E-ISSN: 3107-5843
International Journal of Advanced Engineering and Management System
Volume 02, Issue 02, April-June 2026, pp. 100 - 104

Predictive Energy Management in Smart Homes Using AI and IoT Technologies

S.Govindasamy[1], Assistant Professor, Department of Electrical and Electronics Engineering, R P Sarathy Institute of Technology, Salem636305, govindasam981@gmail.com.

P.Kavin Rose[2], UG Scholar, Department of Electrical and Electronics Engineering, R P Sarathy Institute of Technology, Salem-636305, rkavinrose@gmail.com.

M.Saran[3], UG Scholar, Department of Electrical and Electronics Engineering, R P Sarathy Institute of Technology, Salem-636305, saranm93@gmail.com.

A.Sabarinathan[4], UG Scholar, Department of Electrical and Electronics Engineering, R P Sarathy Institute of Technology, Salem-636305, sabarinathansabari23@gmail.com.

Abstract:

This paper presents a predictive energy management system for smart homes using Artificial Intelligence (AI) and Internet of Things (IoT) technologies. The proposed framework utilizes IoT-enabled sensors and smart meters to continuously monitor household energy consumption and environmental conditions. AI-based predictive models analyze historical and real-time data to forecast energy demand and optimize appliance scheduling. The system intelligently manages energy usage by reducing peak load consumption, minimizing energy wastage, and improving overall efficiency. Experimental evaluation demonstrates enhanced energy savings, reduced operational costs, and improved user comfort compared to conventional energy management approaches. The proposed AI-IoT integrated solution offers a scalable and sustainable approach for next-generation smart residential energy systems.

Keywords: Artificial Intelligence, Energy Consumption Optimization, Internet of Things (IoT), Machine Learning, Smart Homes

1. Introduction

1.1 Background of Energy Consumption

The demand for electrical energy has increased significantly in recent years due to rapid urban development, population growth, and widespread use of electrical devices in residential environments. Conventional energy management practices often lack efficiency, resulting in unnecessary power consumption and higher electricity costs. In many homes, the absence of intelligent monitoring and control systems leads to energy wastage. Therefore, there is a strong need for advanced solutions that can effectively manage and optimize energy usage.

1.2 Need for Smart Homes

Smart home technology, supported by the Internet of Things (IoT), enables real-time monitoring and automation of household appliances. Various sensors and smart devices collect data such as energy usage, temperature, and occupancy levels. This information allows users to improve comfort and efficiency. However, without intelligent data analysis, these systems are limited in their ability to optimize energy consumption effectively.

1.3 Problem Statement

Existing IoT-based systems mainly provide monitoring and basic automation features but lack advanced predictive capabilities. Many systems rely on fixed rules or manual control, which cannot adapt to changing user behavior or environmental conditions. As a result, energy is not utilized efficiently, leading to increased costs and reduced performance. An intelligent system capable of predicting and optimizing energy usage is therefore required.

1.4 Objective of the Paper

This paper aims to design and develop an intelligent energy management system using artificial intelligence for IoT-enabled smart homes. The system focuses on real-time data monitoring, predictive

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analysis using machine learning algorithms, and automated control of appliances to minimize energy wastage while maintaining user comfort.

2. Literature Review

2.1 Machine Learning-Based Prediction (2021–2023)

Machine learning techniques have been widely applied to improve energy efficiency in smart home environments. Several studies propose hybrid frameworks that combine multiple artificial intelligence methods to enhance prediction accuracy and reduce energy consumption. These approaches demonstrate effective cost and energy savings; however, many models rely on specific datasets and lack adaptability to different regions and varying electricity pricing conditions [1].

2.2 Deep Learning Approaches (2023–2024)

Deep learning models, particularly Long Short-Term Memory (LSTM) networks, are commonly used for predicting energy consumption due to their ability to capture temporal patterns in data. These models achieve high accuracy when combined with optimization techniques. However, their dependency on high computational resources, such as GPU support, limits their implementation in low-cost and resource-constrained smart home systems [2].

2.3 Reinforcement Learning Methods (2024)

Reinforcement learning has gained attention for its ability to manage energy dynamically by learning optimal control strategies through interaction with the environment. These methods can adapt to changing user behavior and energy demand, resulting in improved efficiency. Despite these advantages, their complexity and high training requirements make them less practical for small-scale residential applications [3].

2.4 Hybrid IoT-Renewable Systems (2025)

Recent research focuses on integrating IoT technologies with renewable energy sources such as solar power and battery storage systems. These hybrid systems aim to improve energy efficiency and sustainability using predictive analytics and intelligent control. Although they show significant performance improvements, most existing solutions are designed for large-scale applications and do not effectively address real-time optimization at the individual smart home level [4].

Based on the limitations identified in existing works, this paper proposes an AI-based energy optimization system that is computationally efficient, cost-effective, and suitable for real-time smart home applications.

3. System Architecture

The proposed system architecture for AI-based energy consumption optimization in IoT-enabled smart homes consists of sensing, communication, processing, and control units. Sensors such as ACS712 and DHT11 are used to collect real-time data on energy usage and environmental conditions.

This data is transmitted through the ESP-01 Wi-Fi module to a cloud or local server.The server processes the data using machine learning algorithms to analyze consumption patterns and predict future energy demand. Based on these predictions, control signals are generated and sent back to the system.

Relay modules then automatically control household appliances to optimize energy usage.The system operates in a continuous loop, enabling real-time monitoring, intelligent decision-making, and efficient energy management in smart home environments.

4. Methodology

4.1 Data Collection

The proposed system collects real-time data from the smart home environment using sensors such as the ACS712 current sensor and DHT11 temperature sensor. Parameters including energy consumption, temperature, and appliance usage are continuously monitored. The collected data is transmitted to the server through the ESP-01 Wi-Fi module for further processing.

4.2 Data Preprocessing

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The raw data obtained from sensors may contain noise and inconsistencies. Therefore, preprocessing techniques such as data cleaning, normalization, and feature selection are applied. This step ensures that the data is accurate, consistent, and suitable for machine learning model training.

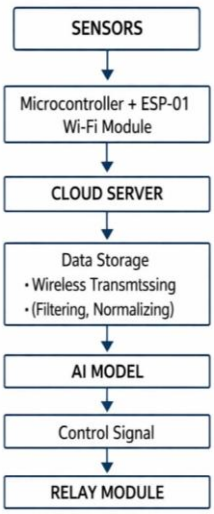

Figure 1: Block Diagram of Proposed System

4.3 AI Model Training

After preprocessing, the data is used to train machine learning models such as Decision Trees, Random Forest, and Artificial Neural Networks (ANN). These models learn patterns from historical energy consumption data and are optimized to improve prediction accuracy.

4.4 Prediction and Control

The trained models are used to predict future energy consumption and identify inefficient usage patterns. Based on these predictions, control signals are generated to manage appliance operation. Relay modules automatically switch devices ON or OFF to minimize energy wastage while maintaining user comfort. The system continuously updates predictions using new data, enabling adaptive and efficient energy management.

5. System Components

5.1 A. ESP-01 Wi-Fi Module

The ESP-01 module, based on the ESP8266 chip, is used for wireless communication in the proposed system. It enables data transmission between the smart home devices and the cloud/server. The module supports TCP/IP protocol and ensures reliable, low-cost connectivity for IoT applications.

5.2 ACS712 Current Sensor

The ACS712 current sensor is used to measure the real-time current consumption of electrical appliances. It provides analog output proportional to the current flow, which helps in calculating energy usage. This sensor plays a key role in monitoring power consumption in the system.

5.3 DHT11 Sensor

The DHT11 sensor is used to measure environmental parameters such as temperature and humidity. This data helps in understanding environmental conditions and can be used to optimize energy usage, especially for appliances like fans and air conditioners.

5.4 Relay Module

The relay module acts as a control unit that switches electrical appliances ON or OFF based on control signals from the system. It enables automation by allowing the AI model to control devices efficiently, reducing unnecessary energy consumption.

5.5 Power Supply

The power supply unit provides the required voltage and current to all system components. It ensures stable and continuous operation of sensors, microcontroller, and communication modules within the smart home system.

6. Results And Discussion

6.1 Energy Consumption Analysis

The performance of the proposed AI-based energy optimization system is evaluated by comparing energy consumption with and without AI control under different time periods. The results are presented in Table I.

Time Period	Without AI (kWh)	With AI (kWh)
Morning	5.2	4.1
Afternoon	6.8	5.0
Evening	7.5	5.8
Night	4.0	3.2

Table 1: Energy Consumption Analysis

From Table I, it is observed that the proposed system reduces energy consumption in all time intervals. The maximum reduction is achieved during the evening period due to optimized control of high-power appliances.

6.2 Graphical Comparison

Fig. 2 illustrates the comparison of energy consumption with and without AI-based optimization. It clearly shows that the proposed system consistently consumes less energy across all time periods.

6.3 Performance Analysis

The overall performance of the system indicates a significant improvement in energy efficiency. The proposed model achieves an average energy reduction of approximately **20–25%** compared to conventional systems. This improvement is attributed to the use of machine

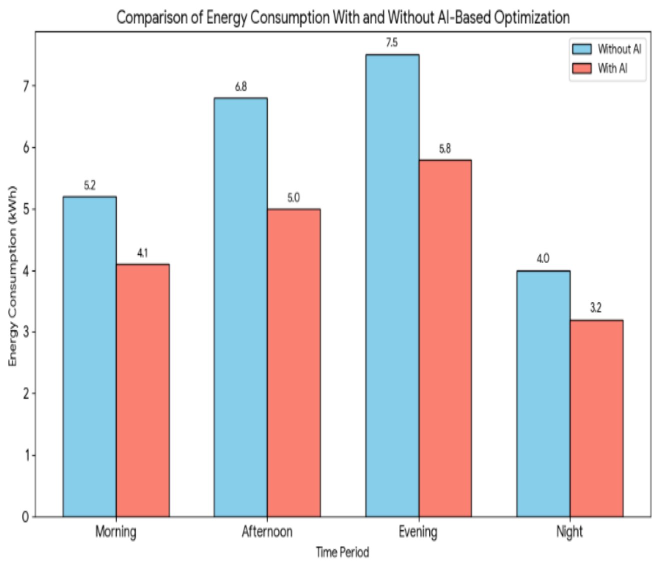

Figure 2: Comparison of Energy Consumption With and Without AI-Based Optimization

learning algorithms that predict energy usage patterns and optimize appliance operation accordingly. The system also demonstrates the ability to adapt to varying user behavior and environmental conditions through continuous learning. As a result, it ensures efficient energy utilization while maintaining user comfort. These findings confirm that the integration of Artificial Intelligence with IoT technologies is an effective approach for smart home energy management.

7. AI Algorithm

7.1 Decision Tree

The Decision Tree algorithm is a supervised machine learning technique used for classification and regression tasks. In the proposed system, it is used to analyze energy consumption data and make decisions based on predefined conditions. The model splits the dataset into branches based on features such as time, temperature, and appliance usage. Each branch represents a decision rule, leading to an outcome that predicts energy consumption levels. Decision Trees are simple to implement and provide fast decision-making, making them suitable for real-time smart home applications.

7.2 Random Forest

Random Forest is an ensemble learning method that combines multiple Decision Trees to improve prediction accuracy and reduce overfitting. In this system, several decision trees are trained on different subsets of the dataset, and the final prediction is obtained by averaging the outputs of all trees. This approach enhances reliability and robustness in energy prediction. Random Forest is particularly effective in handling large datasets and complex patterns, making it a key component in optimizing energy consumption.

7.3 Artificial Neural Network (ANN)

Artificial Neural Networks are inspired by the structure of the human brain and are capable of learning complex patterns from data. In the proposed system, ANN is used to model non-linear relationships between input parameters such as energy usage, temperature, and time. The network consists of input, hidden, and output layers, where each neuron processes information and passes it forward. ANN provides high prediction accuracy and adaptability, enabling the system to learn user behavior and optimize energy consumption dynamically over time.

8. Conclusion

This paper presented an AI-based energy consumption optimization system for IoT-enabled smart homes. The proposed system integrates real-time data collection with machine learning algorithms to predict and control energy usage efficiently. The results demonstrate that the system achieves approximately 20–25% reduction in energy consumption compared to conventional methods.

The system offers advantages such as real-time monitoring, automated control, improved energy efficiency, and cost-effectiveness. It is scalable and suitable for modern smart home applications. Future work will focus on real-time implementation, integration of renewable energy sources, and the use of advanced deep learning models to further enhance system performance. The proposed system demonstrates the effectiveness of AI-driven energy management in real-world smart home environments.

REFERENCES

1. Chen, Y., Li, Z., Zhang, L., Shen, S. (2020). Deep Reinforcement Learning for Building HVAC Control. Proceedings of the 26th ACM SIGKDD International Conference on Knowledge Discovery Data Mining.
2. Li, Y., Chen, L., Tang, F. (2019). Short-Term Load Forecasting Based on Multi-Feature Fusion and Machine Learning Algorithms in Smart Grid. Energies, 12(4), 649.
3. Huang, L., Ai, Q., Wang, Y., Liu, J. (2018). A Cloud-Based Smart Home Energy Management System Considering User Comfort. IEEE Access, 6, 54038-54049.
4. Zhang, L., Tian, Y., Guo, J., Zhou, W., Cheng, Y. (2017). A Home Energy Management System Based on Fog Computing for IoTConnected Smart Homes. IEEE Internet of Things Journal, 5(1), 184197.
5. Wang, X., Zhang, X., Han, Z. (2020). AI-Driven Energy Management for Smart Home Based on IoT. IEEE Access, 8, 198304-198313.
6. Song, Y., Zeng, P., Yang, Y., Huang, Q. (2019). Design and Implementation of an Intelligent Home Energy Management System Based on IoT. IEEE Transactions on Smart Grid, 11(1), 826-834.
7. Kim, J., Choi, W., Lee, S. (2021). Privacy-Preserving and Secure IoT- Based Smart Home Energy Management System. IEEE Transactions on Consumer Electronics, 67(2), 173-180.
8. Strengers, Y., Nicholls, L., Lewis, T. (2019). Social Practices, Monitoring Technologies and Energy Demand. Energy Policy, 127, 137-144.
9. Liang, X., Zhang, C., Shen, S., Zhang, L. (2020). Predictive Energy Management in Smart Homes: A Data-Driven Approach. IEEE Trans- actions on Smart Grid, 11(1), 577-586.
10. Zhao, J., Magoules, F., Chen, J. (2018). Dynamic Pricing and Peak Load Reduction in Smart Grids with Demand Response: A Review. IEEE Transactions on Industrial Informatics, 14(3), 1126-1134.