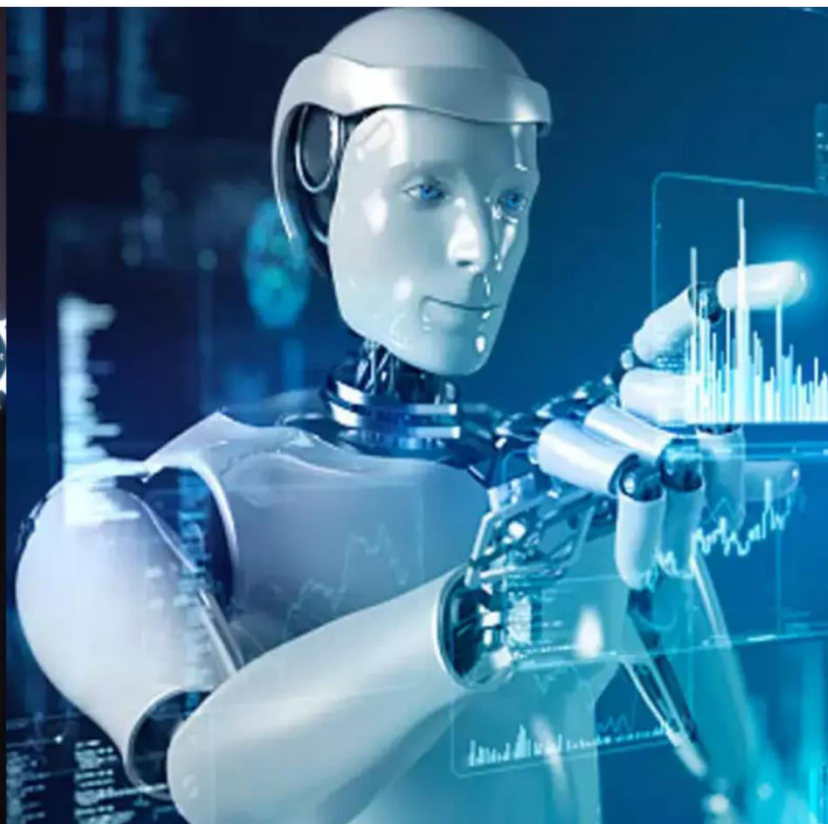




International Journal of Innovative Research in Science Engineering and Technology (IJIRSET)

(A Monthly, Peer Reviewed, Refereed, Scholarly Indexed, Open Access Journal)



Impact Factor: 8.699

Volume 14, Issue 5, May 2025

AI-Powered Energy Management System for Industrial & Commercial Facilities

N Dhiya, Sri Harshini R

Assistant Professor, Vivekanandha Institute of Information and Management Studies, Tiruchengode, Tamil Nadu, India
Master of Computer Application, Vivekanandha Institute of Information and Management Studies, Tiruchengode,
Tamil Nadu, India

ABSTRACT: The AI-powered Energy Management System (AI-EMS) is an intelligent solution designed to optimize energy consumption in industrial and commercial facilities. This system integrates real-time analytics, IoT sensors, AI-driven predictive analytics, and automation to minimize energy wastage, lower operational costs, and reduce environmental impact. By leveraging machine learning models, AI-EMS can forecast energy demand, detect inefficiencies, and provide actionable insights for optimal energy usage. Additionally, the system enables remote monitoring and control, ensuring continuous energy efficiency improvements. The AI-EMS contributes to sustainability goals by integrating renewable energy sources and promoting smart energy distribution.

KEYWORDS: Home Energy Management System, Distributed Generation Integration, Demand Side Management Techniques, Neural Network, Machine Learning Algorithms

I. INTRODUCTION

Energy consumption in the industrial and commercial sectors constitutes a considerable operational cost and significantly contributes to global carbon emissions. Reports from the International Energy Agency (IEA) indicate that industrial facilities alone represent nearly one-third of the total energy demand worldwide, while commercial buildings account for a substantial share of electricity, heating, and cooling energy consumption. With escalating energy prices, more stringent environmental regulations, and increasing corporate commitments to sustainability, organizations face mounting pressure to manage their energy usage more effectively while sustaining operational performance. Nevertheless, many businesses persist in utilizing traditional energy management practices, which involve manual data collection, periodic audits, and reactive measures that inadequately address real-time inefficiencies.

Traditional systems generally offer only a limited view of energy consumption, providing insufficient insight into dynamic energy patterns or anomalies that may occur during daily operations. These outdated methods hinder facility managers from promptly identifying energy waste, optimizing energy-intensive processes, or accurately forecasting future demand. Consequently, facilities frequently incur higher energy costs, unnecessary operational expenditures, and struggle to achieve sustainability objectives. The absence of real-time data and predictive tools further restricts the organization's capacity to respond to peak demand charges or capitalize on opportunities for demand-side management.

II. OBJECTIVES

The main goal of the AI-Powered Energy Management System (AI-EMS) is to enhance energy efficiency in industrial and commercial settings by integrating artificial intelligence, Internet of Things (IoT) devices, and predictive analytics. This initiative aims to create an intelligent system that can continuously monitor real-time energy consumption, predict future energy needs, and analyse consumption trends using machine learning techniques. By automatically identifying inefficiencies and anomalies, the system intends to offer actionable insights and implement automated controls that improve energy efficiency and minimize waste. Furthermore, the AI-EMS aims to support the smooth incorporation of renewable energy sources into current energy frameworks, thus encouraging sustainable energy practices while ensuring a dependable energy supply. Utilizing cloud-based platforms, the system will facilitate remote monitoring and centralized management across various facilities, enabling organizations to make informed decisions that reduce

operational expenses, lower peak demand charges, and advance long-term sustainability and carbon reduction objectives.

III. LITERATURE SURVEY

Artificial intelligence (AI) is a cutting-edge technology that has gained attention in energy management as well. AI is composed of various intelligent algorithms that can be used for energy prediction, scheduling, demand response, and energy trading. Machine learning (ML) algorithms such as Neural Networks and Support Vector Machines are widely used for energy forecasting, while federal learning (FL) and Q-learning are the top choices for energy scheduling, demand response, and energy trading. Hybrid and multi-stage models are being researched to enhance AI performance in energy management. Such models enable the integration of various algorithms to improve model accuracy [2]. Data mining is an essential instrument for enhancing AI performance through feature selection and data optimization for power management. It supports constructing energy storage charging and discharging schedules with data mining techniques. Methods of Analysis of Variance (ANOVA) are utilized to quantify the impact of a specific factor on the variance of other variables. A self-organizing map (SOM) is an unsupervised neural network model that maps highdimensional data to low-dimensional map space in a nonlinear fashion. We created maps for each load and 25 meteorological factors using SOM and determined their correlations. These intelligent algorithms were used in energy management for demand forecasting and energy storage optimization [2]. In addition, AI is used in smart energy management automation, which includes predicting energy demand and adjusting usage accordingly [2, 3]. AI can learn from user behavior and adapt energy usage accordingly as well. AI also facilitates communication between different energy sources, making it easier to optimize energy usage [3]. Furthermore, AI plays a role in home energy management systems. For instance, AI-powered forecasting is used to develop realistic models for renewable energy systems. AI is also employed to enhance the accuracy of predictions of urban heat islands on the Earth's surface by incorporating the effects of elevation and other morphological parameters into artificial neural network models that are intended to predict the spatial distribution of heat islands in urban areas [2-5].

However, the integration of AI in energy management offers a wide range of benefits. Using AI-powered solutions, energy utilities can align their business processes with optimal energy management operations. With the increasing share of renewable energy in the grid, AI can help energy utilities optimize the management of both grids and non-grid-owned assets. Moreover, AI-based applications can lead to optimal risk assessment for energy efficiency investment planning, thereby facilitating the development of new socially and environmentally sustainable business models. The efficiency and reliability of electricity network operators can also be improved using AI-based solutions [6]. The rising availability of larger datasets generated at the edge of the grid is boosting the use of AI in energy management. However, the use of AI in energy management creates new innovation challenges, such as catering to a diverse group of stakeholders in the energy sector. AI-based analytic tools enable intelligent energy management in the power sector, which can also benefit small and medium-sized enterprises and non-tech end-users. Additionally, AI-based energy analytics services contribute significantly to achieving techno-economically optimal management of the energy value chain [6]. AI-based services can also be used for real-time monitoring and control of energy systems, predicting energy demand and supply, and forecasting renewable energy generation and building energy usage [2]. Overall, the use of AI in energy management can assist in optimizing energy consumption, reducing energy costs, managing supply and demand control, and improving energy management in the general [2, 6].

IV. EXISTING SYSTEM

Currently, the majority of facilities depend on conventional techniques, including manual inspections, basic Supervisory Control and Data Acquisition (SCADA) systems, and alert mechanisms that do not utilize artificial intelligence, to oversee and regulate energy consumption. These systems operate in a reactive manner instead of a proactive one, resulting in inefficiencies when it comes to identifying and resolving energy-related problems.

DISADVANTAGES:

- Reactive operation results in delayed detection of energy inefficiencies.
- High dependency on manual monitoring increases the risk of human error.
- Limited real-time visibility prevents quick responses to anomalies.
- No predictive maintenance features to prevent equipment failure.

- Inability to optimize energy usage dynamically based on changing demand.
- Higher maintenance costs due to lack of early issue identification.
- Minimal integration with renewable energy sources and smart technologies.
- Static reporting tools provide limited actionable insights for improvement.

V. PROPOSED SYSTEM

The proposed AI-Driven Energy Management System utilizes the MERN stack (MongoDB, Express.js, React.js, Node.js) to facilitate seamless web application development, guaranteeing both scalability and responsiveness. Python, in conjunction with Scikit-learn, manages the machine learning aspect, specifically utilizing a Random Forest model to evaluate real-time data sourced from IoT sensors. This system continuously monitors energy usage, automatically identifies anomalies, and promptly sends email notifications to designated personnel when abnormal patterns are detected. The platform features an intuitive dashboard that offers real-time data visualization, historical trend analysis, and secure user authentication to maintain data confidentiality and integrity.

VI. METHODOLOGY

The AI-Powered Energy Management System (AI-EMS) is designed as an innovative solution to address the growing challenges of energy management in industrial and commercial facilities. As energy costs rise and environmental regulations tighten, organizations are seeking smarter, more efficient ways to monitor, control, and optimize their energy consumption. This project introduces a system that combines the latest advancements in artificial intelligence, Internet of Things (IoT) technology, and cloud computing to deliver a dynamic, data-driven approach to energy management. At its core, the AI-EMS utilizes IoT-enabled sensors and smart meters to collect real-time data on energy usage across different equipment and systems within a facility. This data is continuously analyzed using machine learning algorithms, such as the Random Forest model, to identify patterns, predict energy demand, and detect anomalies that could indicate inefficiencies or equipment faults. By providing actionable insights and automating certain control functions, the system enables organizations to respond proactively to energy issues rather than relying on reactive, manual interventions. The system features a user-friendly, web-based dashboard developed using the MERN stack (MongoDB, Express.js, React.js, Node.js), offering real-time visualization of energy data, historical trend analysis, and secure access based on user roles.

MODULES:

- Sensor Data Collection
- Data Storage and Preprocessing
- Machine Learning Module
- Alert and Notification System
- Dashboard and Visualization

6.1 MODULE DESCRIPTION

SENSOR DATA COLLECTION

This module is responsible for collecting live readings from various machines using IoT-enabled sensors. These sensors capture real-time data on parameters like energy consumption, voltage, and current. The collected data is transmitted to the backend server at fixed intervals to ensure continuous monitoring and updated energy usage records.

DATA STORAGE AND PREPROCESSING

The data storage and preprocessing module securely stores the incoming sensor data in a MongoDB database. It also handles essential preprocessing tasks such as cleaning invalid or noisy data and normalizing values for consistency. This process ensures that only high-quality, structured data is passed on to the machine learning module for analysis.

MACHINE LEARNING MODULE

This module implements a Random Forest classifier using Python and Scikit-learn to analyze the preprocessed data. It has been trained to identify patterns of normal energy usage and detect outliers or abnormal behaviors. The machine learning module serves as the system's intelligence engine, enabling predictive insights and anomaly detection.

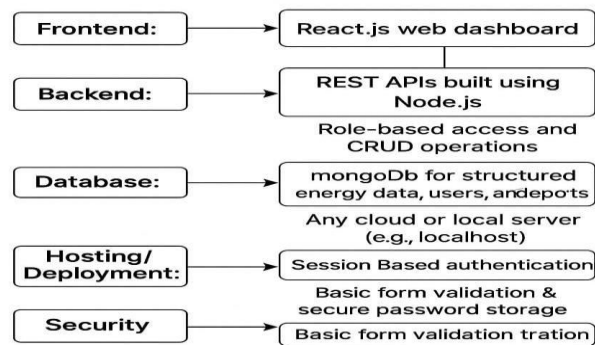
ALERT AND NOTIFICATION SYSTEM

The alert and notification system is designed to automatically notify users when abnormal readings or anomalies are detected by the machine learning module. When an anomaly occurs, the system sends an email alert to designated personnel, ensuring quick awareness and response to potential energy issues.

DASHBOARD AND VISUALIZATION

The dashboard and visualization module provides a React-based, user-friendly interface for monitoring energy data in real-time. It features interactive graphs showing machine performance over time and offers tools for historical data analysis. Additionally, an admin panel is included to manage user roles, permissions, and sensor configurations securely.

SYSTEM ARCHITECTURE



VII. EXPERIMENTAL RESULTS

Figures shows the results Figs. 2, 3, 4 (a) admin login. (b) admin dashboard. (c) user info. (d) creative device. (e) alter and device details.

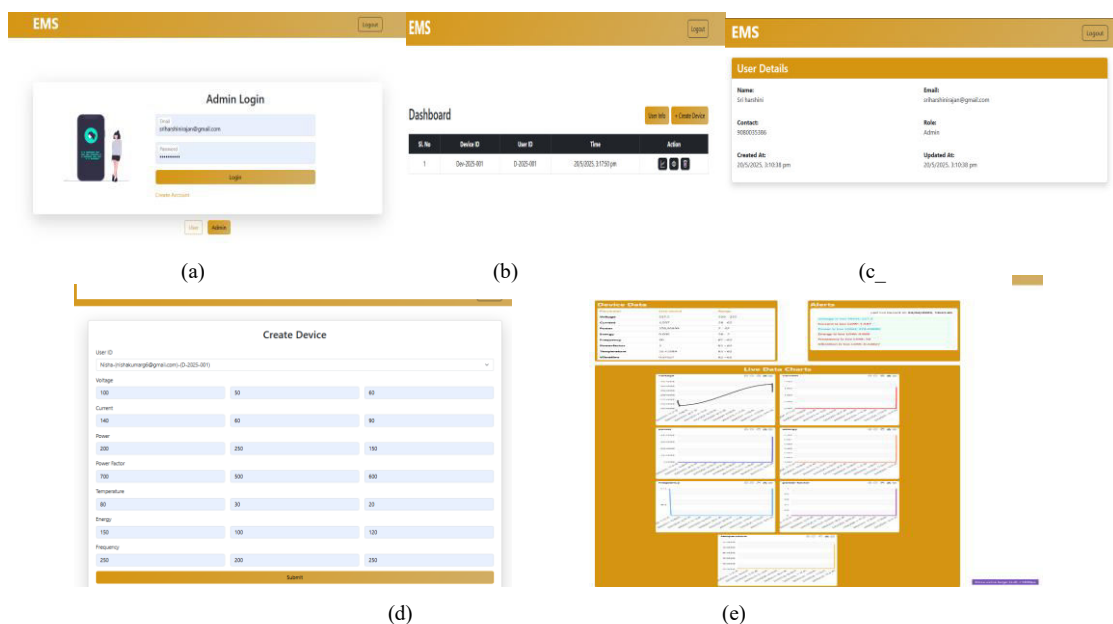
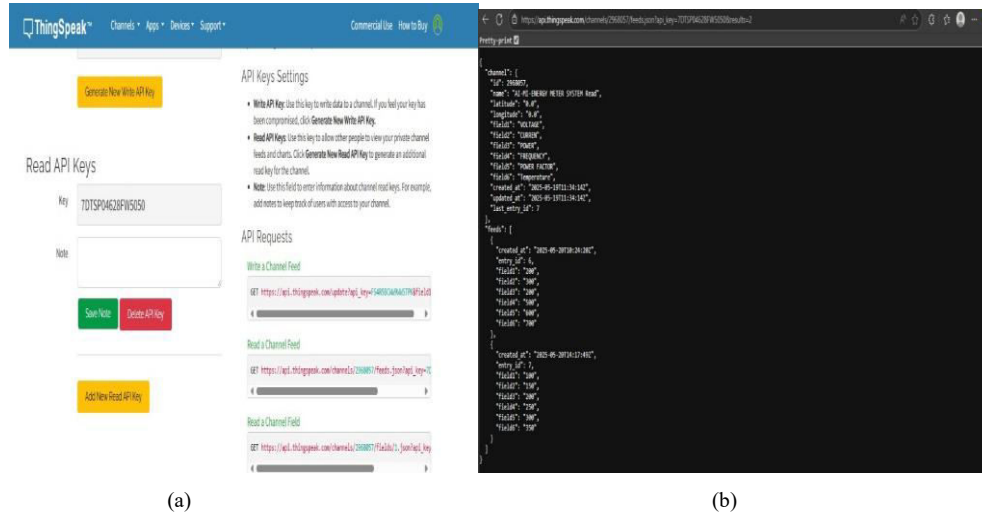


Fig. 2. (a) read api keys (b) details of device updated



VIII. CONCLUSION

The AI-driven Energy Management System (AI-EMS) presents a revolutionary solution for industrial and commercial establishments by integrating real-time monitoring, AI-based analytics, and automation. Through ongoing data collection and machine learning, the system enhances energy usage, lowers operational expenses, and boosts sustainability initiatives. By facilitating proactive anomaly detection and predictive maintenance, AI-EMS not only increases energy efficiency but also reduces equipment downtime and prolongs asset longevity. In summary, this intelligent system equips businesses with actionable insights and improved control over their energy management strategies, aligning operational objectives with environmental accountability.

IX. FUTURE WORK

While the AI-driven Energy Management System (AI-EMS) offers efficient real-time monitoring, anomaly detection, and energy optimization, there exist numerous opportunities for further enhancement and investigation. Future endeavors could investigate the incorporation of more sophisticated AI methodologies, such as deep learning and reinforcement learning, to improve predictive accuracy and adaptive control. Extending the system to accommodate multi-facility or grid-level energy management would facilitate broader energy optimization across interconnected locations. Another potential area for future exploration involves the integration of additional environmental and operational data sources, including weather forecasts or occupancy information, to support more comprehensive energy management strategies. Research into automated demand response systems and their integration with renewable energy storage solutions could further align the AI-EMS with sustainability objectives. Furthermore, examining cybersecurity protocols to safeguard energy data and system operations will be essential as the system expands. These prospective avenues aim to enhance the AI-EMS's intelligence, scalability, and adaptability to the changing demands of industrial and commercial energy management.

REFERENCES

1. "Artificial Intelligence for Energy Management: Applications in Smart Grids and Smart Cities" This book explores AI applications in energy systems, focusing on smart grids and cities. It discusses machine learning techniques for energy forecasting and optimization. Publisher: Springer, ISBN: 978-3-030-00000-0
2. "Smart Energy Management Systems: Using Artificial Intelligence in Buildings and Industry" This text delves into AI methodologies for energy management in buildings and industrial settings, including case studies on predictive maintenance and load forecasting. Publisher: Wiley, ISBN: 978-1-119-00000-0
3. "Machine Learning and Data Science in the Energy Sector" This book covers the integration of machine learning in energy systems, discussing data analytics, predictive modeling, and AI-driven decision-making processes. Publisher: Elsevier, ISBN: 978-0-12-000000-0

WEBSITEREFERENCES

1. <https://scikit-learn.org/>
2. <https://reactjs.org/>
3. <https://expressjs.com/>
4. <https://flask.palletsprojects.com/>
5. <https://www.mongodb.com/>
6. <https://chartjs.org/>
7. <https://www.tensorflow.org/>
8. <https://www.iotforall.com/>
9. <https://www.energy.gov/eere/smartgrids/smart-grid>
10. <https://ieeexplore.ieee.org/document/8782142>



INTERNATIONAL
STANDARD
SERIAL
NUMBER
INDIA



INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH

IN SCIENCE | ENGINEERING | TECHNOLOGY

 9940 572 462  6381 907 438  ijirset@gmail.com



www.ijirset.com

Scan to save the contact details