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A SMART WEB-BASED ENERGY MONITORING SYSTEM FOR RESIDENTIAL ELECTRICITY CONSUMPTION

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Abstract -The application of communication and information technology for monitoring household and building activities is one of the exciting topics in future smart city development research. This project presents the design of electrical energy monitoring using the PZEM-004T energy sensor and Raspberry Pi 4 as a web server. The system is designed for measuring current, voltage, power, and energy and sending it to a database for the purpose for displayed on infographics web pages in real-time. The web page interface has a responsive design, so the stored data in the database can access on both desktop and mobile phones for flexibility. Based on the results for various loading, it can be concluded that the design of the electrical energy monitoring device is working well with an average error of less than 2%. The human interface also shows the real-time electrical parameters on both desktop and mobile phones. Electric power is the basic requirement of human beings, which is used for domestic, industrial, and agricultural purposes. In the process of energizing, the electric current must flow through the electronic circuits of the equipment. This flow of electric current can be controlled and monitored by a Smart Meter, which has an electronic chip for monitoring the energy consumed and a wireless module for data communication. The entire setup consists of an automated metering device, Raspberry Pi, PZEM Module, and buzzer is used. The energy being utilized will be sent to the cloud server.

Key Words:Electronic energy meter, PZEM-004T sensor, Raspberry Pi, Buzzer, and GSM.

1.INTRODUCTION

Electric energy consumption deals with the usage of electric energy for domestic, agricultural, and industrial purposes. The total electricity consumed by the world population in 2012 was estimated to be 20,900 Terawatt-hour (TWh). Global electricity demand by 4(percent) increase in 2018 and it's the highest since 2010. Even though the majority of demand for electric power is met by nuclear and renewable energies, there is been an increasein the setup of coal and gas power plants which drives the CO2 emission to a greater extent. The total energy generated in India increased from 154.7 GW to an astonishing 345.5 GW in 2018, making the world's third-largest electric energy producer falling behind China and the United States. Regardless of this phenomenal progress, India faces an expansive demand for electricity. The International Energy Agency forecasts that the demand for electricity in India will triple between 2018 and 2040. The electric energy demand in India increased to 65 TWh in 2018 which is at a lower rate compared to the previous year; the increase in power demandcomes from the buildings, where air conditioning is of utmost necessity. This project aims at lowering the usage of electricity through efficient dynamic power management using IoT. Home automation systems are developing rapidly, along with advances in electronic and information technology. One application of the home automation system that is growing more and more today is the smart home system to assist homeowners in monitoring and controlling the function of energy consumption automatically, remotely, and centrally. Based on the Ministry of Energy and Mineral Resources, electricity consumption in Indonesia increased year by year, one of the reasons for the increase in electricity consumption is the improvement in-home electricity usage. This happens because the time of use is often incorrect, and ineffective, and lack of consumer awareness to save electricity, due to consumers cannot directly monitor the use of electrical energy they use. However, this method has shortcomings because to find out the results of the monitor, consumers must be directed to the location where the measuring instrument is installed. This method is considered inefficient because the electrical energy monitor resultsare not immediately known. Then it is necessary to design a system that can be used formonitoring electricity consumption using the IoT concept in real-time and long-distance. Therefore, this research proposed a Raspberry Pi-based monitoring system using the PZEM004T sensor as a voltage, current, and power reading device for electrical energy measurement. The design of this system aims to monitor the home electrical energy consumptionso that consumers can find out the energy usage data.

2. AIM AND OBJECTIVE

Aim:
The aim of this project is to reduce electricity by using a Raspberry pi web-based energy monitoring system.

Objective:
The main objective of this project is

- Measures voltage, current, power, and energy.
- Generate an alert using the buzzer once the power reaches a maximum.

3. LITERATURE SURVEY

In 2017, C. Choi, et al. proposes an effective energy monitoring system based on IoT. It will forecast users, and energy demands. It mainly focuses on LoRa technology,

renewable energy generations, etc. But its main drawback is, that it does not discuss how the data is taken and how power is calculated. Hiremath et al. in 2017 made their research on IoT-based energy control and managing devices. He designed and implemented an energy meter that uses Arduino as its microcontroller. This system is used to measure the power consumed by electrical devices. Power consumption is monitored and is sent to the server via a Wi-Fi module. A web-based application is used so that the user can monitor consumption anywhere in the world. The researcher mainly focuses only on the tools used in the experiment. Measurement data andtheir details are not discussed in it. Other scholars like Medina et al. in 2018 conducted a study on IoT-based electrical energy consumption using Raspberry pi. This study was made to know how energy consumption can be controlled and monitored. An android application was used for displaying the data obtained. According to their studies, analog input from the current sensor is connected to Arduino and is controlled by Raspberry pi. This data is then processed and storedin the database. Based on their results some systems are having high accuracy while someother devices are having low accuracy. In 2019, Prasetyo et al. researched Smart Home for monitoring and control of electrical energy. The research was taken place in Indonesia. The research aims to conduct the effectiveness of electricity usage by monitoring and controlling power using cloud-based IoT. The Smart Home design was built using several devices such as an Arduino microcontroller, Internet module, AC Voltmeter, Relay, LDR Sensor, and PIR Motion Sensor. The output ofthe research is still in the form of design, not yet at the stage of developing and implementing the tool. Z. H. Che Soh, I. H. Hamzah, S. A. Che Abdullah, M. A. Shafie, S. N. Sulaiman and K. Daud, ”Energy Consumption Monitoring and Alert System via IoT,” 2019 7th International Conference on Future Internet of Things and Cloud (FiCloud), Istanbul, Turkey, 2019, pp. 265-269. This project presents a home energy consumption monitoring system and alerts on Ubidots Cloud Services. In this research work, an Internet of Things (IoT) framework has been implemented to monitor the energy consumption data at home and send the energy consumption data to IoT Cloud. The system utilizes a sensor module (ACS712) that is connected with an Intel Edison microcontroller to measure the power consumption at the home. The power consumption data is collected and stored in Ubidots IoT Cloud Services. Consumers can monitor their energy consumption at home on daily basis and therefore can control the amount of energy used daily. The data collection experiment is carried out to see the amount of power consumption at home. The power consumption data is also displayed on the LCD before and after the load is connected to the system. The IoT dashboard is accessible onlinefor the user to look into their daily power consumption using the IoT dashboard. IoT Cloud performs some event analytics on the collected power consumption data and notifies the homeowner of caution, and recommendation through email and telegram which will alert their client about their electrical power utilization has exceeded their power consumption limit, thus helping to reduce over-usage of power.

4.EXISTING METHOD

In existing systems, we have power-consuming details and the user can check the power consumption but it doesn’t have adding of additional units of power and controlling of loads from long distances.

Drawbacks:

- In the existing system meter, tampering can be done easily.
- Manual Work is more and errors may happen.
- High cost.
- Consumers don’t have an idea about how much power is consumed.
- Difficult to operate.

5. PROPOSED METHOD

Home automation systems are developing rapidly, along with advances in electronic and information technology. One application of the home automation system that is growing more and more today is the smart home system to assist homeowners in monitoring and controlling the function of energy consumption automatically, remotely, and centrally. Based on the Ministry of Energy and Mineral Resources, electricity consumption in Indonesia increased year by year, one of the reasons for the increase in electricity consumption is the improvement in home electricity usage. This happens because the time of use is often incorrect, and ineffective, and lack of consumer awareness to save electricity, due to consumers cannot directly monitor the use of electrical energy they use. Nowadays, the electrical energy monitoring system that has been used is by installing conventional electrical measuring devices on the electrical circuit. However, this method has shortcomings because to find out the results of the monitor, consumers must be directed to the location where the measuring instrument is installed. This method is considered inefficient because the electrical energy monitor results are not immediately known. Then it is necessary to design a system that can be used for monitoring electricity consumption using the IoT concept in real-time and long-distance. This research proposed a Raspberry Pi-based monitoring system using the PZEM-004T sensor as a voltage, current, and power reading device for electrical energy measurement. The design of this system aims to monitor the home electrical energy consumption so that consumers can find out the energy usage data. The values are displayed on the cloud server. The main microcontroller used in this project is Raspberry Pi which is a Wi-Fi-based controller.

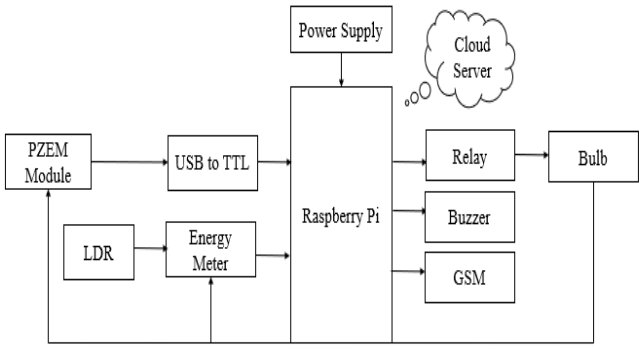


Fig: Block Diagram

Working Principle

• In this project, we are using a sensor named PZEM which is used for measuring power.
• To know the house loads power, we are using this module. The pins of the sensor are connected to Raspberry Pi by using a USB to TTL converter.
• As this comes with a serial communication function, we are connecting it by using a USB to TTL converter.
• By this, the Raspberry Pi takes the values from the sensor. The data is transmitted through a cloud server by using the Thingspeak server.
• The units of energy that the loads are consuming will also be updated using EnergyMeter.
• Based on the power values the load will turn off and the buzzer will hoot as well an SMS will be sent to the consumer.

Advantages:

• It is easy to operate.
• Cost-effective.
• Another advantage of the prepaid system is that the human errors in taking meterreadings and processing bills can be reduced to a large extent.

Applications:

• In houses.
• In offices.
• In Factories.

6. HARDWARE REQUIREMENTS

Energy Meter:

An Electronic Energy Meter (EEM) functionally outperforms the traditional Ferrari wheel meter. One important advantage of EEM is that in nonlinear loads, its metering is highly accurate, and electronic measurement is more robust than that of conventional mechanical meters. The Power companies benefit from EEM in three significant ways.
1. It reduces the cost of theft and corruption in electricity distribution networks with electronic designs and prepayment interfaces.
2. Electronic energy meter measures current in both Phase and Neutral lines and calculates power consumption based on the larger of the two currents.
3. EEM improves the cost and quality of electricity distribution.

Fig: Electronic Meter

PZEM-004T Sensor:

This Peacefair PZEM-004T Multi-function AC Power Monitor is very popular in electrical consumption measurement projects. It is capable of measuring four interrelated electrical variables voltage, current, power, and energy. This tiny PZEM-004T circuit is great for measuring AC (RMS) voltage, current, and power (single-phase). Simply power the board with a power supply (or you can use the AC source you are measuring) and connect the circular sensor to the board. Run the wire through the circular sensor and you`re ready to start measuring the voltage, current, and power. The circuit also comes with a TTL to USB adapter wire for easy connection to a computer or microcontroller.

Fig: PZEM-004T

Raspberry Pi 4:

Raspberry Pi 4 Model B was released in June 2019 with a 1.5 GHz 64-bit quad-core ARM Cortex, A72 processor, on-board 802.11ac Wi-Fi, Bluetooth 5, full gigabit Ethernet (throughput not limited), two USB 2.0 ports, two USB 3.0 ports, 2-8 GB of RAM, and dual-monitor support via a pair of micro HDMI (HDMI Type D) ports for up to 4K resolution. The Pi 4 is also powered via a USB-C port, enabling additional power to be provided to downstream peripherals, when used with an appropriate PSU. But the Pi can only be operated with 5 volts and not 9 or 12 volts like other minicomputers of this class.

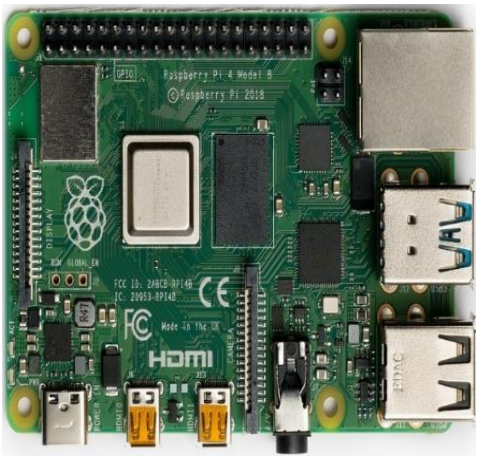


Fig: Raspberry Pi 4

Buzzer:

A buzzer or beeper is an audio signaling device, which may be mechanical, electromechanical, or piezoelectric. Typical uses of buzzers and beepers include alarm devices, timers, and confirmation of user input such as a mouse click or keystroke. The buzzer is an integrated structure of electronic transducers, DC power supply, widely used in computers, printers, copiers, alarms, electronic toys, automotive electronicequipment, telephones, timers, and other electronic products for sound devices.

Fig: Buzzer

GSM:

A GSM modem is a device that can be either a mobile phone or a modem device that can be used to make a computer or any other processor communicate over a network. A GSM modem requires a SIM card to be operated and operates over a network range subscribed by the network operator. It can be connected to a computer through a serial, USB connection.

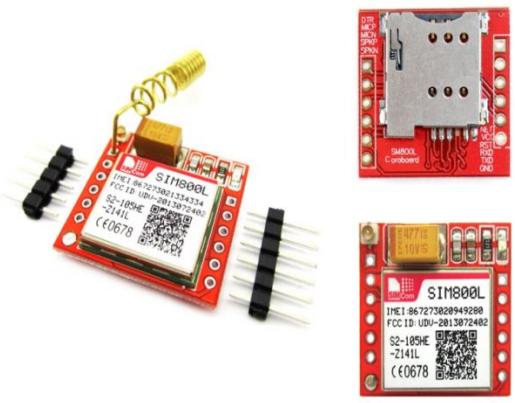


Fig: GSM

LDR Sensor:

A Light Dependent Resistor (also known as a photoresistor or LDR) is a device whose resistivity is a function of the incident electromagnetic radiation. Hence, they are light-sensitive devices. They also called photoconductors, photoconductive cells, or simply photocells. They are made up of semiconductor materials that have high resistance. There are many different symbols used to indicate a photoresistor or LDR, one of the most commonly used symbols is shown in the figure below.

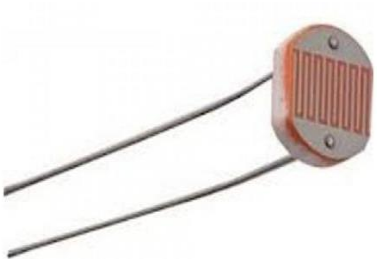


Fig: LDR Sensor

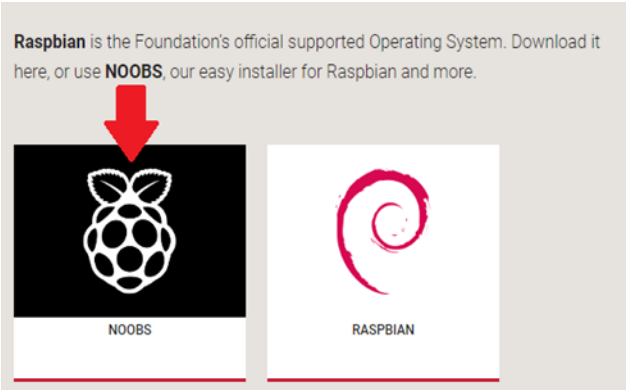
7. SOFTWARE REQUIREMENTS

NOOBS INSTALLATION

NOOBS has plenty of operating systems for us to choose from when we reach that stepthe most notable of which is Raspbian. For now, though let's concentrate on how to install NOOBS on the Raspberry Pi. We will briefly discuss the operating system installations later, in our final step. Using NOOBS is the easiest way to install Raspbian on your SD card. To get hold of a copy of NOOBS.

- Visit www.raspberrypi.org/downloads/

Fig:



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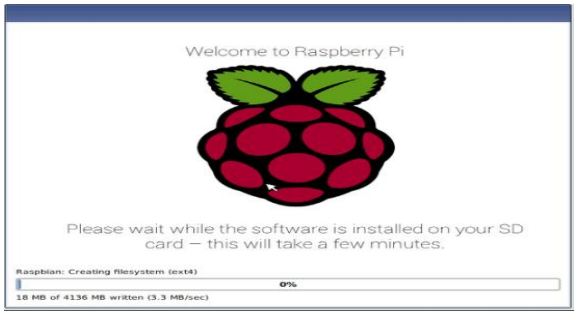

Fig: Raspberry Pi

IP Scanner:

Advanced IP Scanner is fast and free software for network scanning. It will allow you to quickly detect all network computers and obtain access to them. With a single click, you can turn a remote PC on and off; connect to it via Radmin, and much more. This tool can be downloaded from advanced-IP-scanner.com. This tool is free to download and is compatible with Windows as well. Click on the free download button to download advanced IP scanner on your computer.

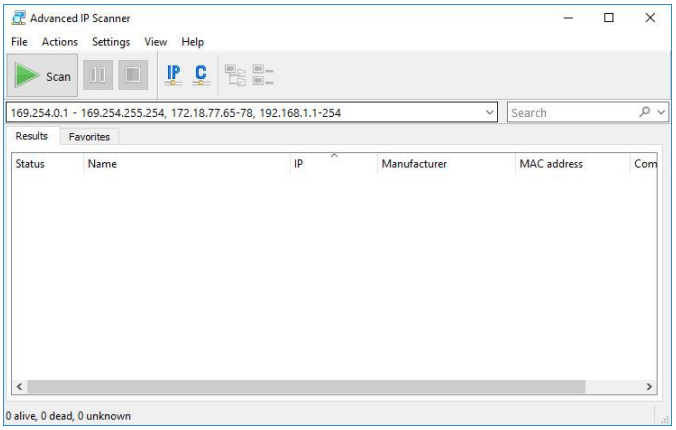

Fig: Advanced IP Scanner Setup

VNC Viewer:

Please follow the following steps to install the VNC viewer in windows

1) Please visit the following link to download the VNC viewer Download VNCviewer
2) Now please click Download VNC Viewer which is shown below
3) Once the download is complete please double click on the downloaded exe file
4) Please select language and click on OK which is shown below
5) Please click on Next which is shown below
6) Accept the agreement and click on Next which is shown below
7) Please click on Next which is shown below
8) Click on Install which is shown below

Simulation Results

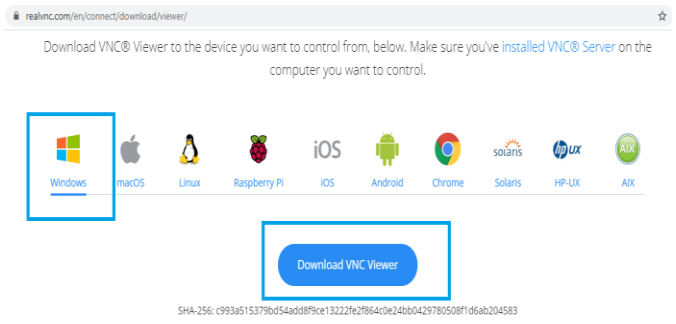

Fig: Download VNC Viewer

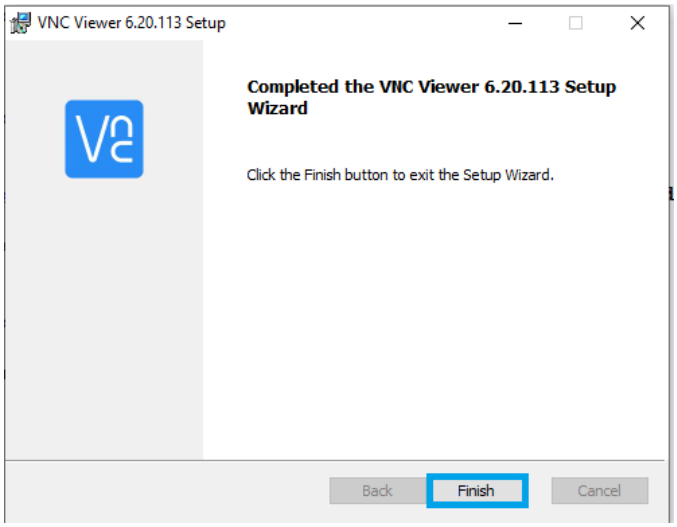

Fig: Completion of VNC Viewer Setup

8. SIMULATION RESULTS

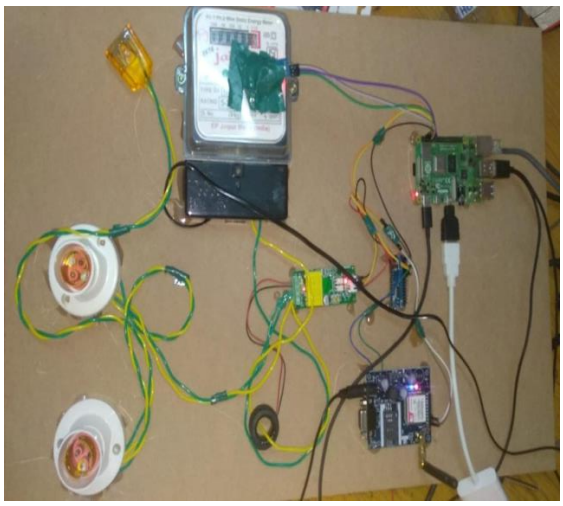

Fig: Experimental Setup

Components:

1. Raspberry Pi 4
2. PZEM-004T Sensor
3. Power Cable
4. Bulbs(100W,200W)
5. Bulb holders
6. Buzzer
7. GSM
8. Adapter 12V
9. Switches
10. Energy Meter
11. CT
12. Portable Fan
13. Arduino UNO

Output

The first switch on the power supply then goes to the advanced IP scanner. Click on the scan option, copy the raspberry pi URL and paste the URL into the VNC viewer. Then raspberry Pi desktop will be displayed. After that go to the file, there is a project.py folder, right-click on the folder, then click on the python 3 idle option, and code will be displayed. After that switch on the loads then run the code, voltage, current, power,energy, frequency, and pf values shown on the python shell. If the power reaches above 250 buzzers will hoot, and an SMS will be sent to consumers' mobile. For that voltage, current, power, energy, frequency, pf values, figures displayed on thingspeak server.

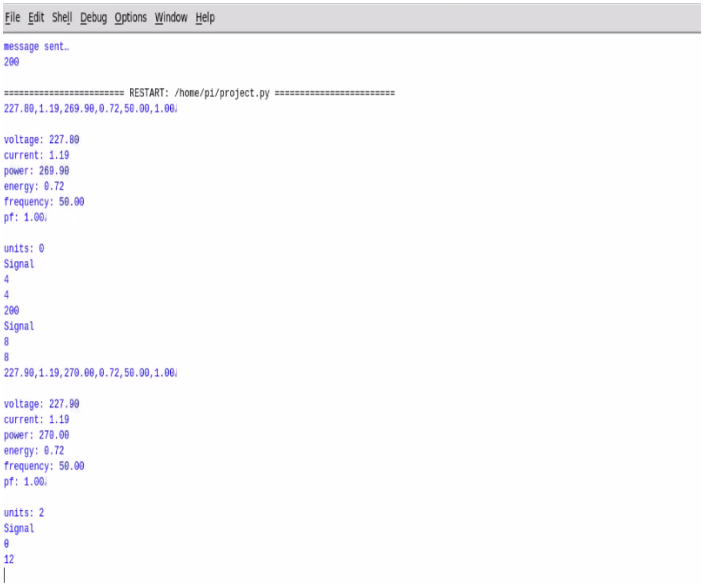

Fig:Voltage, Current, Power, Energy, Frequency and pf values

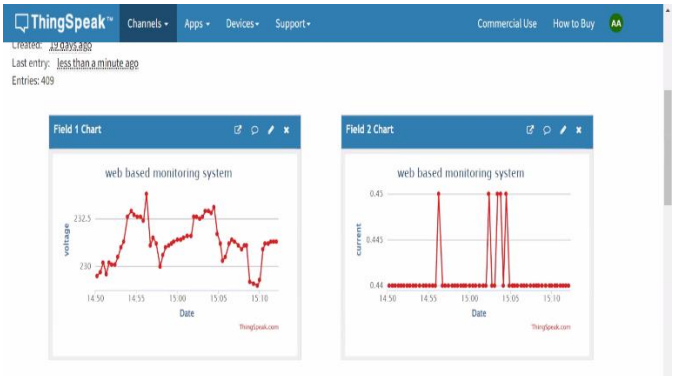

Fig**:** Voltage and Current Graphs

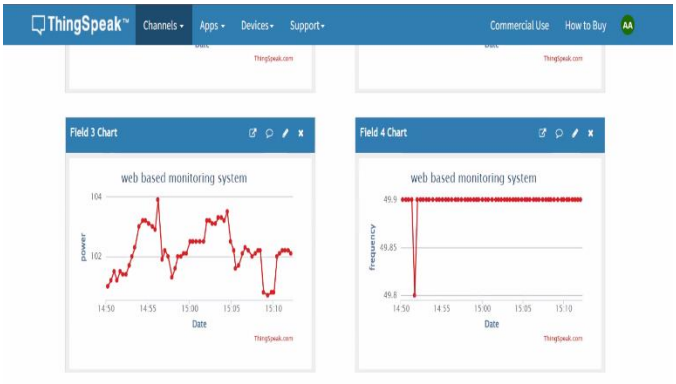

Fig: Power and Frequency Graphs

Fig: pf and Price Graphs

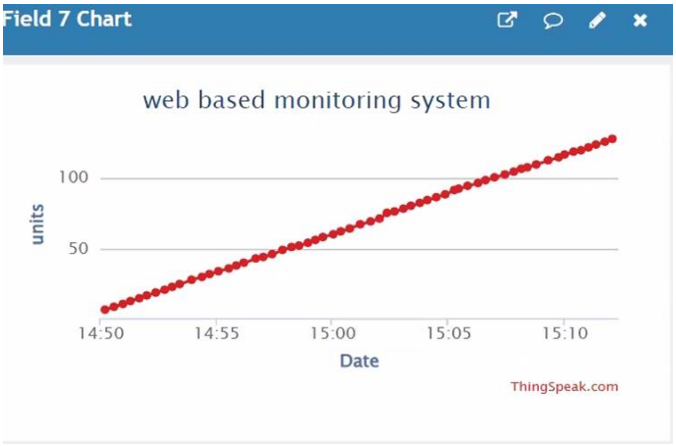

Fig: Units Graph

9. CONCLUSION

Based on this research, it is obtained that the combination of Raspberry Pi 4, Arduino Uno, and PZEM-004T can be used as a monitoring tool for household electrical energy usage. The monitoring system can measure and read the electrical parameters of voltage, current, and power as well as electrical energy with a good level of accuracy. Based on the data obtained by the measuring instrument the design has worked well, and the test results can be accepted because for all loads the error value (deviation) is at an average value of less than

2%. Furthermore, the result shows that the user interface works well on both desktop and mobile phones. This indicates the Raspberry Pi 4 web-based electrical energy monitoring system can work correctly.

FUTURE SCOPE

The design of electrical energy monitoring using the PZEM-004T energy sensor and Raspberry Pi 4 as a web server is presented and it can be concluded that the design is working well with an average error of less than 2%.

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