time

INTRODUCTION

The utilization of solar energy through Photovoltaic (PV) technology has become one of the leading solutions in efforts to reduce dependence on fossil fuels (Ramu et al., 2021). By harnessing the photoelectric effect, PV can convert solar energy into electrical energy using semiconductor materials. The use of this system has expanded across various sectors, from household scales to large industries. However, monitoring is necessary to ensure PV operates optimally and efficiently (Kekre & Gawre, 2017). This monitoring involves the real-time collection and analysis of solar panel performance data, including measurements of voltage, current, power, and the electrical energy obtained (Chooruang & Meekul, 2018). Through this monitoring, users can determine the potential solar energy in an area. Additionally, the system can help identify damage or performance degradation in the PV. This will help maintain the optimal performance of the PV system, thereby reducing maintenance costs (Andi et al., 2023; Tellawar, 2019).

Internet of Things (IoT) technology offers an effective solution for real-time data monitoring (Hassan et al., 2020). Several papers have examined monitoring systems using IoT. For instance, the paper (Durairaj et al., 2024) discusses water quality monitoring to prevent water pollution, measuring parameters such as pH, conductivity, and salinity. This system uses Raspberry Pi to transmit data wirelessly. Furthermore, (Pavithra & Balakrishnan, 2015) explore monitoring and control in home automation systems, including controlling lights, fans, and fire detectors, using Raspberry Pi for data transfer. Additionally, (Roslidar et al., 2023) discuss air quality monitoring to determine pollution levels, measuring parameters such as Carbon Monoxide (CO), Carbon Dioxide (CO2), wind speed, dust

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particles, temperature, and humidity. The ESP8266 device is used to process and transmit these parameter data.

This paper uses IoT technology to monitor PV output, including voltage, current, power, and electrical energy. This monitoring process uses Node-RED. Node-RED is a flow-based development platform that provides a browser-based graphical interface for composing workflows by connecting nodes representing hardware, Application Programming Interfaces (APIs), and online services. This platform can run on local and cloud servers integrated with databases. Several papers have discussed using Node-RED, such as the paper (Hasni & Saparudin, 2023), which discusses using Node-RED to monitor water levels in rice fields to improve production effectiveness and manage water supply. Additionally, the paper (Chandra et al., 2021) explores the application of Node-RED for monitoring soil moisture levels. This system uses NodeMCU for data acquisition and a Node-RED server running on a Raspberry Pi. Furthermore, the paper (Chanthakit & Rattanapoka, 2018) discusses the application of Node-RED for air quality monitoring. The parameters measured include temperature and humidity, Carbon Monoxide (CO) concentration, Ozone Gas (O3), and Particulate Matter (PM2.5). This monitoring system uses ESP8266 for processing, allowing users to determine the air quality status, whether it is healthy or unhealthy. Monitoring using Node-RED offers various advantages, including ease of setup and workflow configuration, flexibility in connecting multiple devices and services, and the ability to analyze and visualize data in real-time (Lekic & Gardasevic, 2018). With Node-RED, users can leverage various available nodes to receive sensor data, process and analyze the data, and send notifications or take automatic actions based on the analysis results (Badii et al., 2020; Nugraha et al., 2023). Additionally, Node-RED supports integration with various data storage platforms and cloud services, enabling long-term data storage and further analysis (Blessing Ngonidzashe & Tuncay, 2023).

PV panels are devices capable of generating electrical energy and require a monitoring system to observe and analyze their performance. Several papers have studied PV monitoring using IoT. For example, in the paper (Deriche et al., 2019), PV panels are monitored to measure panel temperature in real-time using Simple Mail Transfer Protocol (SMTP). The purpose of this system is to provide early detection of PV overheating. Furthermore, in the paper (Kavitha & Malathi, 2019), PV panel parameters such as voltage, current, temperature, and irradiance are monitored. This monitoring system uses the CC3200 microcontroller and the Blynk application as a cloud platform. Additionally, the paper (Kumar et al., 2018) discusses monitoring and controlling PV system performance. This system aids in diagnosing faults in the PV, thus assisting the maintenance process.

Based on these studies, an IoT-based PV panel output monitoring system using Node-RED is proposed. The monitored parameters include voltage, current, power, and energy. This data is obtained from voltage and current sensors installed on the PV panel. The data is then sent to Node-RED via HyperText Transfer Protocol (HTTP), commonly used for data communication on web networks. The data results are displayed on a dashboard as indicators and graphs. Subsequently, the data is statistically processed to obtain the daily average power and total daily energy displayed in accumulated form for today and yesterday. This monitoring uses the ESP8266 device for data processing and acquisition. With its ability to integrate various types of data, Node-RED can perform real-time visualization and further analysis to enhance the performance of the PV system. The benefits of the proposed system include improved monitoring efficiency and advantages in PV system maintenance and management. With real-time data, users can quickly identify and address issues that may arise, such as panel performance degradation or system disruptions. The historical data can also be used for long-term trend analysis and maintenance planning. Thus, this technology not only enhances the overall performance of the PV system but also supports the broader development of renewable energy.

This paper's contribution is designing an IoT-based PV panel output monitoring system using Node-RED. The monitored parameters include voltage, current, power, and electrical energy. This data is processed and displayed on a dashboard through indicators and graphs. Additionally, the data is statistically processed to produce cumulative data such as the daily average power and the total daily energy generated by the PV. With the proposed system, users can monitor the performance of the PV panel and detect any damages, enabling prompt maintenance.

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LITERATURE REVIEW

Solar energy is energy generated from solar radiation and can be utilized for various purposes, such as generating electricity, heating water, and powering vehicles (Deshmukh & Bhuyar, 2018). As an energy source, the sun emits energy through sunlight, which can be converted into electricity using PV panels or into heat through solar collectors (Adhya et al., 2016; Shrihariprasath & Rathinasabapathy, 2016). This energy is renewable and environmentally friendly because it does not produce greenhouse gas emissions or other pollutants harmful to the environment (Kusznier & Wojtkowski, 2021). Solar energy utilization of is increasingly developing along with technological advancements and the reduction in the production costs of solar panels, making it an increasingly economical and efficient solution to meet global energy needs. Additionally, solar energy can be used decentralized, allowing its use in remote areas not reached by conventional power grids (Khan et al., 2019).

The Internet of Things (IoT) is a concept that connects various physical devices to the internet, allowing them to send and receive data (Mois et al., 2017). IoT encompasses many devices, from simple sensors to smart home appliances and complex industrial systems. This connectivity, allows devices to communicate with each other and users, creating an interconnected ecosystem network (Andi et al., 2023; Sharmad, 2016). The application of IoT has had a significant impact across various sectors. In the manufacturing industry, IoT is used for predictive maintenance, reducing machine downtime and enhancing operational efficiency (Perumal et al., 2015; Zickri et al., 2023). In the healthcare sector, IoT devices enable real-time patient monitoring, improving the quality of care and response to emergency conditions (Asante & Olsson, 2016; Kamarozaman & Awang, 2021). Smart homes are another example of IoT applications, where household appliances such as lights, thermostats, and security systems can be accessed and controlled remotely through mobile applications (Kodali & Anjum, 2018; Magtibay, 2019).

Node-RED is a flow-based development platform that simplifies connecting hardware, APIs, and online services (Bin Mohd Nazri et al., 2020). Developed by IBM, Node-RED provides an intuitive graphical user interface, allowing users to create applications by dragging and connecting functional blocks known as nodes. Each node performs a specific task, such as sending or receiving data, processing information, or controlling hardware (Baruah, 2021; Domínguez et al., 2020; Lu et al., 2020). The platform is highly flexible and can be used for various IoT applications, home automation, system integration, etc. One of Node-RED's main advantages is its ability to integrate multiple protocols and services, such as Message Queuing Telemetry Transport (MQTT), HTTP, and WebSockets, facilitating accessible communication between different devices and applications (Clerissi et al., 2018; Suhartinah et al., 2021). Node-RED also supports event-based programming, enabling real-time responses to changes in conditions or incoming data (Anam et al., 2023; Tricomi et al., 2020).

The ESP8266 is a low-cost and versatile Wi-Fi module designed to facilitate the development of IoT-based projects. It has a 32-bit Tensilica L106 processor provides sufficient processing power to run various applications (Macheso et al., 2021). The ESP8266 supports the TCP/IP protocol, enabling devices to connect to Wi-Fi networks and the internet. The module features General Purpose Input/Output (GPIO) pins that can be used to connect sensors, actuators, and other devices (Zare & Iqbal, 2020). Additionally, the ESP8266 supports programming with various platforms and languages, including Arduino IDE, Lua, and MicroPython, making it highly flexible and accessible for developers from different backgrounds. With its low power consumption and good connectivity capabilities, the ESP8266 is a popular choice for various IoT applications, such as environmental monitoring, home automation, and wearable devices (Kanagachidambaresan, 2021).

METHOD

This paper proposes a real-time IoT-based PV panel output monitoring system using Node-RED. The system aims to monitor essential parameters such as voltage, current, power, and electrical energy generated by the PV panel. Data obtained from sensors will be sent to the Node-RED server via HTTP protocol and then visualized as indicators and graphs on a dashboard. Additionally, the statistical accumulation of monitoring data will be displayed to provide an overview of the total daily energy and average power generated. With this monitoring system, users can easily track the performance of the

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PV panel, analyze historical data, and perform maintenance if any issues arise. Fig. 1 shows the data monitoring process for the PV panel using Node-RED. Meanwhile, Table 1 lists the specifications of the PV panel used as the research object in this study. The monitoring system involves several processes, including receiving sensor data from the ESP8266, calculating the daily data accumulation, and accumulating data from the previous day. All processed data will be displayed on the dashboard.

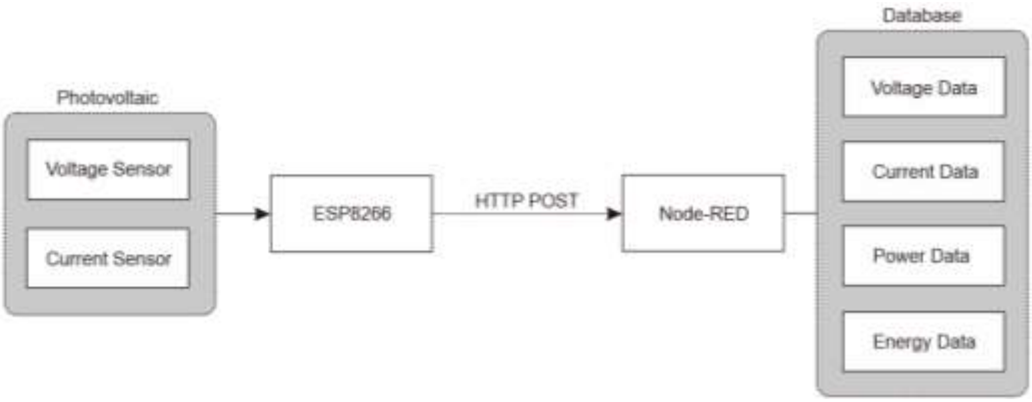

Fig. 1 Panel PV Monitoring Process Using Node-RED

The first stage involves sending sensor reading data from the ESP8266 to the Node-RED server. Figure 2 shows the Node-RED design used to process and display the received data on the dashboard. This flow design starts with obtaining data from the endpoint "/sensor-node-2" using the HTTP protocol. Data is sent from the ESP8266 via a POST request. When the data is received, the system responds with a status code of 200, indicating that the request from the ESP8266 has been successfully received. The data is then parsed by the JSON node, converting it from JSON format to a JavaScript object. The parsed data is processed by the JSON or URL Encoded node, which extracts the values of voltage, current, and power. After extraction, these data are forwarded to six different nodes for display on the dashboard. These nodes include gauge nodes to show real-time voltage, current, and power data, and chart nodes to visualize the data in graphical form.

Table 1. PV Specification

Features	**Value**
Type	Polycrystalline
Peak Power (P_{max})	50Wp
Voltage (V_{mp})	17.5V
Current (I_{mp})	2.9A
Open Circuit Voltage (V_{oc})	21.8V
Short Circuit Current (I_{sc})	3.17A

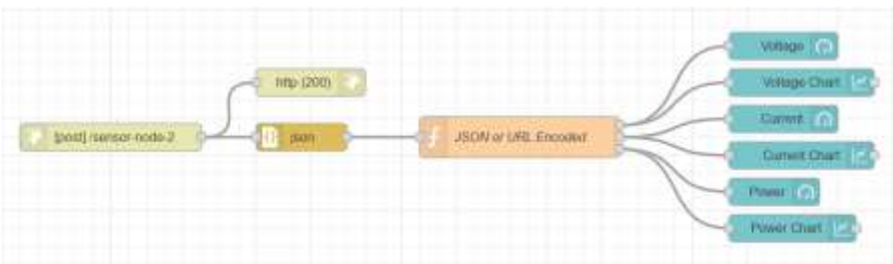

Fig. 2 Flow on Node-RED to Process Voltage, Current, and Power Data

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The next stage involves generating the total energy accumulation and daily average power. The design of this process is shown in Figure 3. This flow starts with the "get power" node, which calculates the electrical power data by multiplying voltage with current. This data is then processed by the "Multiply" node for multiplication. Afterwards, the data is forwarded to several nodes to process and prepare the data before accumulation. The "Start of the day" node is used to initialize daily calculations at the beginning of the day. Next, the "1 hour" node sets the time interval for data collection every hour, which is then accumulated by the "Sum" node. This process is used to calculate the electrical energy gain. The accumulated data is then processed to convert the values into a decimal format with a message frequency limit of 1 message/minute. The final results are the total daily energy displayed by the "Total Energy Today" and "Energy Chart" nodes and the daily average power displayed by the "Average Power Today" node.

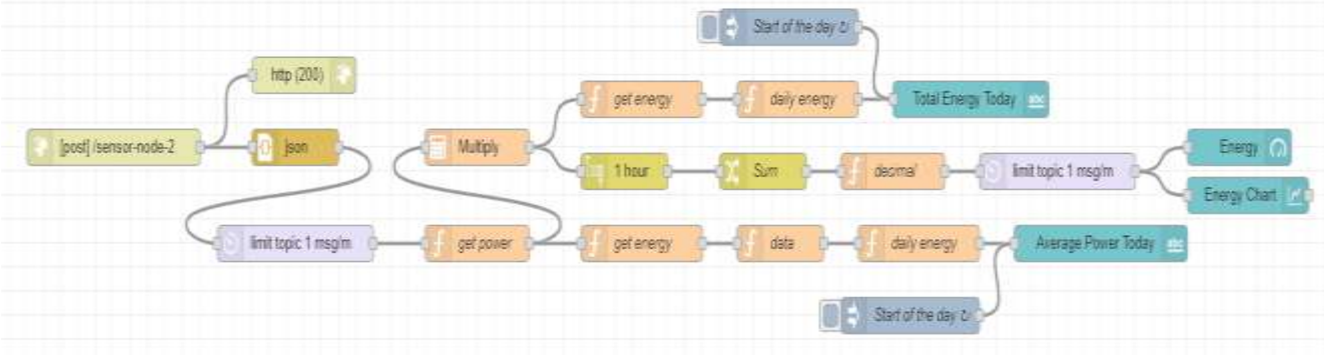

Fig. 3 Flow on Node-RED to Process Total Daily Energy and Average Daily Power

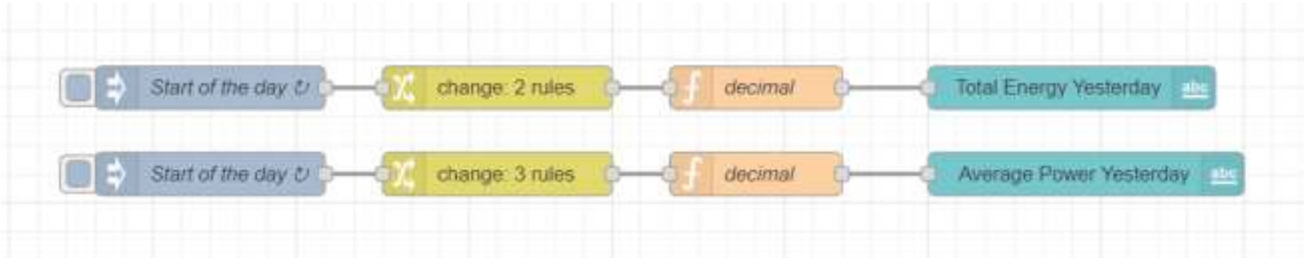

Fig. 4 Flow on Node-RED to Process Previous Total Energy and Average Previous Power

The next stage involves calculating and displaying the previous day's total energy and daily average power. The design of this process is shown in Figure 4. The system starts with the "Start of the day" node, which initializes the process at the beginning of the day. There are two parallel flows for calculating total energy and average power. This flow is designed to provide an overview of the total energy and average power used on the previous day, allowing for analysis to determine any increases or decreases in the PV performance.

RESULT

The results of the PV panel monitoring system design using Node-RED are shown in Figure 5. The result is a dashboard that presents real-time monitoring data from the PV output, including voltage, current, power, and energy. Monitoring data is visualized in the form of indicators and graphs. Meanwhile, the statistical accumulation results are displayed in Figure 6. The statistical results shown include total daily energy and daily average power. This dashboard let users directly monitor the PV panel performance and analyze performance based on accumulated historical data. The collected data is then stored in a database for further analysis. Monitoring was conducted throughout the day, from 7:30 AM to 5:30 PM, for three consecutive days. The power and energy monitoring results are presented in Figures 7, 8, and 9.

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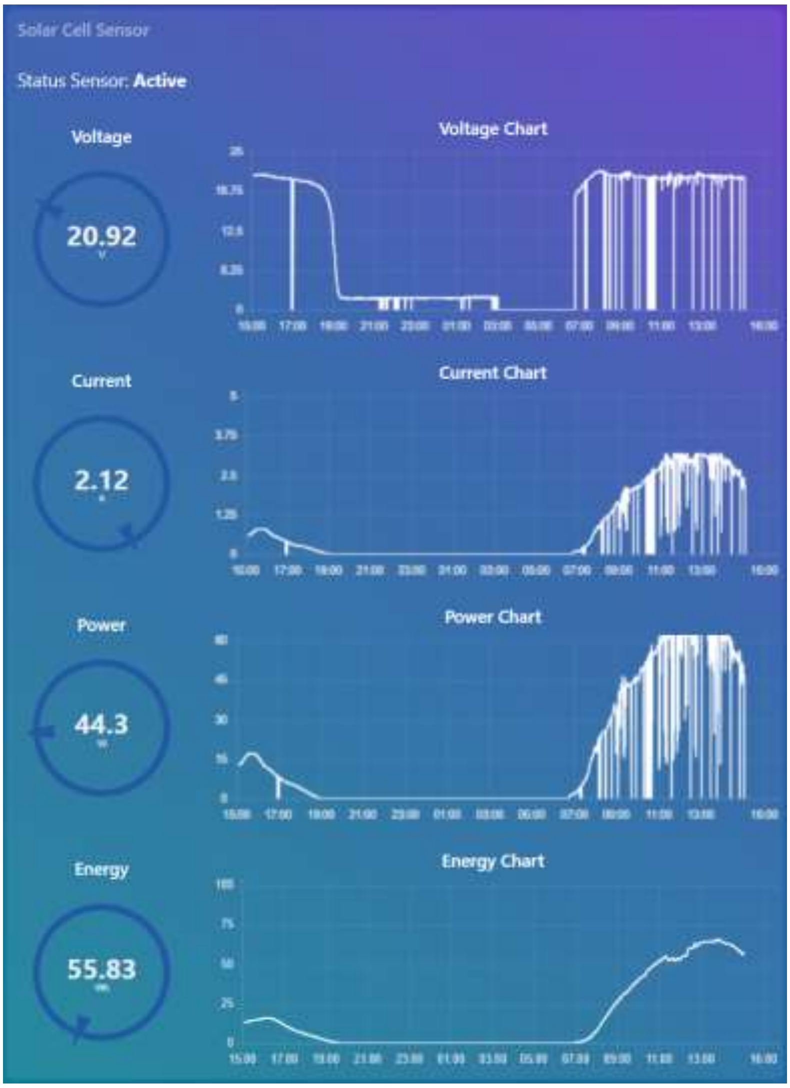

Fig. 5 Interface Display of PV Monitoring Dashboard using Node-RED

Fig. 6 Statistical Results from PV

The graph in Figure 7(a) shows that the electrical power obtained on the first day experienced significant fluctuations. Power increased gradually, peaking between 9:00 and 12:00, then decreased steadily until the evening. Meanwhile, the graph in Figure 7(b) shows that the electrical energy produced by the PV system increased consistently throughout the morning, reaching a peak between 10:30 and 14:30, then decreasing until the evening. The graph in Figure 8(a) indicates that the electrical power on the second day increased gradually from the morning, peaking between 10:30 and 12:30, then dropped sharply and stabilized at a low level until the end of the measurement period. The graph in Figure 8(b) shows that electrical energy increased gradually with two peaks, around 11:00 and 12:30, then decreased

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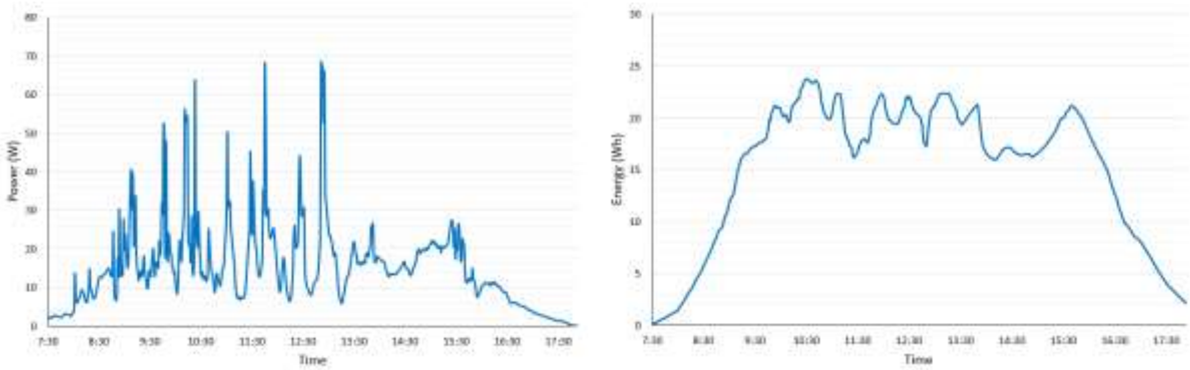
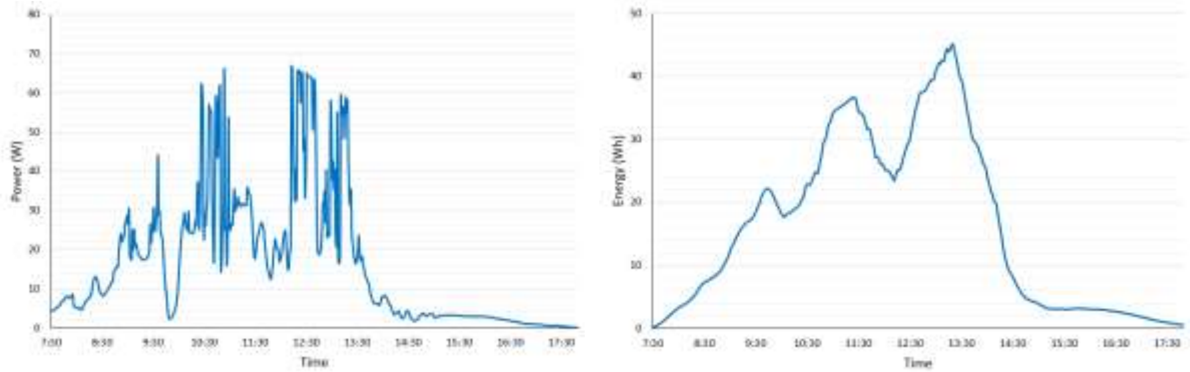
significantly and stabilized until the end of the measurement period. The graph in Figure 9(a) illustrates that electrical power on the third day increased gradually from 7:30, reaching a peak around 12:30 with sharp fluctuations, and then decreased gradually until 17:30. The graph in Figure 9(b) shows that electrical energy increased gradually from 7:30, peaked around 12:30, followed by a temporary decrease before reaching a second peak around 14:30, and then decreased until the end of the observation period at 17:30.



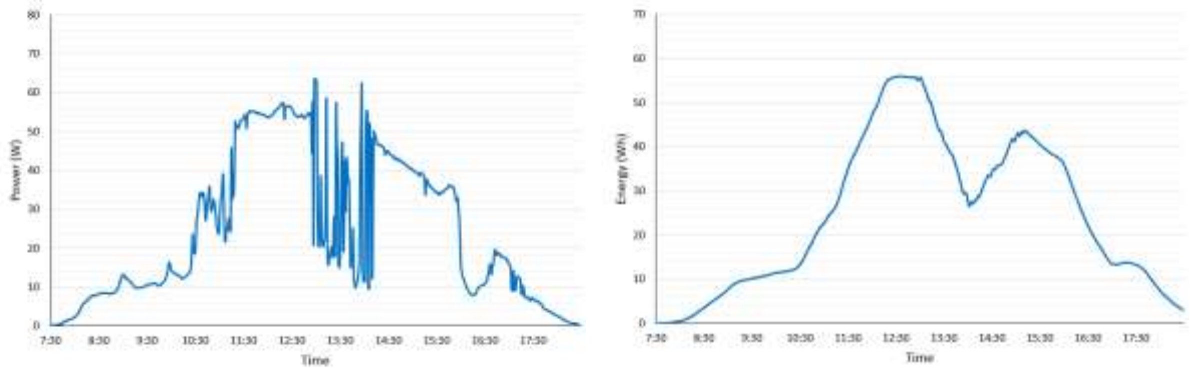
(a) (b)

Fig. 7 The Results of Obtaining Output PV on First Day: (a) Electrical Power and (b) Electrical Energy



(a) (b)

Fig. 8 The Results of Obtaining Output PV on Second Day: (a) Electrical Power and (b) Electrical Energy



(a) (b)

Fig. 9 The Results of Obtaining Output PV on Third Day: (a) Electrical Power and (b) Electrical Energy

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DISCUSSIONS

Based on the monitoring results, it can be observed that the electrical power and energy produced by the PV panel increase during the daytime, reaching a peak around midday and then decreasing towards the evening. This information is crucial for analyzing the performance and efficiency of the PV panel, and for better planning of maintenance and energy management.

Table 2 presents the accumulation results from monitoring the PV panel over three consecutive days. On the first day, the PV panel generated an average voltage of 19.34V and an average current of 0.76A, resulting in an average power of 15.05W and a total energy of 156.29Wh. On the second day, the average voltage slightly decreased to 18.74V, but the average current increased to 0.80A, leading to an increase in average power to 15.94W and a total energy output of 164.69Wh. On the third day, there was a significant increase in all parameters. The average voltage was recorded at 19.35V, with a sharp increase in average current to 1.22A. The average power generated reached 24.30W, a significant improvement compared to the previous days. The total energy produced on the third day also experienced a substantial surge, reaching 267.32Wh.

Based on the data, there is variation in the performance of the PV panel from day to day. The third day showed a significant performance improvement compared to the previous two days regarding voltage, current, power, and total energy produced. Factors such as sunlight intensity, weather conditions, and the efficiency of the PV panel are likely contributing to this daily variation.

However, this research has some limitations. First, the monitoring system was only tested under specific environmental conditions and within a limited time frame. Variations in weather and more extreme sunlight intensities have yet to be thoroughly analyzed. Second, the data generated are still limited to a laboratory scale and have yet to be tested on a larger scale or under real-world field conditions. Third, aspects of data security and privacy in this IoT system have yet to be a primary focus of this research, and they will need to be addressed in broader implementations.

Table 2. The Result of Daily PV Output

Day	Average Voltage (V)	Average Current (A)	Average Power (W)	Total Energy (Wh)
1	19.34	0.76	15.05	156.29
2	18.74	0.80	15.94	164.69
3	19.35	1.22	24.30	267.32

CONCLUSION

Based on the research conducted, the IoT-based PV panel monitoring system using Node-RED and the ESP8266 module has been successfully implemented. The system effectively monitors real-time critical parameters such as voltage, current, power, and electrical energy. It provides data visualization through indicators and graphs on the dashboard. Statistical analysis results indicate that the system effectively calculates daily average power and total energy produced by the PV panel. Performance improvements of the PV system can be identified, and issues that may arise, such as decreased panel performance or system disturbances, can be promptly addressed. Thus, this system offers significant benefits in terms of maintenance and management of the PV system and supports the broader development of renewable energy.

REFERENCES

Adhya, S., Saha, D., Das, A., Jana, J., & Saha, H. (2016). An IoT based smart solar photovoltaic remote monitoring and control unit. *2nd International Conference on Control, Instrumentation, Energy and Communication, (CIEC)*, 432–436. https://doi.org/10.1109/CIEC.2016.7513793

Anam, K., Rofi, D. N., & Meiyanti, R. (2023). Monitoring System for Temperature and Humidity Sensors in the Production Room Using Node-Red as the Backend and Grafana as the Frontend. *Journal of Systems Engineering and Information Technology (JOSEIT)*, *2*(2), 68–76. https://doi.org/10.29207/joseit.v2i2.5222

*name of corresponding author

Andi, K., Kusumanto, R., & Yusi, S. (2023). IoT Monitoring for PV System Optimization in Hospital Environment Application. *Journal of Multidisciplinary Academic and Practice Studies*, *1*(4), 369–376. https://doi.org/10.35912/jomaps.v1i4.1792

Asante, J., & Olsson, J. (2016). *Using Node-Red to Connect Patient, Staff and Medical Equipment*. 1–77. https://www.diva-portal.org/smash/get/diva2:949264/FULLTEXT01.pdf

Badii, C., Bellini, P., Cenni, D., Mitolo, N., Nesi, P., Pantaleo, G., & Soderi, M. (2020). Industry 4.0 Synoptics Controlled by IoT Applications in Node-RED. *International Conferences on Internet of Things (IThings) and IEEE Green Computing and Communications (GreenCom) and IEEE Cyber, Physical and Social Computing (CPSCom) and IEEE Smart Data (SmartData) and IEEE Congress on Cybermatics (Cybermatics)*, *5*, 54–61. https://doi.org/10.1109/iThings-GreenCom-CPSCom-SmartData-Cybermatics50389.2020.00028

Baruah, D. J. (2021). Design and Develop Transformer Monitoring System using Node-MCU and Real Time IoT Platform Connected using Node-Red. *International Journal for Research in Applied Science and Engineering Technology*, *9*(1), 562–568. https://doi.org/10.22214/ijraset.2021.32886

Bin Mohd Nazri, M. S., Long Alif Faiqal Bin Tengku Long Gaafar, T., Sofian, H., & Bakar Sajak, A. A. (2020). IoT Parking Apps with Car Plate Recognition for Smart City using Node Red. *11th International Conference on Information and Communication Systems (ICICS)*, 324–330. https://doi.org/10.1109/ICICS49469.2020.239511

Blessing Ngonidzashe, M., & Tuncay, E. (2023). A Simple Node-RED Implementation for Digital Twins in the Area of Manufacturing. *Trends in Computer Science and Information Technology*, *8*(2), 050–054. https://doi.org/10.17352/tcsit.000068

Chandra, M. B., Puneeth, K., & Dubey, G. (2021). Moisture Level Sensor Using Node-RED. *International Journal of Scientific Research in Computer Science, Engineering and Information Technology*, *7*(2), 406–412. https://doi.org/10.32628/CSEIT217283

Chanthakit, S., & Rattanapoka, C. (2018). MQTT Based Air Quality Monitoring System using Node MCU and Node-RED. *Seventh ICT International Student Project Conference (ICT-ISPC)*, 1–5. https://doi.org/10.1109/ICT-ISPC.2018.8523891

Chooruang, K., & Meekul, K. (2018). Design of an IoT Energy Monitoring System. *16th International Conference on ICT and Knowledge Engineering (ICT&KE)*, 1–4. https://doi.org/10.1109/ICTKE.2018.8612412

Clerissi, D., Leotta, M., Reggio, G., & Ricca, F. (2018). Towards an Approach for Developing and Testing Node-RED IoT Systems. *Proceedings of the 1st ACM SIGSOFT International Workshop on Ensemble-Based Software Engineering*, 1–8. https://doi.org/10.1145/3281022.3281023

Deriche, M., Raad, M. W., & Suliman, W. (2019). An IoT Based Sensing System for Remote Monitoring of PV Panels. *16th International Multi-Conference on Systems, Signals & Devices (SSD)*, 393–397. https://doi.org/10.1109/SSD.2019.8893161

Deshmukh, N. S., & Bhuyar, D. L. (2018). A Smart Solar Photovoltaic Remote Monitoring and Controlling. *Second International Conference on Intelligent Computing and Control Systems (ICICCS)*, 67–71. https://doi.org/10.1109/ICCONS.2018.8663127

Domínguez, M., González-Herbón, R., Rodríguez-Ossorio, J. R., Fuertes, J. J., Prada, M. A., & Morán, A. (2020). Development of a Remote Industrial Laboratory for Automatic Control based on Node-RED. *IFAC-PapersOnLine*, *53*(2), 17210–17215. https://doi.org/10.1016/j.ifacol.2020.12.1741

Durairaj, C., Shivakumar, D., Balaji, H., Selvam, K., & Narayanan, J. S. (2024). IoT Based Water Quality Monitoring System. *AIP Conference Proceedings*, *4*(3), 28–33. https://doi.org/10.1063/5.0190341

Hasni, N., & Saparudin, F. A. (2023). Water Level Monitoring System User Interface Using Node-Red. *Progress in Engineering Application and Technology*, *4*(2), 403–414.

Hassan, M. N., Islam, M. R., Faisal, F., Semantha, F. H., Siddique, A. H., & Hasan, M. (2020). An IoT Based Environment Monitoring System. *3rd International Conference on Intelligent Sustainable Systems (ICISS)*, 1119–1124. https://doi.org/10.1109/ICISS49785.2020.9316050

Kamarozaman, N. Bin, & Awang, A. H. (2021). IoT Covid-19 Portable Health Monitoring System using Raspberry Pi, Node-Red and ThingSpeak. *IEEE Symposium on Wireless Technology & Applications (ISWTA)*, 107–112. https://doi.org/10.1109/ISWTA52208.2021.9587444

Kanagachidambaresan, G. R. (2021). *Role of Single Board Computers (SBCs) in Rapid IoT Prototyping*. Springer International Publishing. https://doi.org/10.1007/978-3-030-72957-8

Kavitha, V., & Malathi, V. (2019). A Smart Solar PV Monitoring System Using IoT. *First International Conference on Secure Reconfigurable Architectures & Intelligent Computing (SRAIC)*, 19–33. https://doi.org/10.5121/csit.2019.91502

Kekre, A., & Gawre, S. K. (2017). Solar Photovoltaic Remote Monitoring System Using IoT. *International Conference on Recent Innovations in Signal Processing and Embedded Systems (RISE)*, 619–623. https://doi.org/10.1109/RISE.2017.8378227

Khan, M. S., Sharma, H., & Haque, A. (2019). IoT Enabled Real-Time Energy Monitoring for Photovoltaic Systems. *International Conference on Machine Learning, Big Data, Cloud and Parallel Computing (COMITCon)*, 323–327. https://doi.org/10.1109/COMITCon.2019.8862246

Kodali, R. K., & Anjum, A. (2018). IoT Based Home Automation Using Node-RED. *Second International Conference on Green Computing and Internet of Things (ICGCIoT)*, 386–390. https://doi.org/10.1109/ICGCIoT.2018.8753085

Kumar, N. M., Atluri, K., & Palaparthi, S. (2018). Internet of Things (IoT) in Photovoltaic Systems. *National Power Engineering Conference (NPEC)*, 1–4. https://doi.org/10.1109/NPEC.2018.8476807

Kusznier, J., & Wojtkowski, W. (2021). IoT Solutions for Maintenance and Evaluation of Photovoltaic Systems. *Energies*, *14*(24), 8567. https://doi.org/10.3390/en14248567

Lekic, M., & Gardasevic, G. (2018). IoT Sensor Integration to Node-RED Platform. *17th International Symposium INFOTEH-JAHORINA (INFOTEH)*, 1–5. https://doi.org/10.1109/INFOTEH.2018.8345544

Lu, C.-Y., Chen, F.-H., Hsu, W.-C., Yang, Y.-Q., & Su, T.-J. (2020). Constructing Home Monitoring System with Node-RED. *Sensors and Materials*, *32*(5), 1701–1710. https://doi.org/10.18494/SAM.2020.2686

Sinkron : Jurnal dan Penelitian Teknik Informatika
Volume 8, Number 3, July 2024 e-ISSN : 2541-2019
DOI : https://doi.org/10.33395/sinkron.v8i3.13929 p-ISSN : 2541-044X

Macheso, P., Manda, T. D., Chisale, S., Dzupire, N., Mlatho, J., & Mukanyiligira, D. (2021). Design of ESP8266 Smart Home Using MQTT and Node-RED. *International Conference on Artificial Intelligence and Smart Systems (ICAIS)*, 502–505. https://doi.org/10.1109/ICAIS50930.2021.9396027

Magtibay, O. B. M. (2019). Applying MQTT Protocol and Node-Red Programming in Designing loT based Home Automation. *International Journal of Advanced Science and Convergence (IJASC)*, *1*(3), 7–12. https://doi.org/10.22662/IJASC.2019.1.3.007

Mois, G., Folea, S., & Sanislav, T. (2017). Analysis of Three IoT-Based Wireless Sensors for Environmental Monitoring. *IEEE Transactions on Instrumentation and Measurement*, *66*(8), 2056–2064. https://doi.org/10.1109/TIM.2017.2677619

Nugraha, H., Hermawan, A. D., Mulya, M. A. J., Firmansyah, I., & Suryadi. (2023). Temperature Sensor Integration into the Node-RED Platform for Transformer Monitoring. *The 4th Engineering Physics International Conference (EPIC)*, 1–7. https://doi.org/10.1088/1742-6596/2673/1/012037

Pavithra, D., & Balakrishnan, R. (2015). IoT based Monitoring and Control System for Home Automation. *Global Conference on Communication Technologies (GCCT)*, 169–173. https://doi.org/10.1109/GCCT.2015.7342646

Perumal, T., Sulaiman, M. N., & Leong, C. Y. (2015). Internet of Things (IoT) Enabled Water Monitoring System. *IEEE 4th Global Conference on Consumer Electronics (GCCE)*, 86–87. https://doi.org/10.1109/GCCE.2015.7398710

Ramu, S. K., Irudayaraj, G. C. R., & Elango, R. (2021). An IoT-Based Smart Monitoring Scheme for Solar PV Applications. In *Electrical and Electronic Devices, Circuits, and Materials* (pp. 211–233). Wiley. https://doi.org/10.1002/9781119755104.ch12

Roslidar, R., Karnaini, K., & Arif, T. Y. (2023). IoT based System for Air Pollution Monitoring in Banda Aceh. *Jurnal Rekayasa Elektrika*, *19*(3), 93–99. https://doi.org/10.17529/jre.v19i3.28686

Sharmad, P. (2016). Thingspeak Based Sensing and Monitoring System for IoT with Matlab Analysis. *International Journal of New Technology and Research (IJNTR)*, *2*(6), 19–23.

Shrihariprasath, B., & Rathinasabapathy, V. (2016). A Smart IoT System for Monitoring Solar PV Power Conditioning Unit. *World Conference on Futuristic Trends in Research and Innovation for Social Welfare (WCFTR)*, 1–5. https://doi.org/10.1109/STARTUP.2016.7583930

Suhartinah, Berchmans, H. J., Nasution, H., FA, M. J., Tarigan, E. F., & M, E. S. (2021). Development of Environmental Testing Chamber Monitoring System Using Node Red. *Conference on Management and Engineering in Industry (CMEI)*, 44–47.

Tellawar, M. P. (2019). An IoT based Smart Solar Photovoltaic Remote Monitoring System. *International Journal of Engineering Research & Technology*, *8*(09), 235–240.

Tricomi, G., Benomar, Z., Aragona, F., Merlino, G., Longo, F., & Puliafito, A. (2020). A NodeRED-based Dashboard to Deploy Pipelines on Top of IoT Infrastructure. *IEEE International Conference on Smart Computing (SMARTCOMP)*, 122–129. https://doi.org/10.1109/SMARTCOMP50058.2020.00036

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Sinkron : Jurnal dan Penelitian Teknik Informatika
Volume 8, Number 3, July 2024 e-ISSN : 2541-2019
DOI : https://doi.org/10.33395/sinkron.v8i3.13929 p-ISSN : 2541-044X

Zare, A., & Iqbal, M. T. (2020). Low-Cost ESP32, Raspberry Pi, Node-Red, and MQTT Protocol Based SCADA System. *IEEE International IOT, Electronics and Mechatronics Conference (IEMTRONICS)*, 1–5. https://doi.org/10.1109/IEMTRONICS51293.2020.9216412

Zickri, Z., Novandri, A., Adriman, R., & Nasaruddin. (2023). Shrimp Pond Monitoring System using Cooperative Wireless Sensor Network Multi-Hop Technique based on Internet of Things. *Jurnal Nasional Teknik Elektro*, *1*, 56–63. https://doi.org/10.25077/jnte.v12n3.1133.2023

*name of corresponding author