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IOT Based Smart Power Monitoring and Managing System for All the Home Appliances

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Abstract-IoT-based Smart Power Monitoring and Controlling System is created to monitor, evaluate, and control home and office appliance's electric consumption in real-time. Through voltage and current sensors via a Wi-Fi-based microcontroller (e.g., an ESP32), voltage, current, active power, and accumulated energy parameters are continuously read. Such information is sent to a mobile application or a cloud platform where one can observe real-time information, observe past energy consumption, and approximate electricity spend.

Keywords: Smart monitoring, Health monitoring, IoT, Innovative solution , device managing.

1. INTRODUCTION

Electric power is part and parcel of daily living with countless applications ranging from house appliances to industry machines. As a complement to rising intensiveness of electric appliances across homes, workplaces, and industries, energy consumptions have expanded significantly thus putting higher costs for electricity, wastages of energies that are avoidable, and stresses for supply powers. Power monitoring systems via conventional means such as monthly billable meters only present cumulative energy consumptions throughout an entire house or building but never present granular details about individual consumptions for appliances. Such information makes impossible for the user to differentiate energy-hungry appliances, standardize usage patterns, or take corrective actions to reduce consumptions of power.

The Internet of Things (IoT) has grown dramatically to enable development of smart connected systems with real-time monitoring and intelligent device control. IoT integration into power management enables power management to be monitored from anywhere for individual device energy usage, to be notified if an unusual condition exists, to turn individual devices or groups of devices on or off or to a remote setting via mobile or web interface applications. These types of systems offer convenience and safety but also encourage energy conservation with cost savings.

2. LITERATURE REVIEW

Recent advancements in the Internet of Things (IoT) have significantly influenced the way electrical energy is monitored and managed, leading to the development of smart power monitoring systems that enable real-time data acquisition and analysis. Earlier systems were based on traditional energy meters that only provided total consumption data without identifying the usage of individual appliances, resulting in inefficient power management and higher energy costs. To address these issues, researchers have implemented IoT- enabled systems using microcontrollers like Arduino and NodeMCU (ESP8266) along with current sensors such as ACS712 to measure energy consumption accurately. These systems transmit data to cloud platforms like Firebase or ThingSpeak, allowing users to monitor their electricity usage remotely through web or mobile interfaces. Studies have shown that integrating IoT with cloud technology enables efficient energy tracking, billing prediction, and fault detection in electrical devices. However, many existing solutions face limitations such as lack of appliance-level monitoring, high implementation costs, and limited alert mechanisms. The proposed project overcomes these challenges by providing a low-cost, scalable, and user-friendly IoT-based power monitoring system that records individual device consumption, stores data in the Firebase Realtime Database, and displays it through a web dashboard.

3. METHODOLOGY

The methodology adopted for the IoT-Based Smart Power Monitoring System focuses on designing a reliable, real-time, and cost-effective solution for monitoring individual household appliances. The system architecture integrates both hardware and software components to achieve efficient energy management. The hardware setup primarily consists of a NodeMCU (ESP8266) microcontroller, which serves as the central processing unit, interfacing with current sensors (such as ACS712) to measure the power consumption of each appliance. These sensors generate analog signals corresponding to the current flow, which are then converted into digital data by the NodeMCU and processed to calculate energy consumption in watt-hours (Wh). The processed data is transmitted in real-time to the Firebase Realtime Database using Wi-Fi connectivity. The software design involves coding the NodeMCU using the Arduino IDE, where embedded C/C++ programming is utilized to acquire sensor readings, perform calculations, and handle data communication with Firebase. The stored data is then visualized through a web- based interface developed using HTML, CSS, and JavaScript, enabling users to view appliance-wise energy consumption, estimated billing amount, and device health status remotely. Additionally, an email alert mechanism is implemented using Firebase Cloud Functions to notify users whenever the electricity bill exceeds ₹500, followed by alerts for every ₹50 increment. This methodology ensures continuous monitoring, accurate data transmission, and proactive user engagement. By combining IoT technology, cloud computing, and web-based visualization, the proposed system provides an efficient and
scalable solution for energy conservation and household

Power management

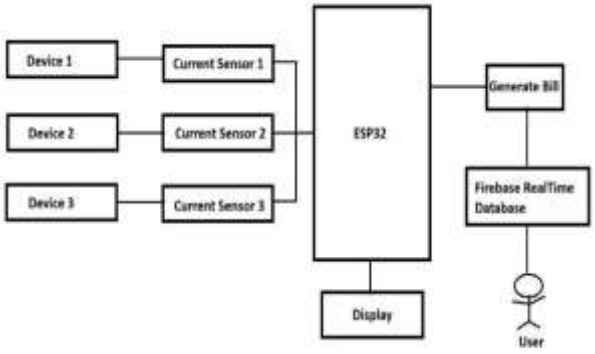

Fig -1: Block diagram

4. RESULTS – SYSTEM DEMONSTRATION

Fig -4(a): Hardware setup

The IoT-Based Smart Power Monitoring System for Individual Appliances was successfully designed and implemented on a prototype board to demonstrate its functionality and real-time performance. The system consists of multiple hardware modules, including a NodeMCU (ESP8266) microcontroller, ACS712 current sensors, SCT-013 current transformers, relay modules, and a TFT display. Each household appliance is connected through a socket interface that allows independent current measurement. The sensors continuously sense the flow of current through each connected device and send corresponding analog signals to the NodeMCU. These readings are processed in real-time to calculate the instantaneous power consumption and total energy usage. The processed data is then transmitted via Wi-Fi to the Firebase Realtime Database, where it is stored and visualized through an HTML-based web interface. Users can access this dashboard remotely to view appliance-wise energy usage, billing information, and overall power consumption trends.

Fig -4(b): Results displayed in TFT display

The system also includes an alert mechanism that automatically sends email notifications when the total electricity bill exceeds ₹500, with further alerts for every additional ₹50, helping users manage energy costs effectively. The relay module integrated into the setup allows remote switching of appliances, demonstrating control capabilities alongside monitoring.

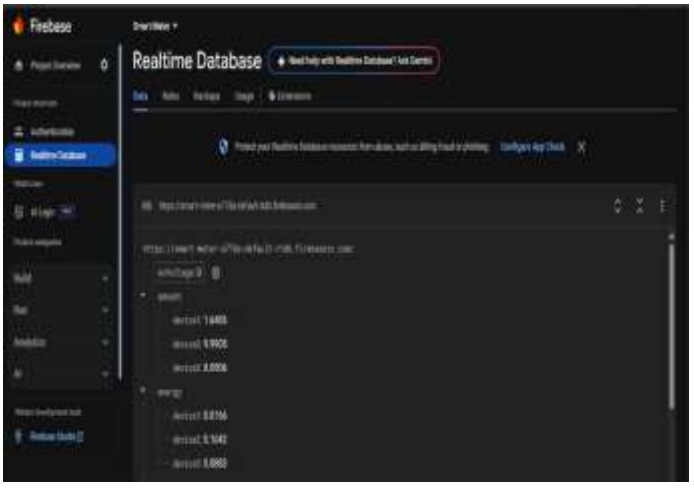

Fig -4(c): Monitored device health status and displayed in firebase

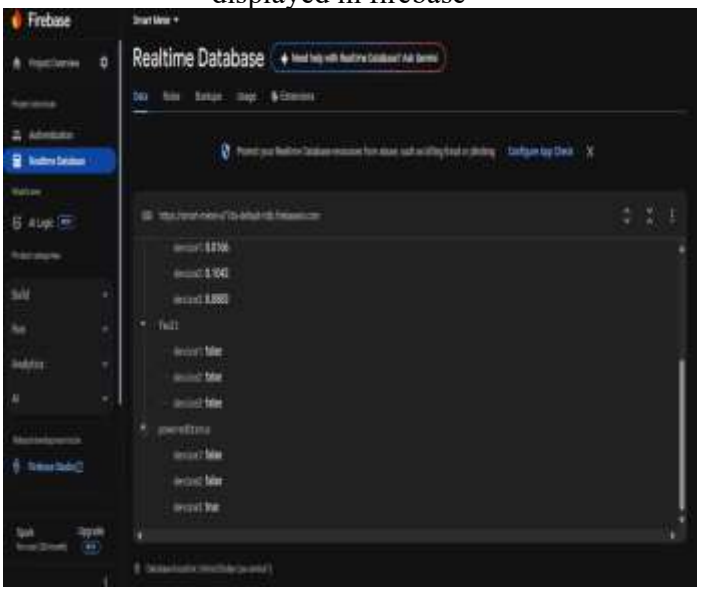

Fig -4(d): current consumed by each device

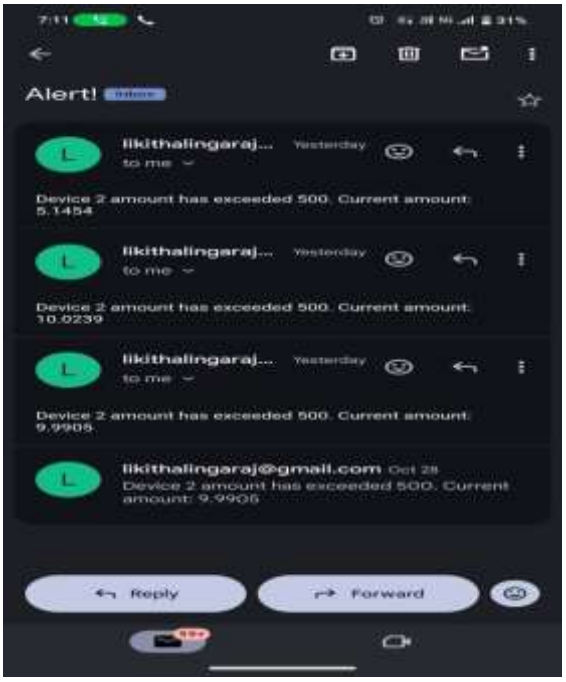

Fig -4(e): E-mail notification of amount for current consumption by each device

Overall, Firebase integration enhances the system's reliability, interactivity, and accessibility by connecting hardware-level data acquisition with intelligent cloud-based processing and real-time user notification.

CONCLUSIONS

The IoT-Based Smart Power Monitoring System for Individual Appliances was successfully designed and implemented to provide a reliable, cost-effective, and intelligent solution for efficient energy management. The project achieved its primary objectives of real-time monitoring, data analysis, and user awareness by integrating embedded hardware with cloud-based IoT technology.

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