THE DEVELOPMENT OF REAL-TIME ENERGY CONSUMPTION MONITORING USING IOT

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ABSTRACT

Energy shortage is a global challenge with significant implications for economies, societies, and the environment, including the Philippines. Promoting energy conservation in households is an effective approach to address this issue. In the Municipality of Midsayap, North Cotabato, Philippines, unmonitored energy consumption leads to excessive energy usage in households. To address this problem, this paper aims to research, build, test and implement a Real-Time Energy Consumption Monitoring (RECM) device using IoT technology. The RECM device, equipped with an SCT013 current sensor, enables real-time 24/7 monitoring of energy consumption. The monitored data is displayed in graphical and numerical formats using the Thing Speak cloud storage service. The RECM device was deployed in households, and a survey was conducted to evaluate its functionality and effectiveness. The results indicate that the design of the RECM device is a highly useful and efficient tool for real-time energy consumption monitoring. This paper provides circuit diagrams, wiring diagrams, and the list of materials used to develop the Real-Time Energy Consumption Monitoring (RECM) device using IoT."

KEYWORDS

IoT, Energy, Energy Consumption, Energy Monitoring, Current Sensors.

1. INTRODUCTION

1.1. Background of the Study

Electricity plays a pivotal role in modern society, powering industries, supporting critical infrastructure, and enhancing the quality of life for individuals worldwide. Electricity continues to position as the “fuel” of the future. Worldwide energy demand grew by 2.3% in 2018. It is the fastest growth of demand in this decade. The performance driven by a global economy and strongly cooling and heating needs in some regions [1]. However, the current state of electricity supply is mired in a crisis. Energy crisis is very common among countries. In the Philippines, according to the Department of Energy in year 2016, there was a significant increase of 10% in the Philippine energy usage and its peak demand is at 8.7% ascribing to several factors such as increase in temperature caused by the El Nino. This kind of weather triggers to increase the use of the electricity for it powers many kinds of appliances for cooling needs in each household or establishments [2]. Without monitoring the household electrical usage may result to the increase in the electrical usage compared to its normal use.

Metering energy consumption of a household collects data of the day-to-day usage of electricity that could be used in estimating and saving energy [3]. In the Muncipality of Midsayap, North Cotabato, power consumers do not get a clear idea on how the power consumption was carried out by the home appliances and to what extent these appliances contribute to the overall power consumption of the household. This gave the researchers the motivation to pursue "The development of Real-Time Energy Consumption Monitoring (RECM) using IoT."

1.2. Objectives

The study aimed to develop a Real-Time Energy Consumption Monitoring (RECM) system using IoT with the following features and functionalities:

1. Enables consumers to monitor their real-time and daily energy consumption.
2. Displays current rating, power usage, and daily consumption through an LCD interface.
3. Establishes an Internet connection to send monitored data to the ThingSpeak cloud storage service.
4. Includes a backup storage to store monitored data in the event of an Internet connection failure.

1.3. Conceptual Framework

Figure 1 depicts the conceptual framework of the study. The independent variables represent the problems faced by electric consumers, while the moderating variable represents the solution to these problems—the RECM system. The dependent variables encompass the features and functionalities of the RECM device.

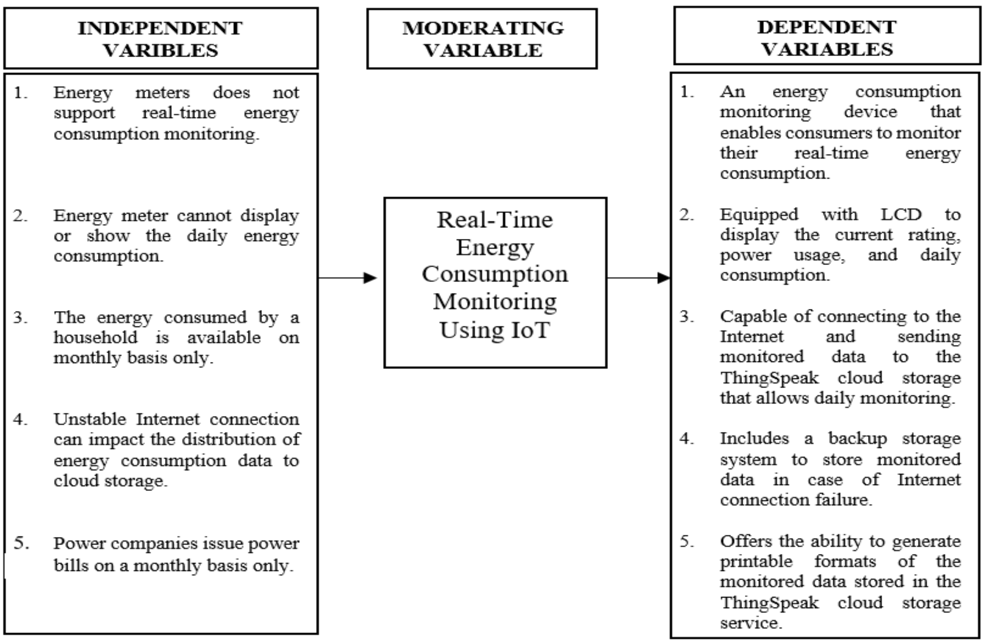

Figure 1. Conceptual Framework of the Study

2. RELATED WORKS

2.1. User Behavior and Feedback in Energy Conservation

Providing individualized energy use information through methods such as improved billing, periodic feedback, and continuous feedback can effectively contribute to reductions in energy consumption [5]. Proving daily feedback on power consumption, along with a generous rebate program, could potentially result in an average reduction of 10-15% in electricity use within an apartment setting [6]. However, homes using a certain energy monitoring device called PCM (Power and Control Monitor) exhibited a statistically insignificant reduction of 12% in mean electrical consumption [7].

While conducting a comprehensive review of the available literature there were not many studies that particularly address user behavior and feedback in the context of energy saving. Despite the fact that there hasn't been much research specifically on this theme, it presents a crucial area of investigation with significant potential for promoting sustainable energy practices.

2.2. IoT Based Energy Consumption Monitoring

The adoption of smart home technologies in buildings or residences presents a significant opportunity to reduce energy consumption [9]. The Internet of Things (IoT) has ushered in a revolution in electronics and IT, enabling everyday objects to connect to the global Internet network [8]. IoT can be effectively utilized to enhance energy efficiency, promote renewable energy utilization, and mitigate environmental impacts associated with energy use [10]. Through IoT technology, remote control and monitoring of various electrical appliances, including air conditioners and lighting systems, are made possible [11].

A specific study by Marques in 2017 highlights the connection between energy consumption monitoring and the Internet of Things paradigm. The study aims to design and develop an autonomous system called iPlug, which enables the monitoring and control of Internet-connected electrical equipment via Wi-Fi [12]. In this study, the RECM device incorporates IoT capabilities allowing a 24/7 real-time monitoring of energy consumption.

2.3. Raspberry Pi-Based Energy Monitoring Systems

Raspberry Pi, in particular, offers more advanced features compared to traditional microcontrollers [13]. Raspberry Pi is low cost and has a reputation as a highly dependable technology for tracking industry energy consumption making it suitable for energy metering projects [14]. The utilization of Raspberry Pi in smart energy meter was found to be energy-efficient, consuming less power while providing faster performance. Furthermore, Raspberry Pi was noted for its dual UARTs (Universal Asynchronous Receiver-Transmitter), enhancing its capabilities for communication and data transfer [15]. The present study also adopts the utilization of Raspberry Pi, similar to the previously mentioned studies, due to its various advantages such as cost-effectiveness, versatility, and efficiency.

3. RESEARCH DESIGN

The researchers used the Developmental Research methods since study involves the development of a real-time energy consumption monitoring system. It focuses on designing, creating, and optimizing a device, the IoT-based energy consumption monitoring system.

A survey was conducted in order to gather feedback from users or electric consumers who have interacted with the RECM device. The objective of the survey was to capture user experiences, identify usability issues, and collect suggestions for improvements or additional features for the future researchers. The survey was conducted in the Municipality of Midsayap, North Cotabato, Philippines. There were fifty (50) respondents who evaluated the design composed of homeowners and COTELCO-PPALMA employees. The data collected from respondents who interacted with the RECM device underwent descriptive statistical analysis. The analysis included the calculation of standard deviation and mean, which were interpreted using the Likert Scale.

4. PROJECT DEVELOPMENT

4.1. Main Materials

SCT-013 Current Sensor. Used to measure and monitor real-time current consumption, displaying the data on the Liquid Crystal Display (LCD).

Arduino Uno Microcontroller. Receives current data from the SCT-013 sensor and sends the monitored data to the Raspberry Pi.

Raspberry Pi 3. Receives monitored data from the Arduino microcontroller and transmits it to the Thing Speak cloud storage service. Additionally, it serves as a backup local storage in case of internet loss.

Raspberry Pi 3- 3.2inch TFT Display Screen. Used to display the desktop of Raspberry Pi 3. It is used to monitor the monitored data in local storage.

Real-time Clock DS3231. Displays the current time on the Liquid Crystal Display (LCD) and automatically resets the Arduino every 24 hours.

4.2. Block Diagram

Figure 2 displays the block diagram of the device. The SCT-013 current sensor transmits the current ratings to the Arduino microcontroller. The Arduino microcontroller then presents the data readings on a Liquid Crystal Display (LCD). The Arduino microcontroller establishes a serial communication link with the Raspberry Pi to send real-time data to the Thing Speak cloud storage service.

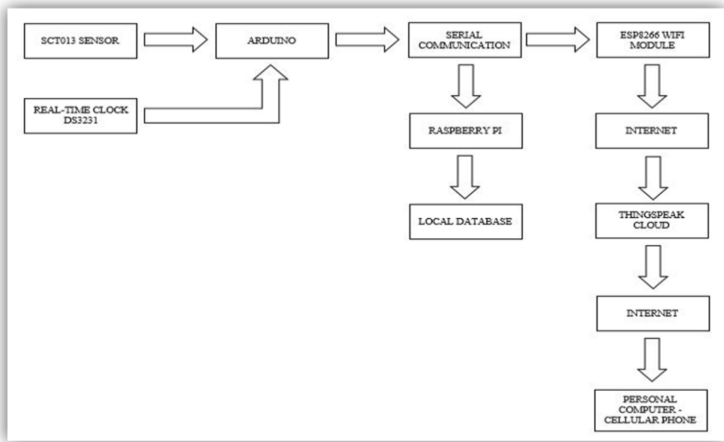

Figure 2. Block Diagram

4.3. Schematic Diagram

Figure 3 illustrates the circuit diagram of the device. The central component is the Arduino microcontroller, responsible for processing and displaying the monitored data on the Liquid Crystal Display (LCD). The Raspberry Pi is also included in the system to transmit the monitored data to Thing Speak. The circuit incorporates an SCT-013 current sensor to measure current ratings and calculate the monitored data.

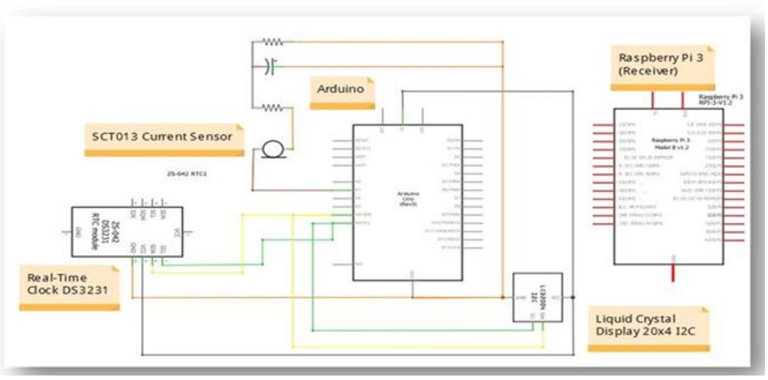

Figure 3. Schematic Diagram

4.4. Wiring Diagram

Figure 4 depicts all the system components and their interconnections. The SCT-013 current sensor and Liquid Crystal Display (LCD) are connected to the main component, the Arduino microcontroller. The diagram also illustrates the serial communication connection between the Raspberry Pi and the Arduino microcontroller.

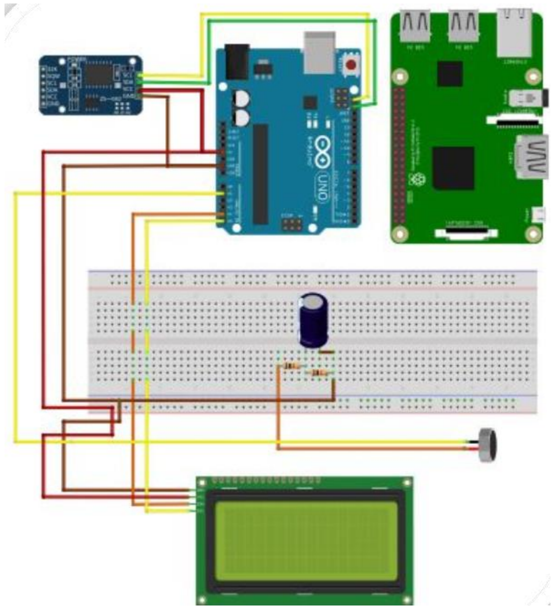

Figure 4. Wiring Diagram

5. RESULTS AND DISCUSSION

The survey analysis evaluating the functionality and effectiveness of the Real-Time Energy Consumption Monitoring (RECM) device. The data obtained from respondents who utilized the RECM device underwent descriptive statistical analysis, which involved calculating the mean and standard deviation. The ratings were obtained using a Likert scale:

1. Strongly Agree (SA)
2. Agree (A)
3. Disagree (D)
4. Strongly Disagree (SD)

The survey results for the *Objective 1*, which focused on the real-time energy consumption monitoring device, showed that respondents *strongly agreed* (mean of 3.93) that the device is convenient and efficient in monitoring real-time energy and daily consumption. The statement highlighting the device's ability to monitor energy consumption in real-time received the highest mean of 4.00, indicating a strong agreement.

Objective 2, which pertained to the device's liquid crystal display (LCD) for displaying current rating, power usage, and daily energy consumption, yielded a mean of 3.94. Respondents *strongly agreed* that the device can display the necessary data for monitoring daily energy consumption. The statement emphasizing the clear display of real-time energy consumption on the LCD received the highest mean of 4.00, representing a strong agreement.

Objective 3 focused on the device's connection to the Internet and sending monitored data to the Thing Speak cloud storage service. The mean score was 3.84, indicating *a strong agreement* that the device interface with cloud storage is working properly and practical compared to costlier storage devices. Statements related to the automatic storage of data in Thing Speak and the accuracy of graphical and numerical displays received the highest mean of 3.93, signifying a strong agreement.

Objective 4 examined the device's ability to store monitored data in a backup storage in case of Internet connection failure. The mean score was 3.90, indicating a *strong agreement* that the device's local storage effectively stores data even without internet connectivity. Statements about the presence of local storage as a backup and data storage frequency received the highest mean of 3.97, representing a strong agreement.

Objective 5 focused on the device's capability to generate a printable format of the monitored data stored in Thing Speak cloud storage. The mean score was 3.87, indicating *a strong agreement* that the device can provide a hardcopy of the data, particularly for those who prefer reading information in printed form. Statements regarding the comprehensiveness and organization of the report, information on peak hours of energy consumption, and quick generation of the printable format received the highest mean of 3.87, signifying a strong agreement.

6. CONCLUSIONS

The results obtained from the gathered data indicate that the respondents strongly agreed with all the objectives. Consequently, the design project successfully achieved the features and functionalities of the RECM device. As a result, the RECM device proves highly beneficial in monitoring energy consumption for consumers, enabling electric consumers to gain awareness of their daily energy usage.

7. RECOMMENDATIONS

For future designers aiming to pursue and enhance the existing design and scope of the study, the researchers offer the following suggestions:

1. Consider upgrading the current sensor to handle a larger load in terms of ampere.
2. Implement an automatic power tripping mechanism when the maximum limit of power consumption per day, week, or month is reached.
3. Develop a daily summary report sent via text message to notify consumers of their energy consumption within a 24-hour period.

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