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Implementation and Analysis of Photovoltaic Microgrid Monitoring by using WLAN and LoRaWAN

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Abstract*: This project implemented and analyzed a photovoltaic microgrid monitoring system utilizing LoraWAN and WLAN communication protocols. A Raspberry Pi Pico microcontroller was employed for data acquisition, successfully measuring key parameters including voltage, current, temperature, humidity, and light intensity of the photovoltaic microgrid. The implementation aligns with the increasing need for effective monitoring of solar PV systems, as highlighted in the sources for performance evaluation, fault detection, and optimization of energy generation. The use of LoraWAN was explored for its potential in long-range, low-power communication, while WLAN provided a means for potentially higher bandwidth data transmission and remote access to the monitoring data. By collecting and analyzing these parameters, the project contributes to a better understanding of photovoltaic microgrid operation, in line with the broader applications of IOT in renewable energy management.*

Keywords: LoRaWAN, WLAN, Raspberry Pi Pico, Data Acquisition, Sensors, Photovoltaic Microgrid

I. INTRODUCTION

The increasing global demand for energy is driving a significant expansion in renewable energy sources, with solar photovoltaic (PV) systems playing a pivotal role in sustainable energy generation. To ensure the optimal performance and reliability of these PV installations, effective monitoring systems are essential. This need is particularly pronounced in the context of microgrids, which are localized energy networks that can integrate various distributed energy resources, including solar PV. Comprehensive monitoring within a photovoltaic microgrid allows for a deeper understanding of its operation, facilitates performance evaluation, enables fault detection, and supports strategies for energy management and optimization.

This project addresses the critical need for advanced monitoring by focusing on the implementation and analysis of a photovoltaic microgrid monitoring system. The system leverages a Raspberry Pi Pico microcontroller for efficient data acquisition from the microgrid's PV components. Utilizing this microcontroller, the project successfully monitors key operational and environmental parameters, specifically voltage and current to determine power output, as well as temperature, humidity, and light intensity to assess the conditions influencing the PV system's performance. The monitoring system employs a dual communication approach, integrating LoraWAN (Long Range Wide Area Network) and WLAN (Wireless Local Area Network) protocols. This combination aims to capitalize on the long-range, low-power capabilities of LoraWAN for distributed sensing and the potentially higher bandwidth of WLAN for more intensive data transmission and remote accessibility. By acquiring and analyzing these crucial parameters, this project contributes to a more detailed understanding of photovoltaic microgrid behavior, aligning with the broader advancements in Internet of Things (IOT) based solutions for renewable energy management.

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II. METHODOLOGY

To design a photovoltaic (PV) microgrid monitoring system using LoRaWAN and WLAN technologies, it's essential to develop methodologies that ensure efficient data acquisition, transmission, and analysis. By examining existing research and implementations, we can derive the following methodologies:

System Architecture Design:

- *LoRaWAN Integration:* Utilize LoRaWAN modules to transmit data from sensors measuring parameters like voltage, current, and temperature. LoRaWAN's long-range and low-power characteristics make it suitable for expansive PV installations.
- *WLAN Integration*: Implement WLAN for high-speed data transmission within localized areas of the microgrid, facilitating real-time monitoring and control.

Data Acquisition and Transmission:

- *Sensor Deployment:* Install sensors at critical points to monitor parameters such as irradiance, module temperature, and power output.
- *Communication Protocols:* Employ MQTT over LoRaWAN for efficient, low-bandwidth data transmission, and HTTP/HTTPS over WLAN for higher bandwidth requirements.

Network Topology:

- *Hybrid Approach:* Combine LoRaWAN for long-distance, low-power communication with WLAN for high-speed, short-range data transfer, optimizing both coverage and performance.

Data Management:

- *Cloud Integration:* Transmit collected data to cloud platforms for storage, processing, and visualization, enabling remote monitoring and analysis.

Performance Evaluation:

- *Parameter Analysis:* Assess network performance by measuring latency, packet loss, RSSI, and coverage area to ensure reliable data transmission.

Security Measures:

- *Data Encryption:* Implement encryption protocols to secure data transmitted over both LoRaWAN and WLAN networks, protecting against unauthorized access.

By integrating these methodologies, a robust and efficient PV microgrid monitoring system can be established, leveraging the strengths of both LoRaWAN and WLAN technologies.

III. PROJECT IMPLEMENTATION

1. Overview:

The project aims to implement a photovoltaic microgrid monitoring system using a combination of LoraWAN and WLAN technologies. This section will detail the step-by-step implementation process, including hardware setup, software configuration, and integration of components.

2. Hardware Setup (Components Used):

Solar panel: The solar panel serves as the primary energy source for the microgrid. It converts sunlight into electrical energy, which is then monitored by the sensors.

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Other hardware components include: Raspberry Pi (Pico), LCD, Current sensor, Voltage sensor, DHT sensor, LDR sensor, Nodemcu, and LORAWAN. The implementation diagrams (discussed previously) illustrate the connections between these components in the transmitter and receiver units.

3. Implementation Diagrams:

The project utilizes block diagrams to illustrate the hardware setup:

Transmitter Block Diagram: This diagram illustrates the connection between the Raspberry Pi, sensors (voltage, current, LDR, DHT), LCD, and Lora transmitter. It visually represents how data is collected from the solar panel and environment and prepared for wireless transmission.

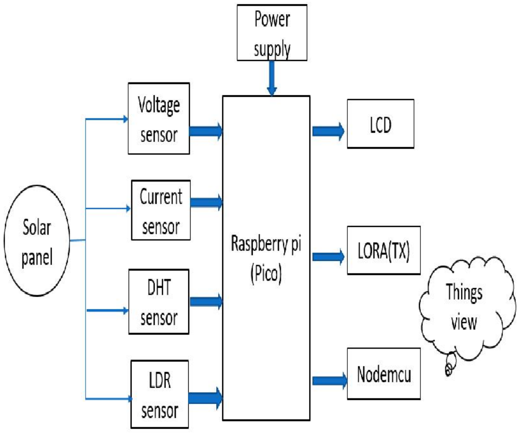


Fig 1:Transmitter Block Diagram

Receiver Block Diagram: This diagram shows the setup of the Raspberry Pi (or potentially a combination with NodeMCU), Lora receiver, and LCD for displaying received data. It outlines how the transmitted data is received and initially displayed before being forwarded to the IOT platform.

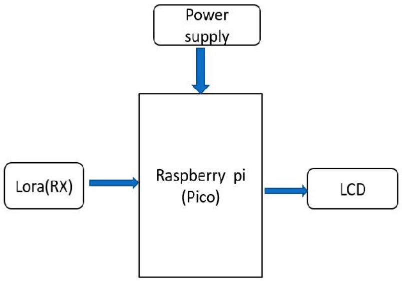


Fig 2:Receiver Block Diagram

4. Software Configuration Development Environment:

The following software tools are used in the project:

*Thonny (Version 4.1.7):*This IDE is used for writing and executing Python scripts on the Raspberry Pi (Pico).

Micro Python: This is the programming language utilized for coding the Raspberry Pi and NodeMCU.

Sensor Data Collection: Software scripts are developed to read data from each sensor and format it for transmission.

Data Transmission: Code is implemented to send the collected data from the Lora transmitter to the NodeMCU (via the receiver unit).

Data Processing: Scripts are used on the NodeMCU to receive data and forward it to the IOT platform (Thing Speak).

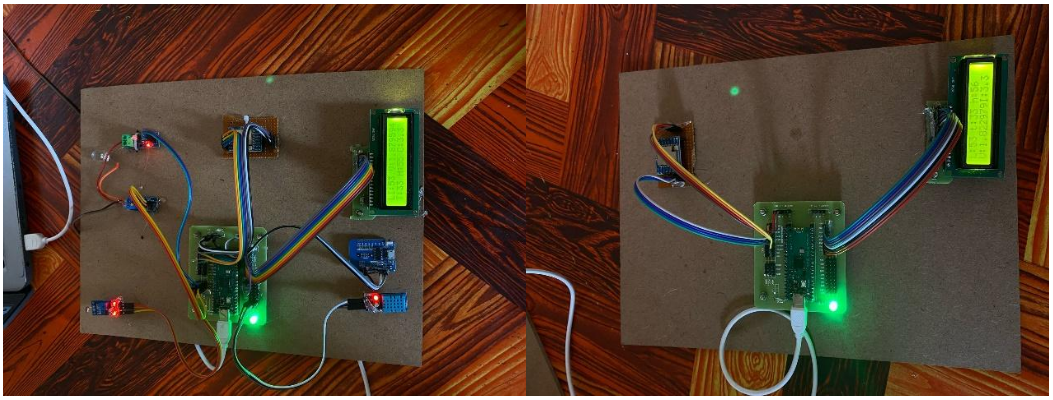
5. Integration Connecting Components:

The implementation involves the following key integration steps:
Ensuring that all sensors are properly connected to the Raspberry Pi.
Setting up the Lora transmitter and receiver for effective communication.
Connecting the NodeMCU to the WLAN for data transmission to the IOT platform.

This section lays the groundwork for understanding how the hardware and software components are brought together to create the complete monitoring system. The subsequent "Testing and Validation" section will then assess the functionality of this implemented system

IV. LABOARTORY SETUP

Transmitter Receiver



V. RESULT AND DISCUSSION

The implemented photovoltaic microgrid monitoring system yielded the following key results:

- *Local Sensor Readings*: The Lora transmitter unit displayed real-time sensor data (voltage, current, light intensity, temperature, humidity) on its LCD, providing immediate on-site feedback.
- *Successful Wireless Transmission*:Data was successfully transmitted wirelessly from the Lora transmitter to the receiver unit, establishing a functional LoraWAN communication link.
- *Remote Monitoring via Thing Speak*: The sensor data was successfully uploaded to the Thing Speak IOT platform, where it was visualized as "Things view outputs" (graphs, charts). This enabled remotemonitoring ofthe photovoltaic microgrid parameters through an internet connection. These visualizations likely included trends of solar panel voltage, current, power, light intensity, and environmental conditions over time

The results demonstrate the successful implementation of a real-time photovoltaic microgrid monitoring system using LoraWAN for data transmission and WLAN for uploading to the Thing Speak IOT platform. The local display on the transmitter and the remote visualizations on Thing Speak confirm the system's ability to provide up-to-date information on the microgrid's performance and environmental conditions. The successful data transfer highlights the effectiveness of both LoraWAN and WLAN for this application. The data collected on Thing Speak provides a valuable resource for future analysis of the solar panel's long-term performance.

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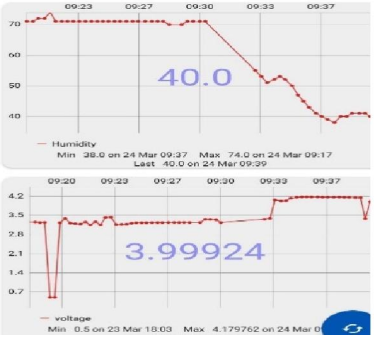
In the morning session:



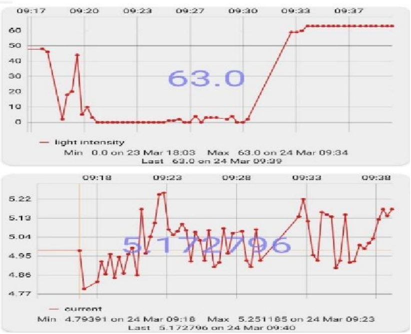


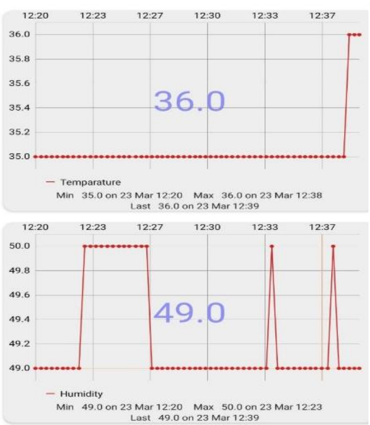
Fig A.1*Humidity & Voltage* Fig A.2*Temperature* Fig A.3*Light Intensity & Current*

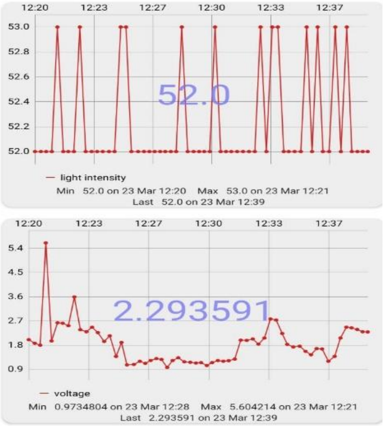
Humidity & Voltage: Humidity levels fluctuated between **38.0% at 09:37** and **74.0% at 09:17**, with a final recorded value of **40.0% at 09:39.** Monitoring humidity is essential to prevent equipment degradation and ensure the long-term stability of the photovoltaic system. Voltage readings indicated a **minimum of 0.5V on 23 Mar at 18:03**and a **maximum of approximately 4.18V on 24 Mar at 09:36,** with the last recorded value being **4.0V at 09:40.** Voltage plays a crucial role in determining the power output of solar panels and must be monitored to ensure optimal performance.

Temperature: The temperature readings ranged from a **minimum of 31.0°C at 09:17**to a **maximum of 42.0°C at 09:36,** with the last recorded value being **39.0°C at 09:40.** These fluctuations are typical in solar monitoring environments, as **temperature directly impacts the efficiency of photovoltaic systems.** Higher temperatures can reduce solar panel efficiency, making it essential to monitor and manage heat levels for sustained performance.

Light Intensity & Current: The **maximum recorded light intensity was 63.0 units at 09:34,** with the last recorded value also being **63.0 units at 09:39**. Light intensity is a critical factor in solar energy generation, as higher irradiance levels lead to increased power output. **Regular monitoring of light intensity** ensures that the photovoltaic system operates at peak efficiency during optimal sunlight conditions. Current readings ranged from a **minimum of approximately 4.79mA at 09:18** to a **maximum of about 5.25mA at 09:23,** concluding with a value of **approximately 5.17A at 09:40.** The **power output of the system is calculated using the formula: Power (W) = Voltage (V) × Current (mA).** Monitoring current fluctuations is essential to optimizing energy generation and ensuring the stability of the solar power system.

In the afternoon session:





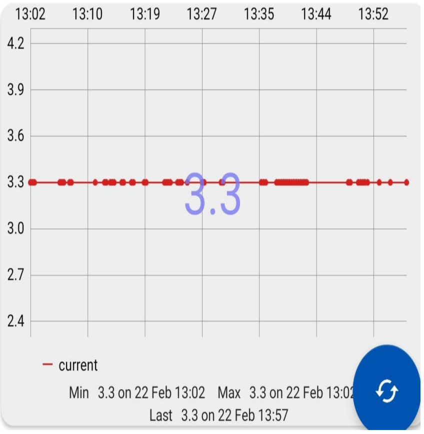


Fig B.1*Temperature & Humidity* Fig B.2*Voltage and Light Intensity* Fig B.3*Current*

Temperature and Humidity: The temperature ranged from a minimum of **35.0°C at 12:20 PM**to a maximum of **36.0°C at 12:38PM,** with the last recorded value being **36.0°C at 12:39 PM**. Humidity levels fluctuated between **49.0% at 12:20 PM** and **50.0% at 12:23 PM,** with a final recorded value of **49.0% at 12:39 PM**. These variations are typical in solar monitoring environments, as temperature and humidity significantly impact photovoltaic system performance.

Voltage and Light Intensity: Voltage readings ranged from a minimum of 0.97V at 12:28 PM to a maximum of 5.60V at 12:21 PM, with the last recorded value being 2.29V at 12:39 PM. monitoring voltage is important as it directly affects the power output of the solar panels. Variations in voltage can indicate changes in sunlight intensity or inefficiencies in the photovoltaic system. Similarly, light intensity influences solar panel efficiency, with a maximum recorded intensity of 53.0 units at 12:21 PM and a minimum of 52.0 units at 12:20 PM, concluding at 52.0 units at 12:39 PM. Since higher irradiance levels lead to increased power generation, regular monitoring of light intensity and voltage helps ensure efficient energy harnessing and optimal performance of the photovoltaic system.

Current: The current remained steady at 3.3mA from 13:02 PM to 13:57 PM without any significant variations. A stable current flow is essential for consistent energy generation, as fluctuations can affect the overall power output of the system. Since power is calculated using the formula Power (W) = Voltage (V) × Current (mA), maintaining an optimal current level is crucial for ensuring efficient solar energy production and maximizing the performance of the photovoltaic system.

In the evening session:

Fig C.1*Voltage& Humidity*

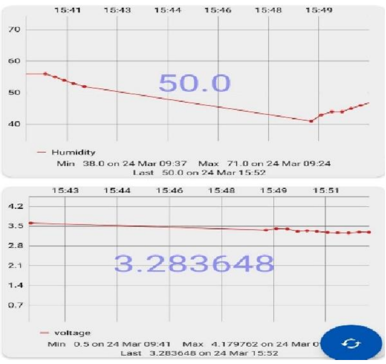


Fig C.2*Temperature & Current*

Fig C.3*Light Intensity:*

Voltageand Humidity: During the evening, voltage and humidity play a crucial role in the overall efficiency and stability of the solar energy system. Voltage readings varied between a minimum of 0.5V at 15:41 PM and a maximum of 4.179V at 15:24 PM, with the last recorded value being 3.283V at 15:52 PM. These fluctuations indicate variations in solar energy conversion efficiency, but the stability of voltage in the evening ensures continuous energy generation. Meanwhile, humidity levels fluctuated between 38.0% at 15:37 PM and 71.0% at 15:24 PM, eventually stabilizing at 50.0% at 15:52 PM. Monitoring humidity levels is essential to prevent system degradation and ensure long-term operational stability.

Temperature and Current: Temperature and current significantly influence the performance of photovoltaic systems. During the evening, the temperature ranged from a minimum of 32.0°C at 15:24 PM to a maximum of 42.0°C at 15:36 PM, with the last recorded value being 36.0°C at 15:52 PM. Excessive heat can reduce solar panel efficiency, making temperature regulation a key factor in sustaining energy production. The current ranged from 4.89mA at 15:38 PM to 5.22mA at 15:33 PM, concluding with 4.972A at 15:52 PM. Since power output is determined using the formula Power (W) = Voltage (V) × Current (mA), maintaining a stable current flow ensures optimal energy production while minimizing fluctuations in power generation.

Light Intensity: Light intensity played a significant role in the system's performance, with the highest recorded value being **63.0 units at 15:34 PM** and the last recorded value at **61.0 units at 15:52 PM**. Since light intensity directly affects solar panel efficiency, its gradual decline in the evening indicates a reduction in available sunlight, which in turn

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impacts power generation. Regular monitoring of light intensity is essential for assessing photovoltaic performance and ensuring optimal energy harvesting during peak hours.

VI. CONCLUSION

In this study, a solar power monitoring system was successfully developed using a microcontroller, PV panel, sensors, and a battery charging module. The system enables real-time data collection from remote locations and continuously tracks key parameters such as voltage, current, temperature, humidity, and light intensity through a graphical user interface (GUI). With IOT integration, the system allows continuous monitoring and recording of environmental and electrical parameters, providing valuable insights for performance analysis.

The collected real-time data can be utilized for forecasting power generation potential, estimating revenue, and optimizing solar panel efficiency. By implementing this IOT-based monitoring system, data analysis is enhanced, reducing the need for manual intervention and improving overall operational efficiency. This approach also minimizes maintenance requirements while ensuring better network management and system reliability.

As solar radiation levels vary based on location and time, optimizing power output requires effective tracking of sunlight exposure. A **Solar Power Tracking System** can be integrated to adjust the panel's position for maximum energy absorption. Additionally, the monitoring system can help identify any faults or inefficiencies in the setup, ensuring timely maintenance and improved performance of the solar PV system

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