

Development of a Low-Cost IOT-Based Smart Energy Meter System

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ABSTRACT—

The current study is an extension of the existing research works on the subject matter of smart energy meters through IoT application. This study is motivated by the results presented in the *International Journal of Innovative Technology* and a freely available energy consumption dataset of a Spanish household. This paper adopted a similar methodology to explore regional energy usage patterns and gain insights into effective electricity consumption. The proposed model of the smart energy meter incorporates IoT components such as microcontroller, voltage sensor, current sensor, and basic power source to keep the cost of implementation minimal and functional.

This smart energy meter system offers timely energy measurement and alerts on any unexpected variations in energy usage, thus providing efficient monitoring of energy usage and saving on labor cost related to meter reading and bill generation. The user can gain insights into his electricity usage pattern through the proposed model and make informed decisions on energy consumption management. Other benefits that may be derived from this system include remote energy usage monitoring, usage analysis, and energy theft prevention. Compared to other conventional energy

meters, the proposed model has better energy usage awareness and accuracy. The project further explores future developments that involve incorporation into smart grids, renewable energy systems, and advanced Internet of Things (IoT) technology. This project is also relevant to achieving the UN's Sustainable Development Goals (SDGs) of number 7, 9, 11, 12, and 13.

Keywords— IoT-based Energy Meter; Real-Time Monitoring; Energy Management System; Smart Grid Technology; Sustainable Energy; Remote Monitoring

I. INTRODUCTION

Electricity is no doubt one of the fundamental aspects of our daily lives and is consumed in increasingly large quantities day by day. Most households and industries continue to use conventional energy meters for monitoring the consumption of electricity. The conventional energy meters are only capable of registering the overall consumption for billing purposes without providing any additional details regarding the usage pattern of electricity. Thus, many consumers fail to identify instances of energy wastage or any sudden surge in power consumption due to inefficient energy meters. The manual process of

energy measurement also consumes time and human effort.

With the advent of IoT technology, there have been several advancements in energy management systems in recent times. With IoT, machines can transmit data via the internet. Smart energy meters use IoT technology for transmitting real-time energy measurements.

The primary purpose of this project is to design an affordable smart energy meter utilizing IoT components like microcontroller, voltage sensor, current sensor, and power supply modules. This system has been designed to track the consumption of electricity and detect any abrupt changes in the consumption level. This can help minimize the need for manual labor for reading the meters and generating the bills. Features like remote monitoring, usage tracking, and detection of any theft make this system more efficient.

The project has been carried out by considering previous research works as well as energy consumption data. Further enhancements in this project could be done by integrating this smart meter with smart grid and renewable energy systems.

II. LITERATURE REVIEW

Several research studies have been carried out regarding the usage of smart energy meters, powered by IoT technology, for effective energy consumption management. The focus of most research studies carried out on IoT based smart meters is on making them easy to use without requiring manual labor, billing processes that are quick and convenient, and giving instant access to energy consumption data. One of the research papers published in the International Journal of Innovative Technology and Exploring Engineering (IJITEE) discussed IoT based energy meters used for energy management. Real time monitoring, automated billing process, and remote access to electricity consumption data were some of the features of the research. The study brought out the importance of real-time monitoring when it comes to energy management.

There was a research paper conducted using an open source dataset sourced from Spain where there was energy consumption data from household consumers. The aim of this study was to understand electricity consumption behavior from energy data.

III. METHODOLOGY

The implementation of IoT in the development process of the energy meter contributed to the increased usability and application area of this device. The list of necessary devices includes the ESP32 microcontroller, voltage sensor ZMPT101B, current sensor ACS712, LCD screen, and DC to DC Step Down power supply converter. The reason why those particular pieces of equipment were chosen is their affordability and ability to provide constant monitoring.

As for the operation algorithm, it can be noted that this process does not require any additional efforts from the user. In other words, the sensors monitor the electricity input and send the measurements to the microcontroller. Afterward, the controller calculates the value of consumed electricity. As soon as the data has been calculated, it appears on the LCD screen and, what is more important, can be remotely accessed using the Internet connection. Among the main advantages that this system has is the ability for customers to track their energy consumption on a daily basis compared to monthly billing statements. It will be easier to spot any sudden increase in energy consumption. Some extra features like remote metering, energy consumption analysis, billing precision, and theft control also make the meter more useful. In contrast to the conventional ones, the proposed smart meter provides users with an access to information regarding energy consumption.

The approach to the creation of the suggested model is based on some earlier studies of IoT smart meters along with data on energy consumption. The main aim of this research was to create an inexpensive system for use in IoT applications in general and energy grid and sources integration in particular.

IV. RESULTS AND DISCUSSION

The model of IoT-based smart energy meter developed in this paper has been successfully tested by subjecting it to different loads of electricity. The voltage and current sensor were actively sensing the electrical signals while testing. The calculations have been done by ESP32 microcontroller that displayed the reading on LCD display and also sent them over WiFi network. These results prove that the designed system has performed well and shows improved flexibility in comparison to normal energy meters.

The implementation of the model showed that the real-time electricity meter readings could be observed. As the model continuously monitors and keeps record of electrical usage, it makes it possible to detect sudden changes in the consumption pattern. Remote monitoring reduced the need of physical visits of meter reading along with easy integration with the billing modules.

The system performed well when implemented and was successful in providing consistent readings for the purpose of small scale monitoring. Other important features such as electricity usage analysis, theft detection and billing added more functionalities to the system. Simplicity of implementation with cost-effective components kept the cost of the system low with all required features.

The results obtained from the proposed model were satisfactory to some extent but there were some limitations which existed within the model which cannot be overlooked at all in case of using it. Internet connectivity had to be kept alive throughout the entire period of remote monitoring. In the case of the model expansion to a higher level, security requirements and storage capacity requirements can be increased. Table I: Comparison Between Conventional Meter and Proposed IoT Smart Meter

| Feature | Conventional Energy Meter | Proposed IoT Smart Energy Meter |
|----------------------|---------------------------|---------------------------------|
| Real-time Monitoring | No | Yes |

| | | |
|---------------------------|-----------|-----------|
| Remote Access | No | Yes |
| Automatic Billing Support | Limited | Available |
| Energy Usage Analysis | No | Yes |
| Theft Detection | Difficult | Possible |
| WiFi Connectivity | No | Yes |
| Cost Efficiency | Moderate | High |
| Data Storage | Manual | Digital |

From Table I above, one can see that the new Internet of Things (IoT) enabled energy meter is better than the existing ones used in many places today. Some of the benefits offered include real time monitoring, remote monitoring capability, and detection of energy theft.

V. CONCLUSION

The proposed IoT-based smart energy meter can be said to be economically and realistically used for measuring the power consumption of people and organizations in real-time. With the use of sensors like ESP32, voltage sensor, and current sensors, the designed project can efficiently measure the power consumption of individuals in their daily activities. Features like remote monitoring, analysis of consumption, and sudden increase in consumption make this project efficient and reduce the requirement of manual work done by the previously used models. With the aid of this project, one understands and learns the pattern of electricity usage of individuals. Also, the design of this project gives a clear picture of the advantages brought about by the usage of IoT in managing the consumption of energy in everyday activities. The IoT-based energy meter enables one to have better access to electricity consumption than other models.

Despite its applicability for small-scale purposes, this project can be made to suit larger projects by incorporating smart grid, renewable energy sources, cloud storage, and mobile application.



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