Web-Based Energy Monitoring System and Tariff Calculation for Residential Electricity Consumption

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ABSTRACT-

The goal of this project is to develop and deploy a web-based energy monitoring system for residential electricity consumption using Internet of Things (IoT) technology and various hardware elements, including a Raspberry Pi Pico, LCD display, current coil, relay energy meter PZEM004T, ESP8226, and RFID. The planned system will enable households to track their energy usage in real-time via a web-based interface, giving them insights into their energy usage habits and assisting them in finding ways to lower their electricity bills. The device will also compute the electricity rate depending on energy consumption and display it on the LCD screen. The hardware elements will cooperate to track and measure energy use, with the current coil identifying the power theft and give alert to the user via web server or via mobile application. An RFID tag and reader will be used for the purpose of prepaying option, that will display the amount which has been paid by the user. This web-based energy monitoring system will give households an affordable and practical tool to track their energy usage, prepaid amount, lower their electricity bills, and contribute to a more sustainable future.

Keywords: Electrical energy monitoring, PZEM-004T sensor, and the Raspberry Pi Pico.

1. INTRODUCTION

Over time, residential households' use of electricity has increased, resulting in rising electricity costs and environmental issues. Energy monitoring devices that enable households to track their energy usage in real-time and find solutions to lower their electricity bills are becoming more and more necessary to address these challenges. In this project, we suggest an Internet of Things (IoT)-based web-based energy monitoring system that makes use of a variety of hardware elements, including Raspberry Pi Pico, LCD display, current coil, relay 3.3, relay energy meter PZEM004T, ESP8226, and RFID, to measure and monitor energy consumption in residential homes. With a web-based interface, the system will enable homeowners to track their energy usage in real-time, giving them insights into their usage patterns and assisting them in finding ways to lower their electricity bills. Also, based on energy consumption, the system will determine the electricity rate and display it on the LCD panel. With the current coil monitoring the current flowing through the circuit and the energy metre PZEM004T measuring the voltage and power consumption, the hardware components will work together to measure and monitor the energy usage. The Raspberry Pi Pico will process and store the data after receiving it wirelessly from the ESP8226 module. Relay 3.3 will manage the power supply to the relay and the energy

metre, ensuring that only the essential parts are turned on when required. An RFID card reader will be used to authenticate the user and guarantee that only permitted users can access the system. Users can check their energy use and tariff information on the LCD panel after swiping their RFID card to gain access to the system. Homeowners will be able to monitor their energy usage, lower their electricity costs, and contribute to a more sustainable future with the help of this web-based energy monitoring system.

2. RASPBERRY PI PICO BASED ENERGY MONITORING

The electrical system's voltage, current, and power are all monitored by the energy monitoring system. The PZEM-004T energy usage metre, a Raspberry Pi 4 acting as a web server for data storage and user interface are used in this study. Due to the PZEM-004T and Raspberry Pi's incompatible communication formats, the Raspberry pi was utilised as a repeater to send data from the PZEM-004T to the Raspberry Pi Pico. As seen in Figure 1, the Raspberry Pi Pico, Esp8266, and PZEM-004T are connected.

On the Raspberry Pi web-based energy monitoring system, there are three key subsystems: energy measurement, data transmission, and the website. Initially, PZEM-004T measures the voltage and current flowing through the load. PZEM-004T then uses this voltage and current to estimate energy. Then, PZEM-004T receives a request byte from Raspberry Pico. The PZEM-004T then uses serial communication to transfer data about voltage, current, power, and energy to microcontroller. Then it transmits its data to Raspberry Pi 4. The Raspberry Pi stores its data in a database on the final subsystem. Furthermore, a web-based user interface displays the database's data.

Figure 2 depicts the schematic for the Raspberry Pi Pico's web-based energy monitoring system. First, the PZEM-004T is connected to the AC power supply and the CT sensor for voltage and current detection, which is utilised to determine power and energy. The RX and TX pins of the PZEM-004T are then connected to the digital pins of the Raspberry Pi Pico. Data is transformed , so that the communication protocol used by the Raspberry Pi Pico is compatible. Finally, a USB connection between Esp8266 and Raspberry Pi Pico is required so that it can transmit data to Raspberry Pi Pico.

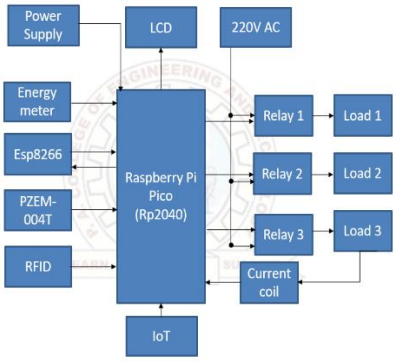

Figure 1: Block Diagram of Raspberry Pi Pico Web-Based Energy Monitoring System

3. EXPERIMENTAL SETUP

I. Raspberry Pi Pico

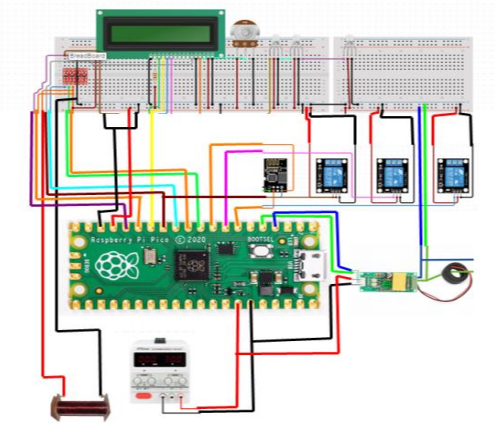

Figure 2: Schematic of Raspberry Pi Pico Web-Based Energy Monitoring System

Via a web-based interface, the proposed system will allow homes to monitor their energy use in real-time, providing them with insights into their usage patterns and helping them identify methods to reduce their electricity costs. On the LCD panel, the device will also compute the electricity rate based on energy consumption. The hardware components will work together to monitor and quantify energy use, with the current coil detecting the passage of current. With the help of this web-based energy monitoring system, households will have an affordable and useful tool to monitor their energy use, cut their electricity costs, and help create a more sustainable future.

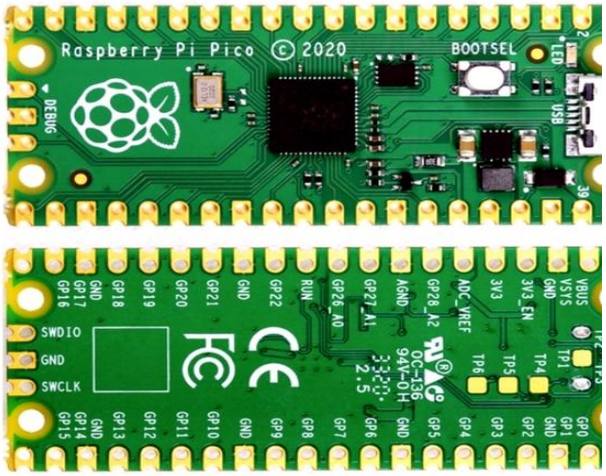

Figure 3: Raspberry pi Pico

Raspberry Pi Pico is a microcontroller board mainly developed for robotics and embedded applications. Unlike other Raspberry Pi modules, this board is not a full computer. Pico is the most economical board among other Raspberry Pi modules. This tiny board incorporates 26 GPIO pins that you can configure either as an input or as output. Moreover, RP2040 is added to the board that is considered as the first in-house microcontroller introduced by Raspberry Pi. Mostly the RP2040 microcontroller pins are taken to the user IO pins on the right and left edge of the module.

PIN DESCRIPTION

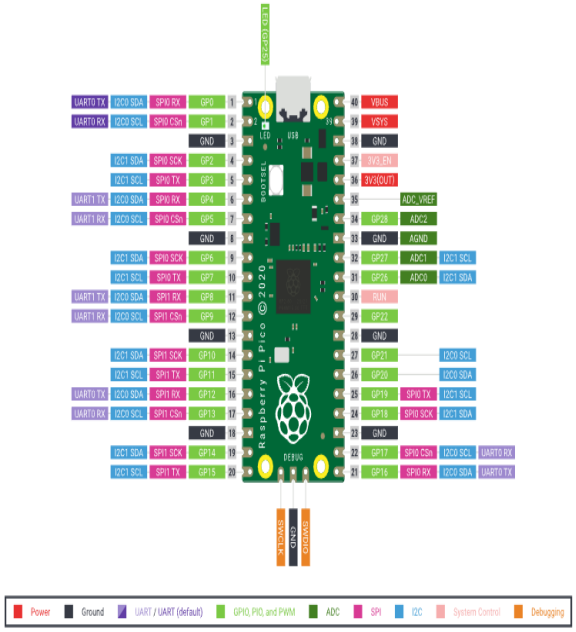

Figure 4: Raspberry Pi Pico Pin Description

II. EM-18 Reader Module

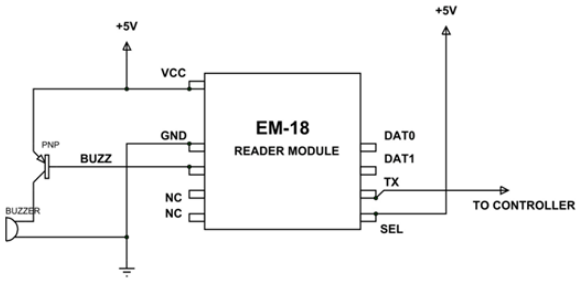

Figure 5: Block Diagram of EM-18 module

EM-18 is used like any other sensor module. First we choose the mode of communication between module and controller. Next we will program the controller to receive data from module to display. Next power the system. When a tag is brought near the MODULE it reads the ID and sends the information to controller. The controller receives the information and performs action programmed by us.

III. PZEM-004T

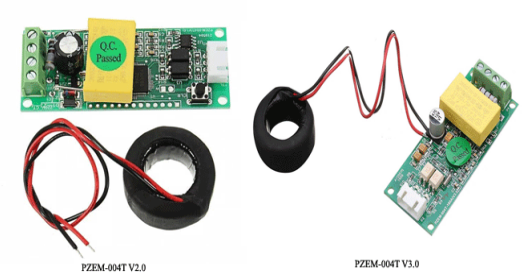

Figure 6: Hardware of PZEM-004T

PZEM-004T is an electronic module that functions to measure: Voltage, Current, Power, Frequency, Energy and Power Factors. With the completeness of these functions / features, the PZEM-004T module is ideal for use as a project or experiment for measuring power on an electrical network such as a house or building.

The PZEM-004T module is produced by a company called Peacefair, there are 10 Ampere and 100 Ampere models. Please be careful because the wiring between the 10 Ampere models with 100 Amperes is different, if a short circuit or a short circuit can occur in the electrical network.

IV. ESP8266

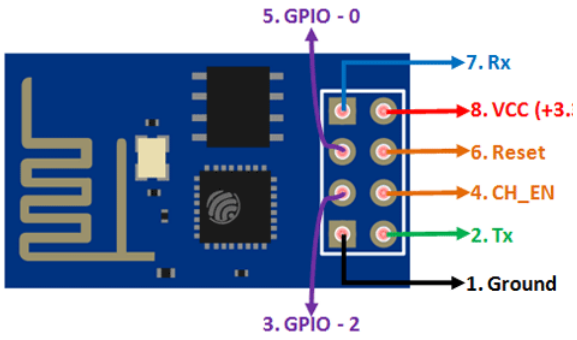

Figure 7: Block Diagram of Esp8266

ESP8266 is Wi-Fi enabled system on chip (SoC) module developed by Espressif system. It is mostly used for the development of the Internet of Things (IoT) embedded applications. The ESP8266 is a low-cost Wi-Fi microchip with full TCP/IP stack and microcontroller capability produced by Shanghai-based Chinese manufacturing company Espressif Systems. The ESP8266 is capable of either hosting an application or offloading all the Wi-Fi networking functions from another application processor. Each ESP8266 Wi-Fi module comes pre-programmed with an AT command set firmware, now you can simply hook this up to your Arduino device and get as much Wi-Fi ability as a Wi-Fi Shield offers.

4. RESULTS AND DISCUSSION

A. User Interface of Raspberry Pi Pico Web-based Energy Monitoring System

The user interface of Raspberry Pi Pico web-based energy monitoring system is shown in Fig 8. This system designed for access to a local network. On this research, this monitoring system can be accessed from a desktop or mobile phone.

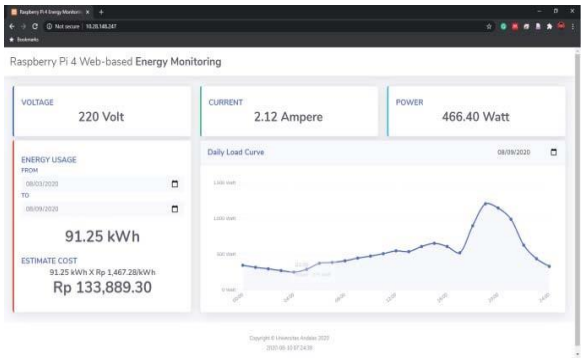

Figure 8: User interface of ubidots server

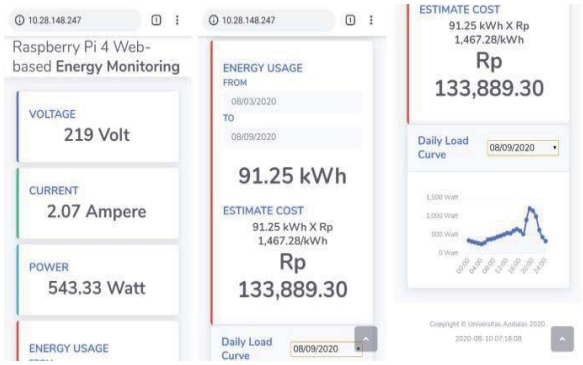

Figure 9: Output of Web-Based Energy Monitoring System

5. CONCLUSION

In conclusion, the suggested web-based energy monitoring system utilising IoT technology and various hardware elements such as Raspberry Pi Pico, LCD display, current coil, relay, energy metre PZEM004T, ESP8226, and RFID is a practical and affordable solution for tracking energy usage in residential homes. The device enables homeowners to keep an eye on their energy usage in real-time and offers insights into their habits, enabling them to find ways to cut their electricity costs. On the LCD panel, the system also shows the electricity tariff that was calculated based on energy consumption. The gear works in unison to measure and monitor the energy usage, and the ESP8226 module wirelessly transmits the data to the Raspberry Pi Pico, which analyses and stores it. By managing the power supply to the energy metre and the relay, the relay makes sure that only the essential parts are turned on when they are required. An RFID card reader is employed to verify the user's identity and guarantee that only approved users can access the system. This adds another level of security to the system. This web-based energy monitoring system provides households with a useful and effective way to keep track of their energy usage, lower their electricity costs, and support a more sustainable future.

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