International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 13 Issue: 04 | Apr 2026 www.irjet.net p-ISSN: 2395-0072

An Intelligent Energy Consumption and Optimization Dashboard Using Machine Learning Techniques

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Abstract - *The increasing demand for energy and the need for sustainable resource utilization have made intelligent energy management systems essential. Traditional monitoring systems lack predictive capabilities and real-time adaptability. This paper presents an intelligent energy consumption and optimization dashboard that uses machine learning techniques for forecasting and anomaly detection. The system integrates data preprocessing, predictive modeling, and anomaly detection to provide meaningful insights.*

Machine learning models improve forecasting accuracy, while anomaly detection helps identify unusual energy usage patterns. The system also includes an interactive dashboard for real-time visualization, cost estimation, and smart scheduling.

The results show improved decision-making, reduced energy wastage, and better efficiency, supporting the development of smart energy systems.

Key Words: Energy Management, Machine Learning, Forecasting, Anomaly Detection, Smart Dashboard

1.INTRODUCTION

The rapid growth in energy consumption has increased the need for efficient energy management systems. Traditional systems provide limited insights and cannot predict future usage.

With advancements in artificial intelligence and smart technologies, modern systems can analyze energy data and forecast demand. Machine learning techniques are useful for identifying patterns and detecting anomalies.

This paper proposes an intelligent dashboard that combines machine learning models with visualization tools for real-time monitoring and optimization.

2. RELATED WORK

Several researchers have contributed to the development of energy management systems using modern technologies. Studies on artificial intelligence-based anomaly detection have shown that such techniques can significantly improve system efficiency by identifying irregular energy usage patterns. Machine learning algorithms have also been widely used to detect anomalies and forecast energy consumption in various environments.

In addition, IoT-based energy monitoring systems have been developed to enable real-time data collection from sensors and devices. These systems provide continuous data streams, which improve the accuracy of analysis and predictions. Forecasting models, particularly those based on machine learning, have demonstrated strong performance in predicting future energy consumption using historical data.

However, most existing solutions focus on a single aspect such as forecasting or anomaly detection. Very few systems combine all functionalities into one platform. The proposed system addresses this gap by integrating data processing, forecasting, anomaly detection, and visualization into a unified and efficient framework.

3. PROPOSED SYSTEM

The proposed system is designed as a modular and scalable framework that performs intelligent energy management. It begins with data acquisition, where energy consumption data is collected from different sources. This is followed by data preprocessing, which includes cleaning, normalization, and feature selection to prepare the data for analysis.
The system then applies machine learning models to forecast future energy consumption based on historical patterns. At the same time, anomaly detection algorithms are used to identify unusual or abnormal energy usage that may indicate faults or inefficiencies.
Finally, all results are presented through an interactive dashboard that allows users to visualize energy trends, monitor system performance, and make informed decisions. This integrated approach ensures improved efficiency and reduced energy wastage.

4. SYSTEM ARCHITECTURE

The architecture of the system consists of multiple interconnected components that work together in a structured manner. Initially, raw energy data is collected from sensors or datasets. This data is then passed through a

preprocessing stage, where it is cleaned and transformed into a suitable format for analysis.

After preprocessing, machine learning models are applied to perform forecasting and anomaly detection. The forecasting model predicts future energy consumption, while the anomaly detection model identifies irregular patterns in the data.

The output of these models is then sent to the visualization layer, where an interactive dashboard displays the results in the form of graphs, charts, and indicators. This architecture enables real-time monitoring, predictive analysis, and efficient energy optimization.

5. METHODOLOGY

The methodology of the proposed system involves three main stages: data preprocessing, forecasting, and anomaly detection. In the data preprocessing stage, the collected data is cleaned to remove noise and missing values. It is then normalized and relevant features are selected to improve model performance.

In the forecasting stage, machine learning algorithms are trained on historical data to predict future energy consumption. These models learn patterns and trends, which help in making accurate predictions.

In the anomaly detection stage, specialized algorithms are used to identify unusual patterns or sudden spikes in energy usage. These anomalies may indicate faults, inefficiencies, or abnormal behavior. Together, these steps ensure accurate analysis and effective energy optimization.

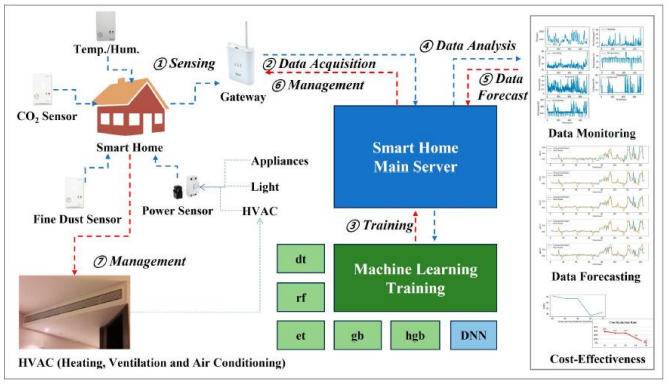

Fig.- 1. System architecture of the proposed energy optimization framework

6. IMPLEMENTATION

The system is implemented using Python due to its powerful libraries and ease of use. Libraries such as Pandas and NumPy are used for data preprocessing and manipulation. Scikit-learn is used to implement machine learning models for forecasting and anomaly detection.

For visualization, the Dash framework is used to create an interactive dashboard that displays energy consumption trends, predictions, and anomalies. The system is designed to be user-friendly and efficient, allowing users to easily monitor and analyze energy data.

7. RESULTS AND DISCUSSION

The results of the system demonstrate its effectiveness in analyzing and optimizing energy consumption. The energy consumption analysis shows clear patterns and identifies peak usage periods, which helps in better planning and management.

The forecasting model produces predictions that closely match actual energy consumption values, indicating high accuracy. This helps in planning future energy requirements and avoiding wastage.

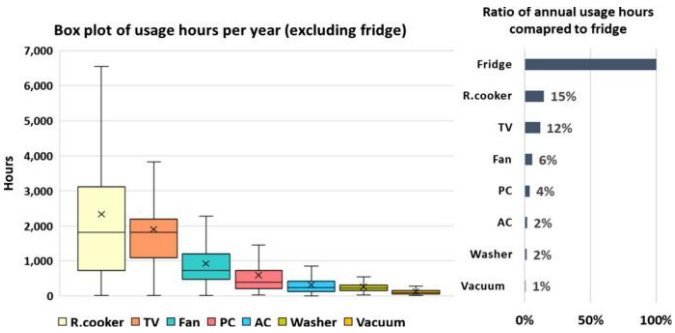

Fig. 2. Energy consumption trend over time

The anomaly detection system successfully identifies abnormal spikes and irregular patterns in energy usage. These detections help in identifying potential issues and improving system reliability. Overall, the results confirm that the proposed system enhances efficiency and supports better decision-making.

8. CONCLUSION

This paper presents an intelligent energy consumption and optimization dashboard that uses machine learning techniques for forecasting and anomaly detection. The system provides a comprehensive solution for monitoring, analyzing, and optimizing energy usage.

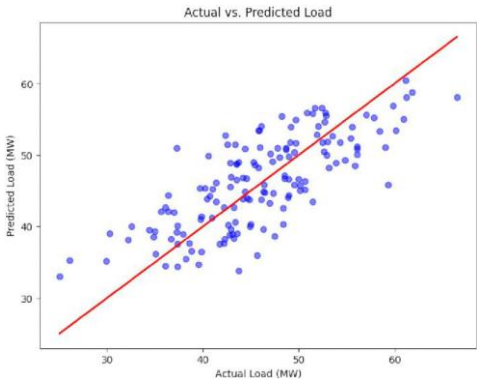

Fig.- 3. Actual vs predicted energy consumption

It improves efficiency, reduces energy wastage, and enhances decision-making capabilities. The integration of multiple functionalities into a single platform makes it a powerful tool for modern energy management systems.

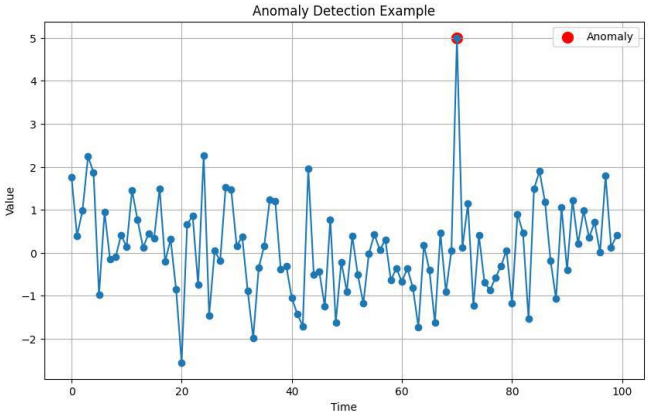

Fig.- 4. Detected anomalies in energy consumption

9. FUTURE WORK

In the future, the system can be enhanced by integrating IoT devices for real-time data collection and monitoring. A mobile application can also be developed to provide easy access to the dashboard. Additionally, advanced deep learning models can be used to improve prediction accuracy and handle more complex data patterns. These improvements will further increase the system's effectiveness and usability.

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