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Digital twin technology for enhanced smart grid performance: integrating sustainability, security, and efficiency

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This research paper presents the development and analysis of a multifaceted smart grid prototype. It combines various technologies for the smart grid operation. The first technology is environmental analysis of smart grid and solar panel cleaning. Secondly, radio-frequency identification (RFID)-based security and access control system has been integrated for smart grid. The third component is internet of things (IoT)-based energy monitoring and load management. For environmental analysis sensors such as temperature, humidity, light-dependent resistor, and flame sensors are connected to a NodeMCU controller for real time monitoring. Moreover, IoT based solar cleaning system is developed in the form of prototype with the help of Blynk and servo motor. The second component of prototype is smart security system which is developed with the help of Arduino and RFID module to facilitate secure access control. The third part of prototype employs voltage and current sensors with an ESP32 microcontroller and the Blynk application for real-time energy consumption analysis. This setup enables remote monitoring of voltage, power dynamics, and consumption patterns in a smart grid. It also offers an IoT based solution for load management and load shedding within the smart grid.

Abbreviations: ACS, Alternating Current Sensor; ANN, Artificial Neural Network; ESP32, Espressif Systems' 32-bit microcontroller; IEEE, Institute of Electrical and Electronics Engineers; IoT, Internet of Things; LDR, Light-Dependent Resistor; LUBE, Lower Upper Bound Estimation; LoRa, Long Range (wireless communication protocol); LTE, Long-Term Evolution (a standard for wireless broadband communication); MABE, Multiple-Authority Attribute-Based Encryption; MFRC522, Magnetic Field Radio-Frequency Identification Module; MOSFET, Metal-Oxide-Semiconductor Field-Effect Transistor; NAN, Neighborhood Area Network; RFID, Radio-Frequency Identification; RES, Renewable Energy Sources; Sec., Security; UID, Unique Identifier; WSN, Wireless Sensor Network; WSOA, White Shark Optimization Algorithm.

The complete prototype overall demonstrates a comprehensive approach to 1) smart grid management, 2) environmental analysis, 3) security, and 4) energy monitoring.

KEYWORDS

energy distribution, energy efficiency, environmental sustainability, grid management, IoT, solar energy, smart grid, grid reliability

1 Introduction

1.1 Integrating environmental, security, and technological strategies in smart grid optimization-motivation of research

The environmental analysis of a smart gird is an important parameter that need to be considered. It provides real time information about air quality, weather conditions, and renewable energy potential (Ullah et al., 2023a; Zheng et al., 2024) of a smart grid. This information is used for 1) optimizing grid operations and 2) supporting resource efficiency. It also helps in 3) advancing sustainable energy practices in the dynamic landscape of smart grid technology (Sage, 2022; Ameur et al., 2023). Similarly, the security and authorized access within a smart grid is another critical parameter that required a complete infrastructure (Iqbal et al., 2022; Leila et al., 2023) against cyber threats and unauthorized access. An security infrastructure is always required in a smart grid that maintain the reliability, integrity, and confidentiality of data (Bolurian et al., 2023; Rehman et al., 2023a). This also ensure stability of smart grid systems and safeguard it against malicious activities (Alrumayh and Almutairi, 2023; Nikolakis et al., 2018). Moreover, in the smart grid with dust accumulation on solar panels challenges arise. This dust accumulation compromise energy efficiency and results in diminished power output (Badshah et al., 2024; Masood et al., 2018). Dust on the solar panels requires frequent cleaning that causes maintenance costs in remote locations. Anoth challenge in the smart grid environment is load management and power cutoff. The energy consumption and demand analysis in a smart grid is another crucial parameter that need attention (Ali et al., 2022; Rehman et al., 2023b). With the complete understanding of energy demand patterns, strategic load management can be done. All this can optimize electricity distribution and also prevent overloads (Pajares et al., 2023; ur Rehman et al., 2023). This approach contributes to grid stability. It prevents system failures during peak demand and also promote a balance between energy supply and consumption (Kazi et al., 2023). These strategies can enhance overall grid reliability and security. They can also minimize energy wastage and support a sustainable and cost-effective approach to energy distribution (Mounsif and Medard, 2023; Karunanidhi et al., 2024). So, this research is motivated by the need to integrate advanced digital tools and strategies in power grid for smart operation. This includes environmental analysis, security measures, and IoT-driven energy and load management. These approaches can collectively enhance the functionality and resilience of smart grids. Addressing these challenges is critical for meeting the evolving energy demands. It also ensures grid security and promote sustainable energy practices.

1.2 Integration of wireless sensor networks (WSNs)—focus of the research

This paper investigates the use of WSNs and IoT for the smooth operation within a smart grid. It explores role of WSNs for environmental analysis and energy management in grid systems. The proposed work also investigates radio-frequency identification (RFID) for the security in the grid. It designed a servo motor and IoT based solution for solar panel cleaning (Khan et al., 2020; Randriantsoa et al., 2021). The study analyzes grid efficiency, electrical load management, and power cutoff strategies with IoT. The study also proposed energy consumption and demand analysis for optimal utilization of resources in a smart grid. WSNs within a smart grid increase power grid efficiency, reliability, and sustainability. It enables real-time monitoring of environmental parameters and control of load management (Taylorfrancis, 2024; ur Rehman et al., 2022). WSNs assess factors like temperature, humidity, air quality, and light intensity within smart grid. They also support the optimal utilization of renewable energy resources. RFID-based security provide secure authentication and access for authorized personnel (Aslam et al., 2020). This is crucial component for sensitive locations like power substations. This ensures operational reliability and integrity in smart grids (Roudbari et al., 2021). Similarly regular cleaning of solar panels is essential to prevent dust accumulation (Yan et al., 2021; Yan et al., 2020). It directly impacts panel performance and it is crucial for maintaining optimal efficiency. This increased energy yield of solar panels and prolonged their life. IoT-based grid management optimizes efficiency and sustainability through real-time monitoring, load shifting, and rapid power cutoff (Papacharalampopoulos et al., 2023; Alsalloum et al., 2020). All the prototypes collectively enhance reliability, prevent overloads, and promote cost savings. Real-time monitoring feature in smart grids provides information about energy consumption and demand analysis (Rehman et al., 2024; Hakimi and Hasankhani, 2020). This leads to efficient load management and aligns energy consumption with renewables. Collectively it brings benefits like grid optimization and cost savings.

1.3 Literature review

This section explores various schemes that have been implemented in smart grid environments for security, energy and load management. The paper (Chen and Liu, 2024) addresses challenges in smart grids. It proposes a novel fault detection method using fuzzy machine learning. It also includes smart sensor metering which demonstrates high accuracy and reliability for improved grid performance. The study (Fotopoulou et al., 2024) presents a novel optimization algorithm for smart grids. It emphasizes increased autonomy by prioritizing renewable energy sources (RES). It utilizes artificial neural networks (ANN) for intermittent RES production forecasts. The algorithm reveals significant reductions in autonomy (up to 46.0%) during RES emergencies at noon and potential curtailments (up to 25.0%) during storage-related emergencies. The article (Akkara and Selvakumar, 2023) examines optimization methods for smart grids. It emphasizes cost control, distribution efficiency, and energy management, with a focus on demand-side operations. This highlights how smart meter-based systems excel in delivering and managing energy when compared to alternative control methods. The ref (Djebali et al., 2024). provides a comprehensive review of digital twins in the smart grid domain. It highlights data management, AI integration, and a collaborative framework for stakeholders. It explores applications in asset management, predictive maintenance, energy optimization, and demand response. It also identifies trends, challenges, and opportunities in the field. The study (Paspatis et al., 2024) suggests an advanced hardware-in-the-loop testing chain to investigate interactions among smart grid components during transient events. The model showcases its applicability through a case study on a microgrid transition algorithm.

The article (Rehman et al., 2022) compares technologies for smart grid neighborhood area networks (NANs). It evaluates IEEE 802.15.4 g, IEEE 802.11s, LoRa, and LTE. Unlike theoretical comparisons, it conducts simulations in grid-like and real-world scenarios, using metrics like Packet Delivery Ratio. Insights from the results aid in choosing the right technology for NANs in smart grids across various network scenarios. The research (Zafar et al., 2023) proposes a secure theft detection technique for smart grids. It uses deep federated learning with a convolutional gated recurrent unit (ConvGRU) model. The approach ensures privacy by training on distributed data. This achieves high accuracy and outperformance of existing methods. This technique holds promise for enhancing smart grid security and efficiency while preserving data privacy. The research (Ullah et al., 2023b) proposes an IoT-based monitoring and control system for integrated renewable energy resources in smart grids and power substations. It addresses challenges such as suboptimal resource allocation and poor load management. Results show improved load management, reduced energy costs, and suppressed carbon emissions. The results are validated through a constructed prototype for real-time monitoring and control of power distribution networks. The article (Meng and Wang, 2023) proposes an evolving-based prediction model for accurate short-term load forecasting in solar-based smart grids. It utilizes the innovative lower upper bound estimation (LUBE) trained on real-time data from the smart grid's digital twin. Enhanced by the white shark optimization algorithm (WSOA), the model demonstrates high accuracy and reliability on practical datasets. The model avoids smart metering device malfunctions for improved results. The ref (Liu et al., 2023) proposes a decentralized access control system with user revocation for smart grids. It addresses security threats and key escrow issues. It utilizes a multiple-authority attribute-based encryption (MABE) scheme. The system ensures data confidentiality and adapts to the decentralized smart grid environment. This demonstrates a trade-off between confidentiality, authentication, distribution, and efficiency.

1.4 Main contribution of the research

This research significantly contributes to advancing sustainable energy systems through the integration of digital twin modeling for smart grid optimization. Key contributions include and Figure 1 shows the graphical abstract of the paper.

1. WSN for Grid Environment Analysis: This study Introduces an enhanced environmental analysis using WSNs equipped with temperature, humidity, LDR, and flame sensors. This advancement enables real-time monitoring and support for efficient and sustainable power grid operations.
2. RFID-Based Smart Grid Security: This study investigates the development of a smart RFID-based grid security system to enhance grid resilience. This ensures smooth operations and prevents unauthorized access to the grid.
3. IoT-Based Smart Solar Cleaning: The proposed study provides innovative development of an IoT-based solar panel cleaning system. This addresses dust accumulation challenges and promotes increased energy yield and cost-effectiveness in solar energy production.
4. IoT-Based Energy Monitoring and Load Management: The study shows significant advancements in power distribution efficiency and sustainability through IoT technologies. Specifically, the research focuses on grid load management and power cutoff strategies. It also provides energy analysis for optimizing grid efficiency and integration of renewable resources.

Figure 1 shows a graphical abstract illustrating the comprehensive analysis of EV charging infrastructure.

2 Problem formulation and methodology

The real-time environmental conditions which include air quality and renewable energy potential pose a challenge to grid. To address this issue an advanced system using WSNs with temperature, humidity, LDR, and flame sensors is developed. This system enables real-time monitoring and sustainable power grid operations. The study employs cost-effective sensor nodes strategically placed within the grid for real-time monitoring. The system provides data analysis to optimize operations and promote sustainable power distribution. The solar panel cleaning system utilizes an ESP32 microcontroller with a servo motor. The ESP32 manages commands and directs the servo motor to execute specific, coordinated movements for effective cleaning. This combination ensures precise automation and the potential for IoT integration. This allows remote monitoring and control of the cleaning process. The tables highlight algorithms crucial for real-time environmental condition monitoring (Table 1), RFID-based smart grid

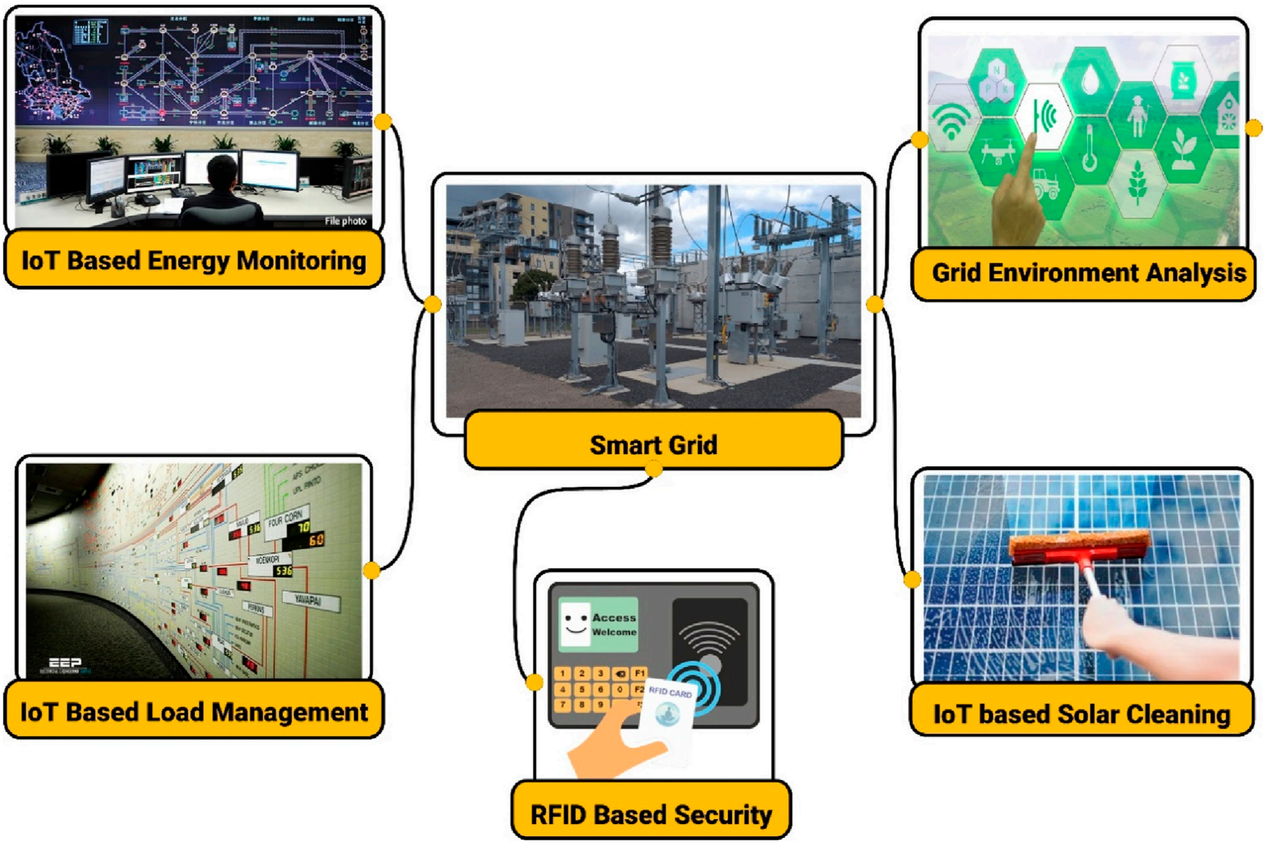

FIGURE 1
Graphical abstract: Digital twin modeling for smart grid optimization: Environmental analysis, security measures, solar panel efficiency, IoT-Driven grid management, and energy consumption dynamics.

security (Table 2), and energy monitoring with efficient load management (Table 3).

Securing smart grids involves a robust RFID-based system for human interaction, aiming to enhance grid resilience. The challenge lies in ensuring data integrity and confidentiality to prevent unauthorized access. Deployment includes integrating RFID at critical infrastructure points, with effectiveness assessed through simulations and real-world testing.

Table 1 explains algorithm for real-time environmental condition monitoring. It begins with initialization at lines one to three, including necessary libraries, defining pin configurations, and setting credentials. Blynk setup occurs at lines 4-6, initializing Blynk with authentication and WiFi details. Sensor and timer setup follows at lines 7-8, initializing a DHT sensor and creating a timer for periodic sensor data updates. Functions are defined at lines 9–13, including one to send sensor data to the Blynk app and another to control a servo motor based on an angle input. The Blynk callback function is defined at line 12 to execute servo control based on commands from the Blynk app. Setup tasks occur at lines 14–17, initiating serial communication, connecting to the Blynk server, and configuring sensors and timers. Finally, the main loop, running Blynk and timer tasks continuously, is described at line 18–19.

Efficient load management and power cutoff are vital for grid stability. Integrating IoT technologies, including real-time monitoring, load shifting, and rapid power cutoff, promotes a sustainable power distribution paradigm. This optimizes grid efficiency and integrates renewable resources. The study employs IoT technologies, utilizing real-time monitoring, load shifting, and rapid power cutoff mechanisms. Data analysis enhances grid efficiency and integrates renewable resources. The methodology involves the use of DC and voltage sensors in combination with ESP32 and relays.

Table 2 outlines a system for RFID-based access control. It begins with initialization at lines 1-4, including the inclusion of necessary libraries and setting up pins for RFID, LEDs, and a Servo motor, followed by the creation of instances for each component. The setup process is described at lines 5-7, where communication and hardware initialization occur, including connecting the Servo motor, defining pin modes, and initializing components. The main loop, detailed at lines 8–15, continuously looks for RFID cards (line 9), reads and verifies the card UID (line 10), and proceeds to authorization (line 11). If an authorized card is detected (line 12), access is granted, indicated by a green LED and Servo movement. However, if the card is invalid (line 14), unauthorized access is indicated with a red LED and a buzzer.

The methodological approach includes several key steps to ensure the robustness and effectiveness of the developed system for real-time environmental monitoring and efficient load management in smart grid systems.

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TABLE 1 Algorithm: Real-time environmental condition monitoring.

1. **Initialization:**
2. **Include** necessary libraries.
3. **Define** pin configurations and credentials.
4. **Blynk Setup:**
5. **Initialize** Blynk with authentication and WiFi details.
6. **Sensor and Timer Setup:**
7. **Initialize** DHT sensor and set pin modes.
8. **Create** a timer for periodic sensor data updates.
9. **Functions:**
10. **sendSensorData():** Read sensor values and send to Blynk app.
11. **controlServo(angle):** Control servo motor based on the angle.
12. **Blynk Callback:**
13. **BLYNK_WRITE(V0):** Execute servo control based on Blynk app commands.
14. **Setup:**
15. **Begin** serial communication.
16. **Connect** to Blynk server.
17. **Set up** sensors and timer.
18. **Main Loop:**
19. **Run** Blynk and timer tasks.

TABLE 2 Algorithm: RFID based smart grid security.

1. **Initialize:**
2. **Include** needed libraries.
3. **Set up** pins for RFID, LEDs, and Servo.
4. **Create** instances for your components.
5. **Setup:**
6. **Begin** communication and hardware setup.
7. **Connect** Servo, define pin modes, and initialize parts.
8. **Main Loop:**
9. **Look** for RFID cards.
10. **Read** and verify card UID.
11. **Authorization:**
12. **If** an authorized card is found:
13. **Show** access with green LED and Servo movement.
14. **If** the card is invalid:
15. **Indicate** unauthorized access with red LED and a buzzer.

1. System Design and Architecture: The first step involves designing the system architecture. This includes the placement of WSNs equipped with temperature, humidity, LDR, and flame sensors within the grid infrastructure. The architecture also incorporates an ESP32 microcontroller-based system for data processing and transmission.
2. Sensor Deployment and Calibration: Sensors are strategically deployed within the grid to capture relevant environmental data. Calibration procedures are conducted to ensure sensor accuracy and consistency in data acquisition.
3. Data Acquisition and Processing: The ESP32 microcontroller processes sensor data in real-time and transmits it to a central monitoring station. Data acquisition protocols are established to ensure communication between sensor nodes and the central system.
4. Noise Filtering: Techniques for noise filtering are implemented to mitigate interference. It ensures the integrity of collected data. This involves preprocessing sensor data to remove noise and enhance signal quality.
5. Sensitivity Testing and Validation: Sensitivity tests are performed to evaluate the system's performance to variations environmental conditions and load scenarios. Validation experiments are conducted to assess the accuracy and reliability of the system under real-world conditions.
6. Integration of IoT Technologies: IoT technologies are integrated to enable efficient load management through real-time monitoring, load shifting, and rapid power cutoff mechanisms. This involves the development of algorithms and protocols for automated control of grid operations.
7. Performance Evaluation: The performance of the system is evaluated based on data accuracy, system responsiveness, and energy efficiency. Comparative analysis are conducted to target the proposed system against existing solutions.

TABLE 3 Algorithm: Energy monitoring and efficient load management.

1. **Initialization:**
2. **Set** Blynk authentication token (auth).
3. **Set** WiFi credentials (ssid and password).
4. **Define** pin assignments for sensors, actuators, and virtual pins.
5. **Set** calibration factors for voltage and current sensors.
6. **Initialize** the DHT sensor.
7. **Set** initial state for the voltage control flag.
8. **Setup:**
9. **Begin** serial communication.
10. **Connect** to WiFi using provided credentials.
11. **Set** MOSFET pins as OUTPUT.
12. **Initialize** the DHT sensor.
13. **Connect** to Blynk using authentication token.
14. **Main Loop:**
15. **Execute** Blynk tasks.
16. **Read** voltage and current values from sensors.
17. **Read** temperature and humidity from the DHT sensor.
18. **Calculate** power and energy.
19. **Display** values on the serial monitor.
20. **Send** sensor readings to Blynk.
21. **Load Control (Blynk Function):**
22. **Update** Load control based on the value received on virtual pin V7.
23. **Repeat:**
24. **Continuously** repeat the main loop.

This research aims to advance smart grid technology towards a resilient, efficient, and sustainable energy infrastructure. The proposed model, depicted in Figure 2, introduces a digital twin modeling approach for optimizing smart grids.

Table 3 summaries an algorithm for a system of monitoring and controlling electrical parameters. It begins with initialization at lines 1–7, where the Blynk authentication token and WiFi credentials are set. Pin assignments for sensors, actuators, and virtual pins are also done. Calibration factors for voltage and current sensors are also defined, and the DHT sensor is initialized. Additionally, the initial state for the voltage control flag is set. The setup process, described at lines 8–13 involves beginning serial communication, connecting to

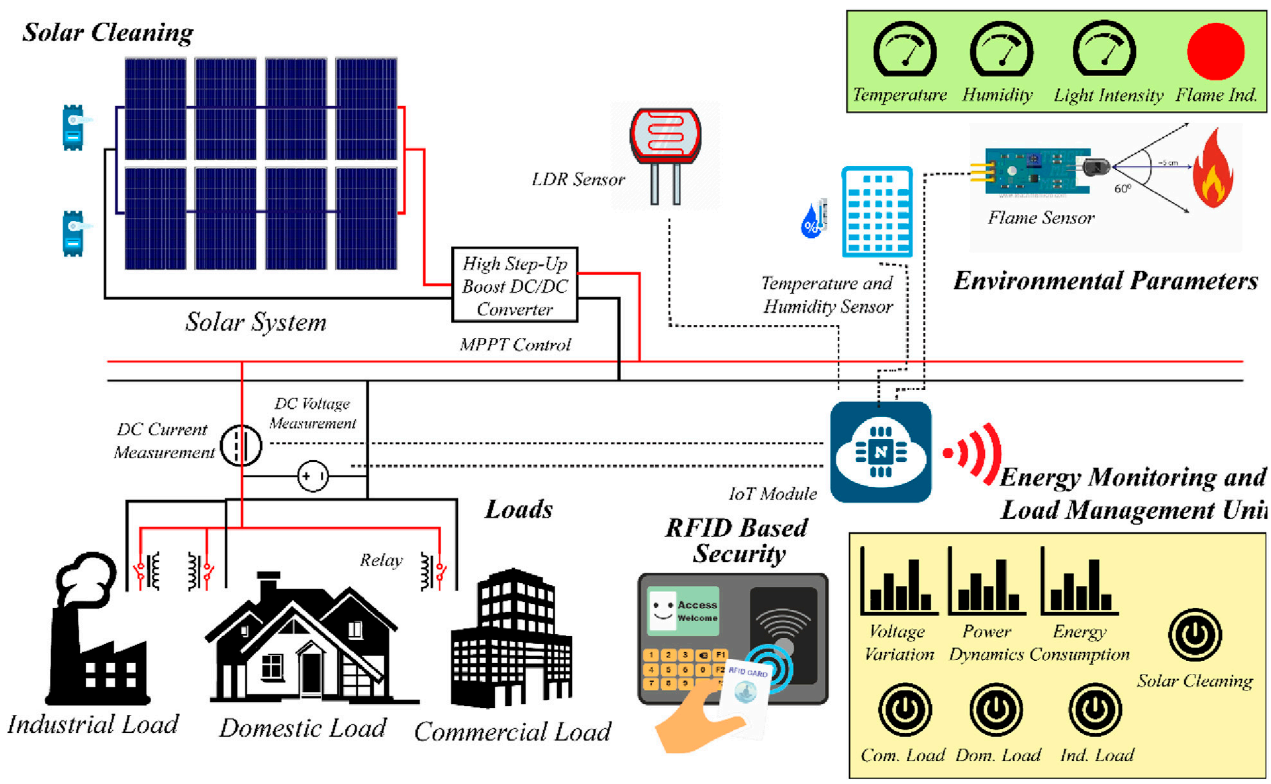

FIGURE 2
Proposed model: Digital twin modeling for smart grid optimization.

WiFi, setting MOSFET pins as OUTPUT. It initialize the DHT sensor again, and connecting to Blynk using the authentication token. The main loop, detailed at lines 14–20, executes Blynk tasks, reads voltage and current values from sensors, reads temperature and humidity from the DHT sensor, calculates power and energy, displays values on the serial monitor, and sends sensor readings to Blynk. Additionally, there's a function (Load Control) defined at lines 21–22 to update load control based on the value received on a virtual pin. The program then continuously repeats the main loop at line 23.

3 Result and discussion section

3.1 Grid environment analysis and solar panel cleaning

In the proposed experimental setup for grid environment analysis, various sensors are employed for comprehensive monitoring. The temperature sensor measures ambient temperature and provides essential data for environmental analysis. On the other hand, the humidity sensor actively monitors humidity levels. The light-dependent resistor (LDR) detects ambient light intensity offering insights into illumination variations. Similarly, the flame sensor identifies potential fire hazards in the smart grid environment. The NodeMCU serves as the central controller and it performs data collection from different sensors for efficient processing.

In the proposed prototype the DHT11 sensor utilizes a thermistor and humidity-sensitive capacitor to measure temperature and humidity. Flame sensors in the prototype detect infrared radiation from flames using a photodiode and amplifier circuit. Then it generates an output signal for flame detection. LDR sensors in the prototype change resistance with light intensity. The it produce an electrical signal corresponding to ambient light levels. Both the flame and LDR sensors interface with NodeMCU for further processing.

The NodeMCU in proposed system serves a dual role. It works as a data aggregator and a facilitator for integrating collected data into the system. NodeMCU data processing algorithms have been implemented to analyze information from different sensors. These algorithms are developed to derive significant insights. These include temperature trends, humidity variations, and light intensity changes. It also provides identification of potential fire risks using real-time data monitoring on the Blynk application.

Furthermore, the proposed study provides a solar cleaning system. This is done with the help of the Blynk application and a servo motor. The proposed model utilizes Blynk and NodeMCU to control the servo motor. Through a Blynk slider widget, the NodeMCU interprets slider values for precise servo adjustments. This achieves real-time and dynamic control of solar cleaning and enhance its efficiency. Figure 3 illustrates the Blynk IoT user interface focused on grid environment analysis and solar panel cleaning.

FIGURE 3
Blynk IoT user interface: Grid environment analysis and solar panel cleaning.

3.2 RFID-based security and access control of smart grid

The proposed prototype focuses on designing RFID-based grid security system. The RFID-based security and access control system provides secure authentication and authorization. It also limits access to unauthorized personnel and reduces the risk of tampering in sensitive locations. The prototype includes connecting an RFID module with Arduino. This enables communication between Arduino and RFID tags using radio-frequency signals. The RFID reader emits waves through an antenna, capturing unique identifiers (UID) from passive or active tags when nearby. Through modulation and demodulation, the reader captures and processes data from tags, including unique identifiers It also integrates the information into systems for applications like access control and inventory management. The communication range depends on factors such as frequency and technology.

The prototype is developed utilizing an RFID card operating at 13.56 MHz in the high-frequency range. This serves as a contactless smart card for secure and wireless applications in identification, and access control of smart grid. The MFRC522 RFID module pins have specific functions for communication with an Arduino, SDA for bidirectional communication and SCK for data transfer timing. MOSI is used for microcontroller-to-module data and MISO is used for module-to-microcontroller data. The optional IRQ pin is used for interrupt-based communication and GND is for electrical stability. The RST pin reset the module and 3.3 V is used for the power supply. For the integration of RFID module MFRC522 with an Arduino Uno, specific pins are connected for proper functionality. The connections include associating SDA with a digital pin 10 and SCK with a digital pin 13. The MOSI pin is connected with digital pin 11 and MISO with digital pin 12. The optional IRQ pin 3.3 V power pin. These connections facilitate communication between the RFID module and Arduino for effective data exchange.

3.3 IoT-based energy monitoring and load management

IoT-based energy monitoring and load management are also included in the proposed prototype. The prototype used a voltage and current sensor with IoT module for real-time energy monitoring and load management. The incorporated IoT devices facilitate real-time monitoring and data analytics. This provides consumption patterns for load management decisions. IoT-based energy monitoring includes voltage sensors, current sensors, Esp32 microcontroller and Blynk application. It enables real-time remote monitoring of voltage variation, power dynamics and energy consumption. The prototype also includes the feature of real-time load management/load shedding using IoT technology. Figures 4, 5 displays a prototype designed for IoT-based energy monitoring, load management, and RFID-based smart security. It highlights an integrated solution for comprehensive control and surveillance in the depicted areas.

For monitoring of the voltage in the prototype, the 0–25 V DC voltage sensor is used. In DC voltage sensor a voltage divider circuit is configured using two resistors to scale down a higher voltage for measurement with a microcontroller. For current

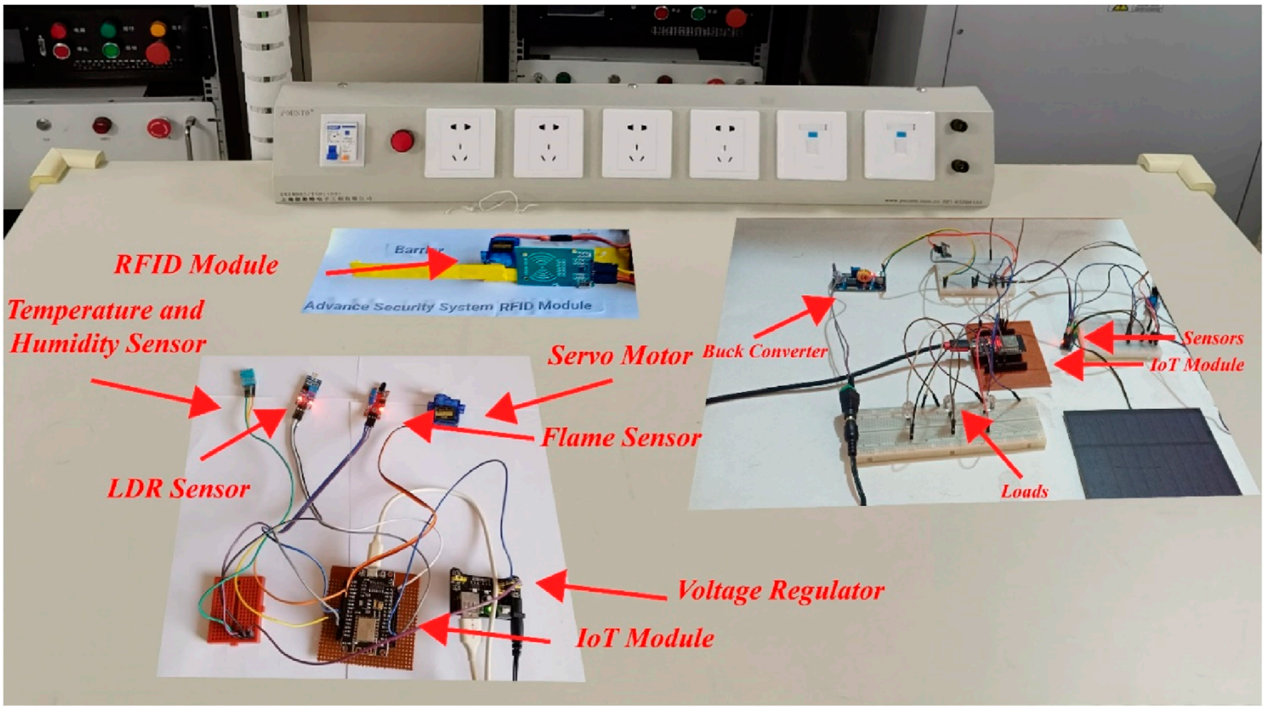

FIGURE 4
Prototype for IoT-Based energy monitoring, load management and RFID based smart security.

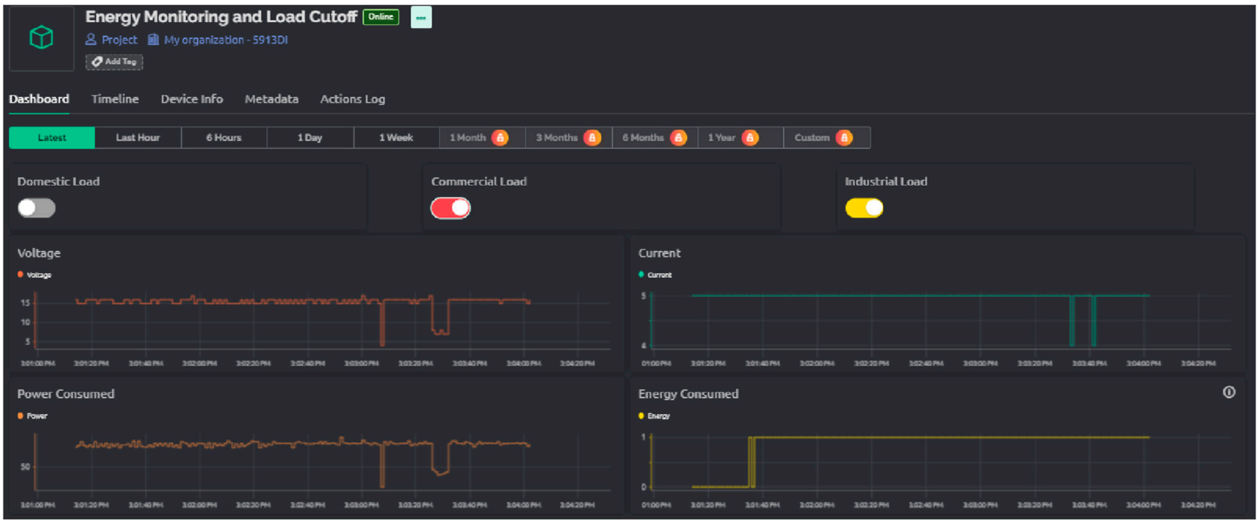

FIGURE 5
User interface for IoT-Based energy monitoring and load management in smart grid.

monitoring, ACS 712 current sensor is used. The ACS712 current sensor utilizes the Hall effect to detect the magnetic field from the electric current. Converting it into a proportional output voltage. Relays are used for real-time load management in the smart grid. Two loads deferrable and fixed loads are considered and managed in the proposed model.

To monitor voltage variations, power dynamics, and energy consumption, an ESP32 is integrated with Blynk application. Utilizing Blynk. virtualWrite (), real-time data is sent to the app, where widgets are configured for user-friendly visualization. This enables remote monitoring and control through the Blynk platform.

4 Conclusion

The research presented in this paper successfully demonstrates an integrated approach to smart grid management, encompassing environmental monitoring, security, and energy management through advanced technological integration. The prototype developed offers a comprehensive solution that addresses several key aspects of smart grid functionality. Firstly, the environmental analysis and solar panel cleaning system is designed with the help of various sensors. These sensors are integrated with NodeMCU controller and provide real-time monitoring of solar panels. Secondly, the prototype includes the implementation of an RFID-based security system in smart grid. RFID technology is integrated with Arduino to restrict authorized access. Thirdly, the IoT-based energy monitoring and load management system is developed with the help of sensors and the ESP32 microcontroller. This part provides energy consumption patterns and facilitates efficient load management. This feature also optimize energy distribution and reducing wastage.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

Author contributions

RA: Conceptualization, Investigation, Formal Analysis, Validation, Writing–original draft. AS: Conceptualization, Investigation, Data curation, Methodology, Writing–original draft. AD: Conceptualization, Investigation, Methodology, Supervision, Writing–original draft. HD: Formal Analysis, Methodology, Supervision, Validation, Writing–review and editing. AB: Conceptualization, Methodology, Project administration, Supervision, Validation, Writing–review and editing. BA: Formal Analysis, Resources, Validation, Visualization, Writing–review and editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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