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AI+IoT Based Energy Monitoring & Predictive Power Analytics System: A Review

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Abstract: ***The increasing demand for electricity has created a need for intelligent and efficient energy monitoring and management systems. Traditional energy monitoring systems mainly provide basic consumption measurements and have limited capabilities for prediction and abnormal usage detection. This review paper presents an overview of AIoT-based intelligent energy monitoring and predictive power analytics systems, focusing on the integration of Internet of Things (IoT), Artificial Intelligence (AI), Machine Learning (ML), cloud platforms, and real-time dashboards. The review examines existing techniques for real-time measurement of voltage, current, power, and energy consumption, along with AI/ML methods used for energy consumption forecasting and anomaly detection. It also compares existing approaches based on monitoring capability, prediction accuracy, anomaly detection, cloud integration, and intelligent analytics. The study identifies major challenges and research gaps in developing a unified system that can provide real-time monitoring, accurate power-demand prediction, abnormal usage detection, alerts, and energy cost estimation. Finally, the paper discusses future opportunities for smart homes, industries, offices, and commercial buildings, with the aim of improving energy efficiency, reducing energy wastage and supporting sustainable energy management.***

Keywords: ESP32, PZEM-004T, ZMPT101B, ACS712, AC Load (Bulb/Fan), 5V Power Supply, Connecting Wires, Arduino IDE, Python, ThingSpeak/Firebase, Web Dashboard, and AI/ML Algorithms.

I. INTRODUCTION

The increasing demand for electricity has created a need for efficient and intelligent energy monitoring and management systems. Traditional energy meters mainly provide electricity consumption values but do not offer intelligent analysis, prediction, or early detection of abnormal energy usage.

This can result in energy wastage, higher electricity costs, and inefficient power management.

With the development of Internet of Things (IoT) and Artificial Intelligence (AI), energy monitoring systems can be improved by combining real-time data collection with intelligent data analysis. IoT enables continuous monitoring of electrical parameters, while AI/ML techniques can analyze consumption patterns, predict future power demand, and identify abnormal energy consumption.

This review focuses on A IoT-based energy monitoring and predictive power analytics, covering IoT-based monitoring, AI/ML-based energy forecasting, anomaly detection, cloud-based data storage, and dashboard-based visualization. The study also examines existing approaches, their limitations, challenges, and future research opportunities for smart energy management..

II. LITERATURE REVIEW

Several researchers have developed IoT-based energy monitoring systems to measure and monitor electricity consumption in real time. These systems use smart sensors and cloud platforms to collect energy data, enabling users to track power usage and improve energy efficiency.

Recent studies have integrated Artificial Intelligence (AI) with IoT to analyze energy consumption patterns, predict future electricity demand, and detect abnormal power usage. AI-based predictive analytics helps reduce energy wastage, optimize electricity consumption, lower operational costs, and support sustainable energy management. However, many existing systems mainly focus on monitoring and lack advanced features such as accurate predictive analytics, real-time anomaly detection, and intelligent decision support. Therefore, this project proposes an AI-IoT Based Intelligent Energy Monitoring & Predictive Power Analytics System to provide a smarter, more efficient, and reliable energy management solution.

III.BLOCK DIAGRAM

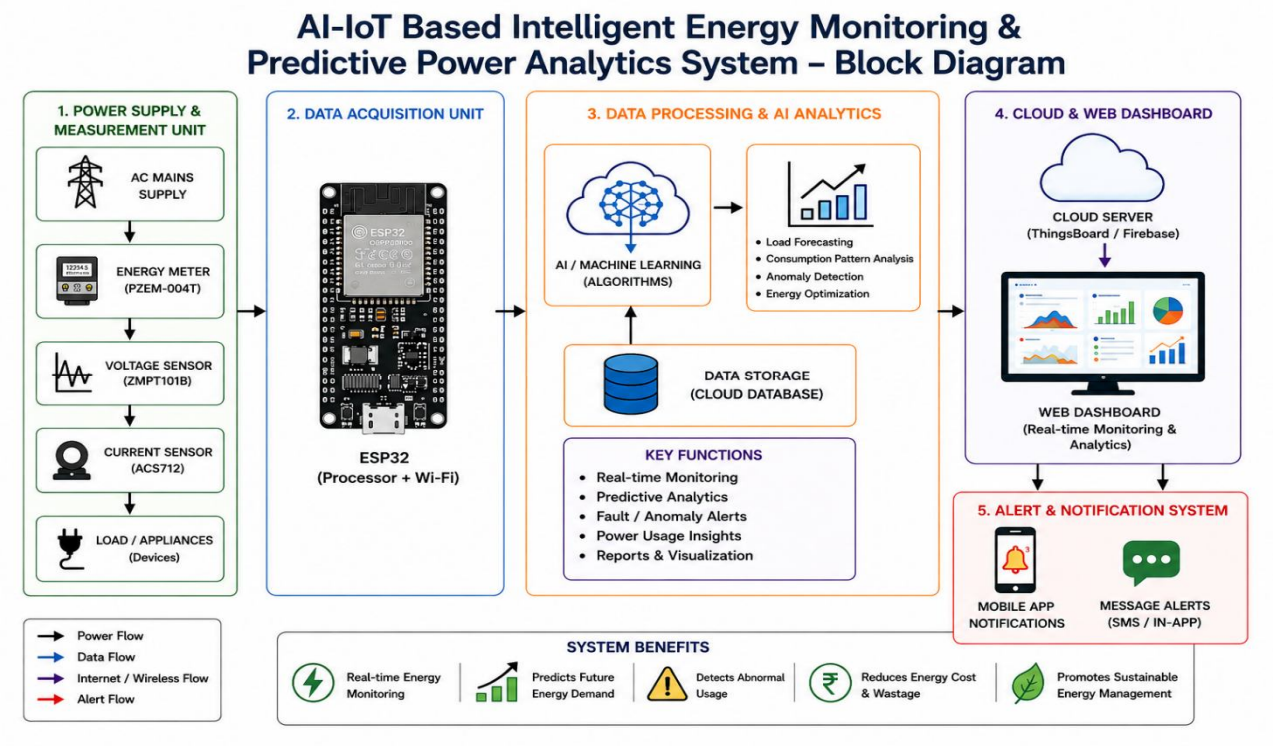

Fig: AI+IoT Based Energy Monitoring & Predictive Power Analytics System.

1) AC Supply and Load: The AC supply provides electrical power to the connected loads such as bulb and fan, and the system continuously monitors their electricity consumption.

2) Energy Sensors: PZEM-004T, ZMPT101B, and ACS712 sensors measure the voltage, current, power, and energy consumption of the connected electrical load.

3) ESP32 Microcontroller: The ESP32 collects the electrical data measured by the sensors and processes the collected information before transmitting it to the cloud platform.

4) Wi-Fi Communication: The ESP32 transmits the collected energy consumption data to the cloud platform through Wi-Fi for continuous monitoring and further analysis.

5) Cloud Storage: The collected energy data is stored on a cloud platform such as ThingSpeak or Firebase, where it can be accessed for monitoring and analysis.

6) Web Dashboard: The web dashboard displays real-time and historical energy consumption data, allowing users to monitor energy usage and identify unnecessary power consumption.

7) AI/ML Analysis: AI/ML techniques analyze the collected energy data to identify consumption patterns and provide intelligent analysis of the energy usage.

8) Power Demand Prediction: Based on the collected energy consumption data, the system predicts future power demand and consumption to support efficient energy management.

9) Abnormal Usage Detection: The system analyzes energy consumption patterns and detects abnormal or excessive power usage that may result in unnecessary energy wastage.

10) Alert Generation: When abnormal or excessive energy consumption is detected, the system generates an alert to help the user take timely action and reduce energy wastage.

11) Energy Cost Estimation: The system estimates the electricity cost based on the measured energy consumption and provides useful information about the user's energy expenses.

12) Final Output: The dashboard provides energy consumption monitoring, future power prediction, abnormal usage alerts, and energy cost estimation in a single platform.

IV. PROPOSED SYSTEM

The proposed work focuses on developing an AI-IoT Based Intelligent Energy Monitoring & Predictive Power Analytics System for smart and efficient energy management. The system will use an ESP32 microcontroller along with suitable energy sensors to measure voltage, current, power, and energy consumption in real time. The collected electrical data will be transmitted through Wi-Fi to a cloud platform for storage and further processing. A user-friendly dashboard will display real-time and historical energy consumption data, allowing users to monitor their energy usage and identify unnecessary power consumption.

In the next stage, AI/ML techniques will be applied to the collected energy data to analyze consumption patterns and predict future power demand. The system will also detect abnormal or excessive energy usage and generate alerts, helping users take timely action to reduce energy wastage. The proposed system will also provide energy cost estimation and intelligent energy analysis in a single platform. Overall, the system aims to reduce energy wastage, lower electricity costs, improve energy efficiency, and support sustainable energy management. It can further be extended for use in smart homes, industries, offices, and commercial buildings.

V. FUTURE SCOPE

1) Smart Appliance Integration: The system can be further integrated with smart appliances for automated energy control and efficient electricity usage.
2) Smart Home Applications: The system can be extended for smart homes to provide intelligent energy monitoring and management.
3) Industrial Applications: The system can be implemented in industries for continuous energy monitoring and efficient power management.
4) Office Applications: The system can be used in offices to monitor energy consumption and identify unnecessary power usage.
5) Commercial Building Applications: The system can be extended to commercial buildings for efficient energy monitoring and management.
6) Advanced AI Analysis: Future development can improve AI-based analysis of energy consumption patterns and provide better energy insights.
7) Improved Power Prediction: The prediction system can be further improved to provide more effective future power-demand analysis.
8) Automated Energy Control: The system can be extended with automated control features to manage electrical loads according to energy consumption.
9) Energy Cost Management: Future development can provide improved energy cost estimation and help users manage electricity expenses.
10) Sustainable Energy Management: The system can support efficient utilization of electrical resources, reduce energy wastage, and promote sustainable energy management.

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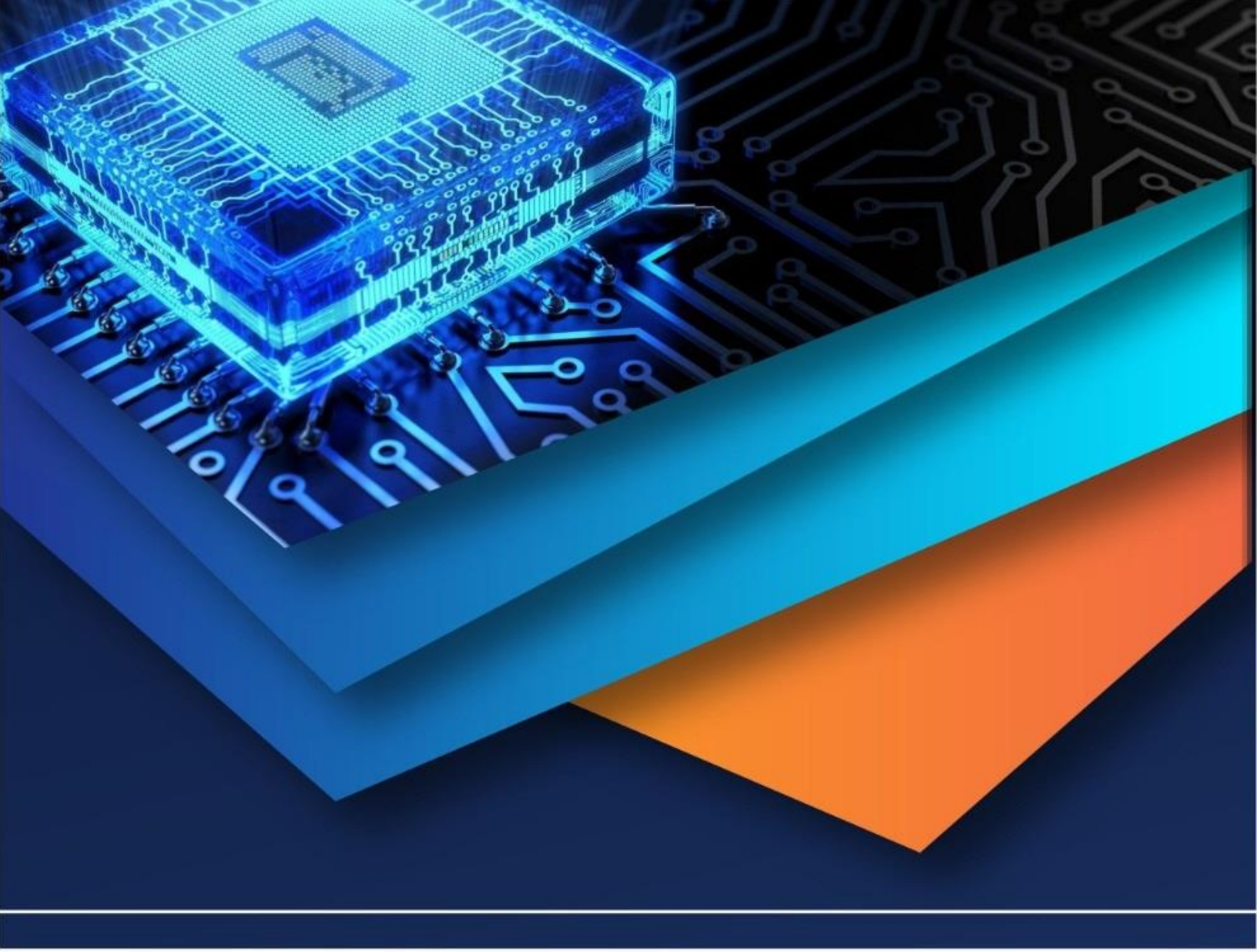

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