IJARCCE ISSN (O) 2278-1021, ISSN (P) 2319-5940

International Journal of Advanced Research in Computer and Communication Engineering

ISO 3297:2007 Certified ⁜ Impact Factor 7.39 ⁜ Vol. 11, Issue 7, July 2022

DOI: 10.17148/IJARCCE.2022.11702

DESIGN of an ENERGY MANAGEMENT SYSTEM for a SCHOOL HOSTEL

Okafor C.S.[1], Nnebe S.U.[2], Onyeyili T.I.[3], Nwokoye C.S.[4]

Dept. of Electronic & Computer Engineering, Nnamdi Azikiwe University, Awka, Nigeria[1,2,3,4.]

Abstract: This research work involves the design and development of an energy management system to be used in monitoring and control of energy usage in the school hostel. The developed system uses the smart energy measuring module PZEM-004T for capturing the real-time energy consumption in each of the rooms in the school hostel. The system measures these data and then incorporates the data with the internet of things (IoT) for data logging and reporting to a web-based online server using the GSM module. The system will also be able to detect bypass current as a result of illegal meter bypass in each of the rooms. Each of the room's maximum loads is set at 200watts. Every piece of information captured from the hostel is sent to the server that is continuously being monitored by an Administrative officer, who responds to reports from the system. This developed system is able to reduce the energy wastage in the school hostel, based on the operational function of the system to cut off the power supply to any room in the hostel with a load above 200watts.

Keywords: IoT, GSM module, Energy meter, Wi-Fi module, Multithreading.

I. INTRODUCTION

Energy is a fundamental asset to the world economy in that the economic growth/development of a country depends heavily on the amount of energy available for consumption by energy consumers [1]. Globalization, modernization, and technological improvement are other major factors responsible for the exponential rate of energy demand by potential consumers. The continuous increase in the number of residential, commercial, and industrial electricity consumers causes the power providers to propose and implement a better, efficient, and environmentally safe technique of accurately measuring electricity consumption thereby facilitating energy management [2], [3]. Electricity and power consumption were previously measured with electric meters; a device that measures the amount of electric energy consumed by a residence, business, or an electrically powered device for billing purposes [2]. However, technological advancements brought about the advent of smart meters which fully supports and incorporates full-scale energy management as used in the research work. A smart energy meter (SEM) is an electric device that consists of an energy meter chip, which is specifically used for measuring the quantity of energy consumed, a wireless protocol such as a GSM module that is used for data communication, and peripheral devices that are used for security purposes, data display, meter controlling, etc. GSM module can be used to transmit data obtained from the Energy meter over the mobile network. Such data can then be fed and integrated into existing localized Energy Management Systems [4]

Energy management is described as the process of tracking and optimizing energy consumption in any structure such as residential and industrial buildings so as to conserve energy usage in those structures [5]. Continuous advancement in studies of control system architecture has led previously to a massive improvement in manual ways in which energy economizes. In previous years, it was done with the aid of analog manual energy meters and manual control implementation. However, the concept of Supervisory Control and Data Acquisition (SCADA) systems in combination with microcontrollers gives rise to a more effective and simplified system of energy management.

The need to monitor and control energy usage in the school hostel is of crucial importance as load usage without proper control can impact negatively on the power supply distribution network, increased power generation costs for the hostel management, and increased carbon emissions from the power distribution network. This management system can also be described as the process of monitoring, and controlling energy in a building, and it requires some important steps such as metering, which involves the measurements of energy usage through the use of specialized energy power measuring sensors, as in our case, the PZEM-004T energy measuring module. Metering is required for collecting energy consumption data. Also, this data is sent over the internet thereby incorporating the Internet of Things (IoT).

In recent times, IoT has enhanced the efficient remote monitoring and control of hardware systems. This is made possible in our solution by employing the use of the GSM module. In monitoring and controlling energy usage, hostel management administrators will have reduced manual or physical interactions with the system as the necessary information needed will be made available online through data transmission from the metering section through a controller and then the GSM module to the webserver which in turn has a database designed to accommodate the recorded energy consumption from the hostel rooms [6].

International Journal of Advanced Research in Computer and Communication Engineering
ISO 3297:2007 Certified ⁜ Impact Factor 7.39 ⁜ Vol. 11, Issue 7, July 2022
DOI: 10.17148/IJARCCE.2022.11702

In order to ensure the integrity of the measured energy consumption data captured by the metering section of the system, bypass detection is of great importance. Bypass involves the user short-circuiting an open circuit between the mains and the building. This prevents the building's energy consumption data from being metered and recorded [7].

Most of the school hostel residents indulge in illegal and bad energy consumption practices by using banned electric gadgets like electric hotplates, boiling rings, and electric cookers which always result in very high energy consumption.

Thus, there is a need to develop and implement an automated IoT-based energy management system that remotely monitors and controls the load consumption by students in the hostel.

II. LITERATURE REVIEW

In reducing the amount of energy consumption, the authors [8], [9] carried out energy audit activities conducted in eight student hostel buildings of the University so as to assess the level of total energy consumption. The energy consumption in each of the hostels was determined through a study that was carried out. The results captured from the audit were evaluated and feasible alternatives for potential energy-saving and conservation measures were consequently identified and recommended to improve energy efficiency in the buildings.

In [10], the authors developed an energy management system that consists of an Energy meter that is capable of measuring a customer's energy usage and then transferring the data to the customer and management board. The IoT system is used to turn ON/OFF, the household appliances use a combination of relay and Arduino. The aim of this developed system is to monitor the amount of electricity consumed. The system was developed using Arduino ESP8266 as the controller and GSM module for IoT. All the details are sent to the consumer's mobile phone through the IoT, the GSM module, and they are also displayed on the LCD. This system of operation saves time and eliminates the human/manual means of energy management which is tedious and time-consuming.

Authors in [11] proposed an AMR approach for energy saving in Smart Grids using Smart Meter and partial Power Line Communication. In this article, an AMR solution that gives a detailed end-to-end application is based on an energy meter with a low-power microcontroller MSP430FE423A and the Power Line Communication standards. The energy metering module ESP430CEl is part of this microcontroller.

In [12], the authors proposed a home energy management system solution that relies on the convergence of sensing, communication, and control technologies, and enables the availability of energy demand data through a communication network in a timely fashion. Communication networks in smart grid applications are classified according to the scale of coverage and included: Home Area Networks (HANs), Neighborhood Area Networks (NANs), and Wide Area Networks (WANs). A typical HAN includes a smart electricity meter that interconnects several home devices and sensors. Information from multiple HANs is aggregated and stored in a database, which in turn forms the NAN or WAN depending on the coverage scope. The combined data from several NANs/WANs are conveyed to the utility administrator to assist him/her take a decision on some system parameters, like price, expected load, etc. Sensors employed for this purpose include an Ultrasonic sensor for detecting the human presence, a PIR sensor for detecting movement of the objects, RFID for Access control, and device identification.

In [13], an automated energy meter that can be used for remote monitoring and controlling was developed. It continuously monitors the energy meter and sends the data at the request of the service provider through SMS. The sent data is received and stored in a server that is domiciled at the electricity board station. Energy provider sends electricity bills to consumers either by SMS, email, or post. This system allows the customer to pay bills online either by credit card, debit card, or net banking.

[14] revealed the development of a measuring instrument that enhances the measurement of electrical parameters as well as sending these parameters to service providers by using GSM technology. The energy meter system is connected with an embedded microcontroller and a GSM module to transmit the data. This data is fed and integrated into energy management systems located at Power Company.

[15] was able to develop a system that will replace the traditional meter reading method with a GSM-based smart energy metering system using IoT. The sensed units are automatically sent to the cloud using IoT. This developed system is very efficient and cheap as it reduces the poor communication between the user and the controller. An efficient systematic approach is used for the design to acquire accurate measurements for the energy meter, prevention of malpractice and bypass, and give an accurate accounting of units.

[16] proposed a combination of both smart metering and charging to help local energy communities. The smart meter is deployed in residences with communication between the smart meter and the aggregator through a cloud database. The smart meter continuously samples the voltage and current every 20ms with a minimum default frequency of 5KHz that can be increased whenever necessary. The average values are locally saved on a memory card and sent to the cloud database on the Amazon Web Service Platform.

[17] designed a smart meter system that has a feature to impose the power load allocation firmed by the service provider on different types of consumers. Their work also includes a module that has the provision of an on-demand

ISSN (O) 2278-1021, ISSN (P) 2319-5940
International Journal of Advanced Research in Computer and Communication Engineering
ISO 3297:2007 Certified ⁜ Impact Factor 7.39 ⁜ Vol. 11, Issue 7, July 2022
DOI: 10.17148/IJARCCE.2022.11702

electric power load facility from the service provider by sending messages. Some other smart meter systems were based on different kinds of technologies such as PLC (Power Line Communication), Bluetooth, ZigBee, Wi-Fi (Wireless fidelity), and GPRS (General Packet Radio System).

[18] proposed development of an automatic meter reading system focusing on the design for an energy meter implemented with Zigbee wireless communication protocol conforming to IEEE 802.15.4 standard. They used a microcontroller to manage energy data and Zigbee to enable communication between the energy meter and data centers. This developed system used Zigbee as a wireless communication medium but with the drawback of a lesser range of coverage.

III. METHODOLOGY

This developed energy management system comprises the following components and the block diagram showing these components is shown in figure 1;

i. Power supply unit
ii. Metering/Sensing unit
iii. Controller main unit
iv. Controller sub unit
v. Switching sub unit
vi. IoT unit
vii. Memory unit
viii. Alarm unit

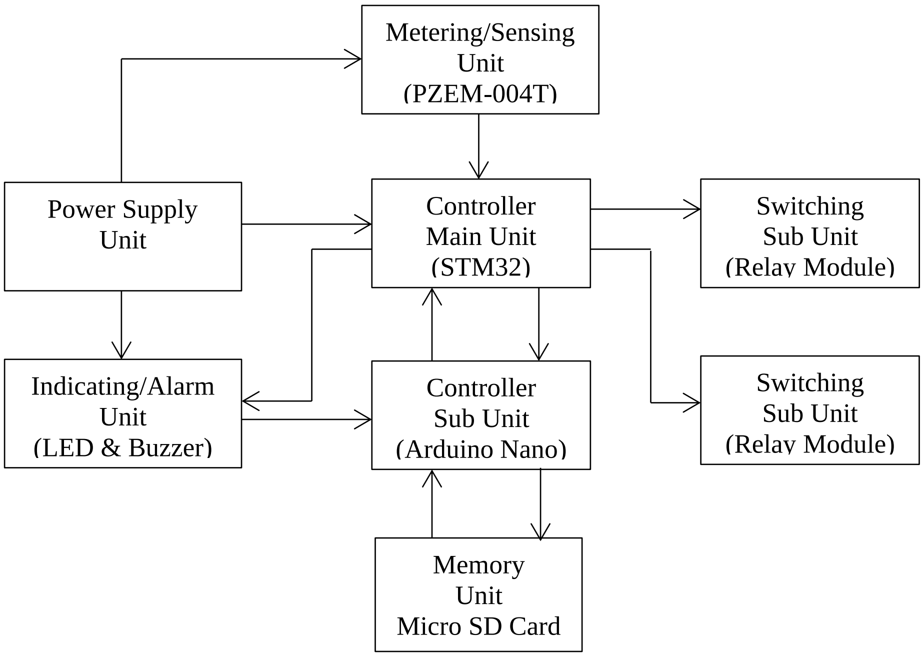

Figure 1: Block Diagram of the developed Energy Management System

The various components of the system block diagram include the following:

A. Power Supply Unit

The 5VDC power supply unit is used to energize or activate the entire developed energy management system.

B. Metering/Sensing Unit

The sensing unit is responsible for capturing energy usage data by directly interfacing with the power supply infrastructures. The metering device is equipped with a PZEM-04T energy sensor, capable of measuring voltage, current, power, energy, frequency, and power factor. Along with this high-quality sensor, is a current transformer (CT) sensor that measures current through a conductor using the magnetic field generated around the conductor as alternating current flows through it.

International Journal of Advanced Research in Computer and Communication Engineering
ISO 3297:2007 Certified ⁜ Impact Factor 7.39 ⁜ Vol. 11, Issue 7, July 2022
DOI: 10.17148/IJARCCE.2022.11702

C. Controller

The main controller of the whole system is an ARM microcontroller known as the STM32F1038C. This device is capable of executing instructions concurrently using the Free RTOS (Real-Time operating systems). The ARM is highly efficient due to its speed and memory size.

D. Controller Sub-Unit

This section is made up of an Arduino Nano, which is initially included for IoT and SD card access. The reason for using Nano is to bridge the gap between the 3.3VDC used by the ARM microcontroller and the 5VDC used by the SD card module as the ARM microcontroller may have issues accessing directly the micro-SD card module, but with Nano and the inbuilt 5.0V to 3.3V TTL converter chip on the micro-SD card module, ARM microcontroller can conveniently access the micro-SD card module.

E. Switching Sub-Unit

The switching sub-unit is actually a relay system that is controlled by the main controller unit and is used for cutting off automatically power supply to individual rooms of the hostel building whose load is above the set threshold of 200W or that bypasses the metering device in the room.

F. IoT Unit

This is basically a GSM/GPRS module that can communicate via GPRS to the internet. It can enable remote control and monitoring of the whole system which is now the norm in IoT devices.

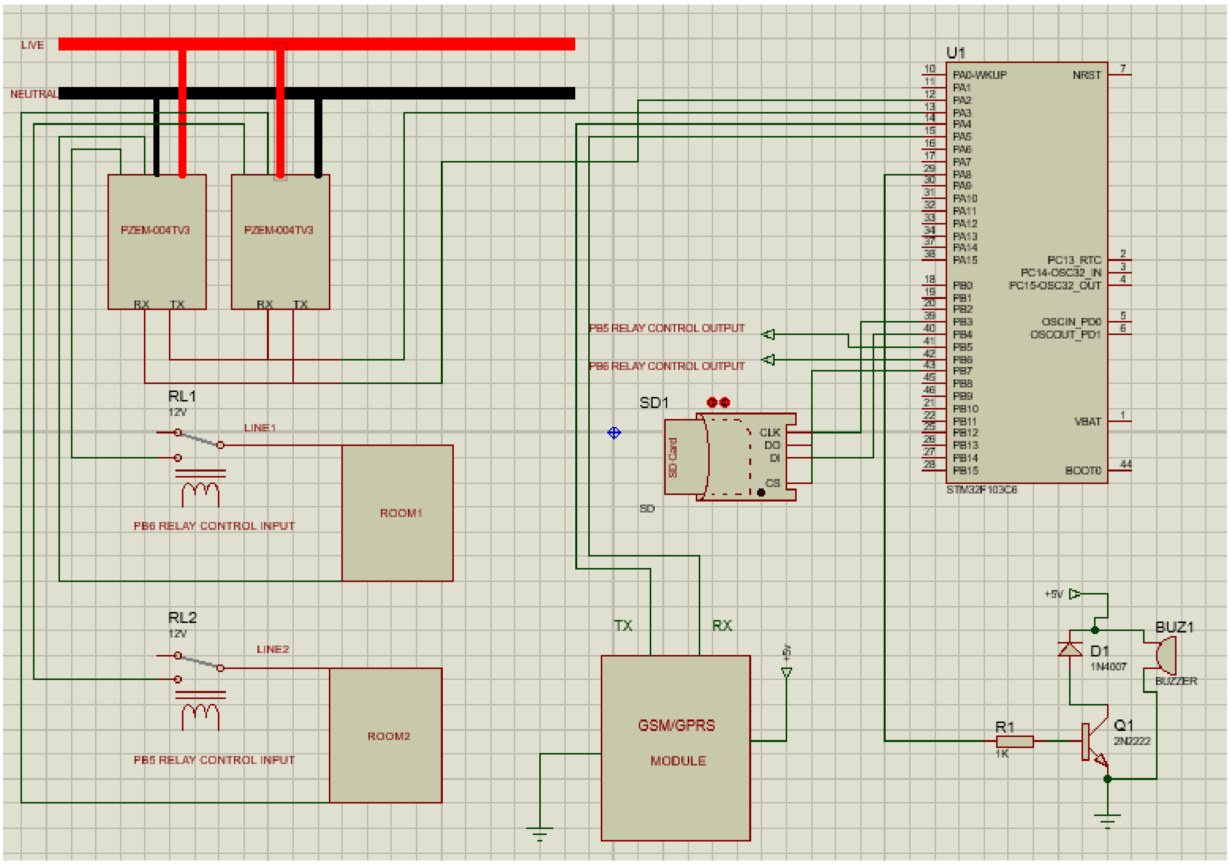

Figure 2: Schematic Diagram of Developed Energy Management System

G. Use a case diagram of the website

A use case diagram is a graphical depiction of a user's possible interactions with the system. A use case diagram can as well show many use cases and different types of users in the developed system.

Here, the administrator is given the responsibility to register meters to the system, and link meters to various rooms through the lines present in the meter as meters will have supply lines. Also, administrators can generate passwords for users through the system and also change the power limit dynamically. These settings will reflect automatically whenever the meter makes a request to the server.

International Journal of Advanced Research in Computer and Communication Engineering
ISO 3297:2007 Certified ⁜ Impact Factor 7.39 ⁜ Vol. 11, Issue 7, July 2022
DOI: 10.17148/IJARCCE.2022.11702

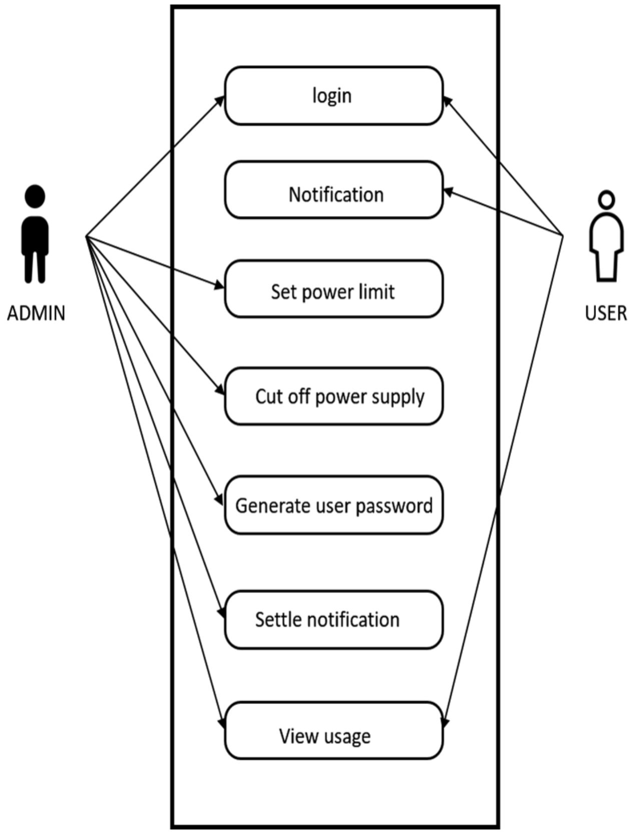

Figure 3: Use Case Diagram of the Website

H. Database Model of the System

The database is designed to store users' data such as their login information, and administrator login information for accessing the administrator page which requires their email address and password. The database engine is actually MYSQL and is designed to work with structured data. Each block in the model represents an entity, and there are nine (9) entities represented in the model to capture the hostel energy management data requirements.

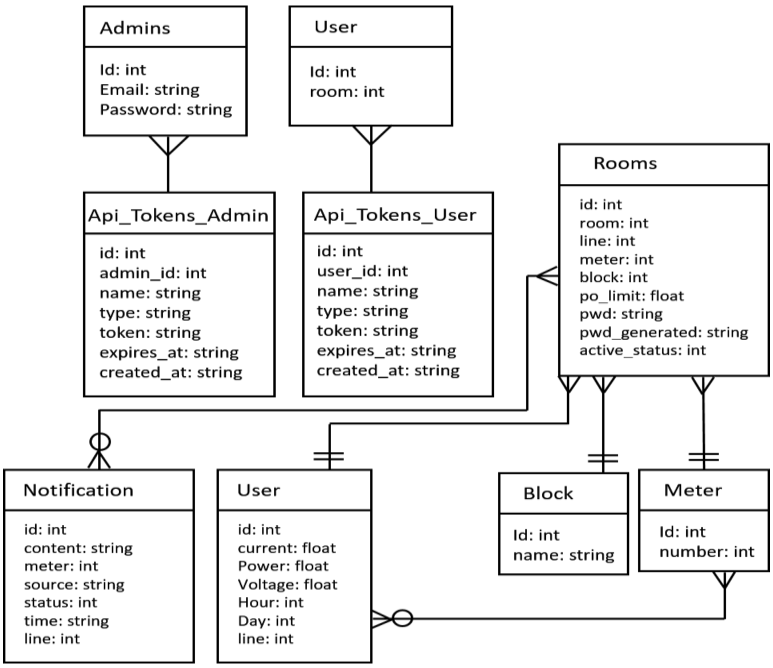

Figure 4: Database E-R model of the system

 ISSN (O) 2278-1021, ISSN (P) 2319-5940

International Journal of Advanced Research in Computer and Communication Engineering

ISO 3297:2007 Certified ⋇ Impact Factor 7.39 ⋇ Vol. 11, Issue 7, July 2022

DOI: 10.17148/IJARCCE.2022.11702

It is assumed that the hostel management system is abstracted from the hostel energy management system and key information for students' identification such as school registration number is not included in this design. The Block entity stores information about the available hostel blocks. Blocks have names and they are made of many rooms. Each room must be linked to a meter line through which its energy consumption can be directly monitored. Also, every meter must be linked to at least one room through its meter line. Also, each of the rooms consists of one to four residents/occupants, who are tagged as users and can access their room energy usage data using their assigned password and room number.

I. Bypass Detection

In alternating current distribution, current flows through the live wire into the system and returns through the neutral wire. In meter bypass, a conductor is connected between the meter input and output terminals thereby directing much of the current that was supposed to flow into the meter away from it. The meter begins to read less of the actual current drawn by the building.

If the current measured by the meter does not tally with that measured by a current sensor around the neutral wire, then bypass is detected. A Current Transformer sensor is clipped over the neutral wire and the current flowing through it is captured via electromagnetic induction.

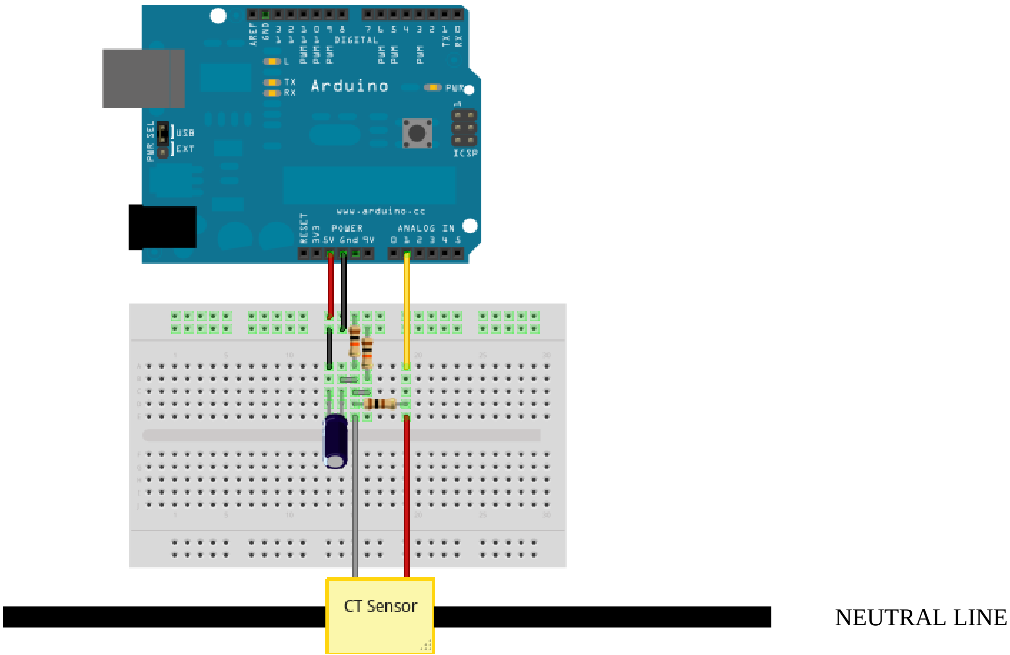

Figure 5: Measuring Mains Current Only [6]

J. Operating Principle of the Developed System

The energy management system works by measuring the real-time energy usage data using the PZEM-004T energy metering module. The module is tied to the live and neutral wires of the incoming distribution line. The output section of the module for High voltage transmission is then connected to a relay which is then connected to the rooms. A microcontroller is used to activate and deactivate the relay thereby controlling the power supply to the rooms. The PZEM-004T also has other external ports for its own power supply and a Universal Synchronous Asynchronous Receiver Transmitter (USART) communication pin which is interfaced with the STM32F103C8 ARM microcontroller so as to get the recorded parameters of the metering module. The module is capable of measuring voltage, current, power, frequency, energy and gives us the needed parameters for energy usage monitoring and control.
When the microcontroller obtains the energy usage data from the PZEM-004T module through the USART communication protocol, it performs a comparison operation between the measured power value and the power limit set by default in the system. If the power usage is greater than the set limit, the microcontroller deactivates the relay immediately thereby cutting off the room from the power source, activates the buzzer, and then sends a notification message through the GSM/GPRS module to an online Access Point Interface (API) hosted on a web server. In cases where the measured values are below the set limits, the operation continues as usual where the measured values are transmitted using a POST request to the webserver for the database storage.

International Journal of Advanced Research in Computer and Communication Engineering
ISO 3297:2007 Certified ⁜ Impact Factor 7.39 ⁜ Vol. 11, Issue 7, July 2022
DOI: 10.17148/IJARCCE.2022.11702

Through the webserver, hostel management administrators can access the energy usage data for different days of the week and also cutoff power supply specifically for each room if need be. The website provides an interface for administrators to log in using their assigned email addresses and password. The website also enables new meters to be registered along with room assignments. Each meter has lines consisting of live and neutral wires which are connected to different rooms. When the meters are registered, the number of rooms is also registered along with the lines they will be connected to. The lines in the meter are also linked to relays through which current flow can be controlled by the main controller of the whole metering system

K. Control and Unit testing

1. *Control Implementation:* The control sub-system of this solution, is the STM32 Blue Pill (STM32duino) ARM microcontroller capable of hosting a freeRTOS real-time operating system and features a 32-bit ARM Cortex M3 processor running at 72MHz frequency with 128kb of flash memory and 20kb of SRAM. This microcontroller interfaces with the PZEM-004T energy metering module to get the power usage information; it also interfaces with the GSM/GPRS module for internet-related activities and is responsible for relay controls.
2. *Control Unit Testing*: The microcontroller consists of two jumpers that enable the switching of the microcontroller between the two modes. They are the Boot 0 and Boot 1 pins which are used to select the memory from which it boots. To upload the code to the flash memory of the microcontroller, the main boot space is selected thereby enabling booting into the system memory. Booting into this space makes the microcontroller easy to be programmed using its USART1 serial interface.

TABLE I: UNIT TEST FOR CONTROL SYSTEM

Test	Steps	Expected Result	Actual Result
On/Off	Switch the microcontroller by Powering the 5volts or 3.3volts pins and then connecting the ground pins.	The microcontroller turns on, the LED connected at PC13 blinks repeatedly every second until a new program is written.	The microcontroller turns on, and the LED blinks repeatedly every second.
Response to all peripherals	Attach and detach peripherals	The peripherals are ready for controls	The peripherals are ready for controls

L. Development Environment Setup

The development environment is the Arduino ide having the stm32 development core installed by adding the git-hub link to the Arduino ide preferences as shown in figure 6 below:

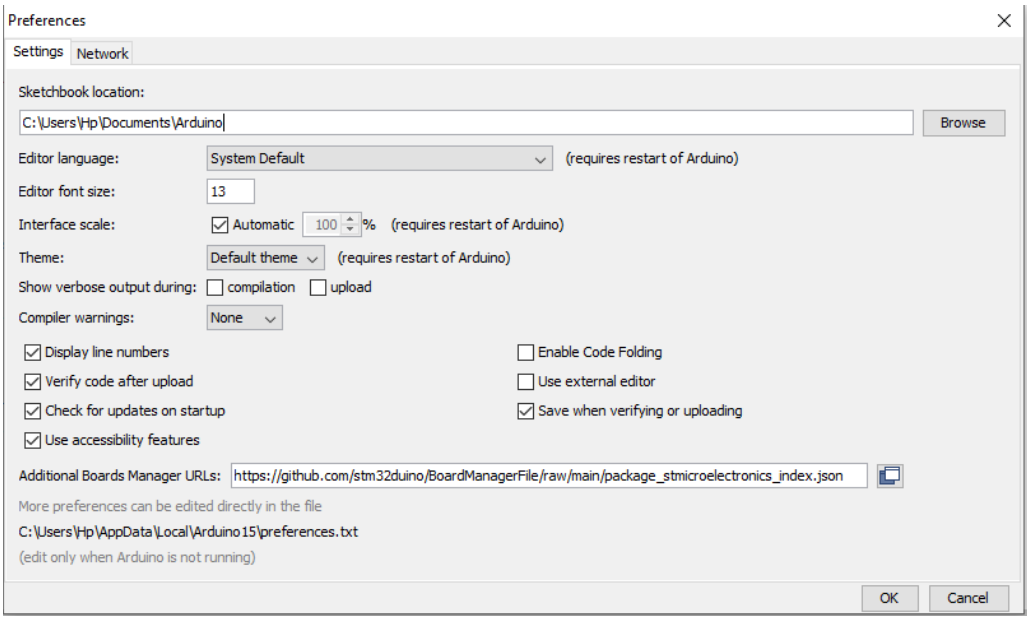

Fig. 6: Stm32 development core setup

IJARCCE ISSN (O) 2278-1021, ISSN (P) 2319-5940

International Journal of Advanced Research in Computer and Communication Engineering

ISO 3297:2007 Certified ⁐ Impact Factor 7.39 ⁐ Vol. 11, Issue 7, July 2022

DOI: 10.17148/IJARCCE.2022.11702

M. Metering Subsystem and Unit testing

1. Metering Subsystem Implementation

The metering sub-system consisting of the PZEM-004T is implemented by first assigning identification addresses to the modules using the Peace Fair Electronic Technology software available for free. The module is connected to a computer through any of the available USB ports. When the high voltage live and neutral wires of the module are powered on, the software detects the module and communication can be initiated for the necessary parameters.

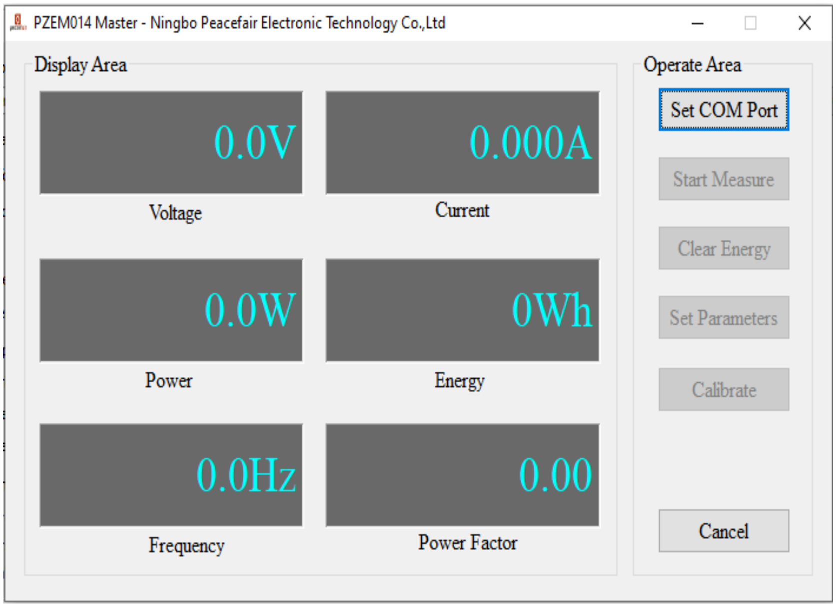

Fig. 7: Peace Fair Software

The PZEM-004T is interfaced with the microcontroller USART2 serial communication port. Communication between the module and the microcontroller is achieved using the PZEM004TV3 Arduino library. The essence of this software here is to provide the platform for testing and address assignment. Through this software, a single USART port can be used to communicate with multiple PZEM-004T modules after assigning addresses to them for their identification.

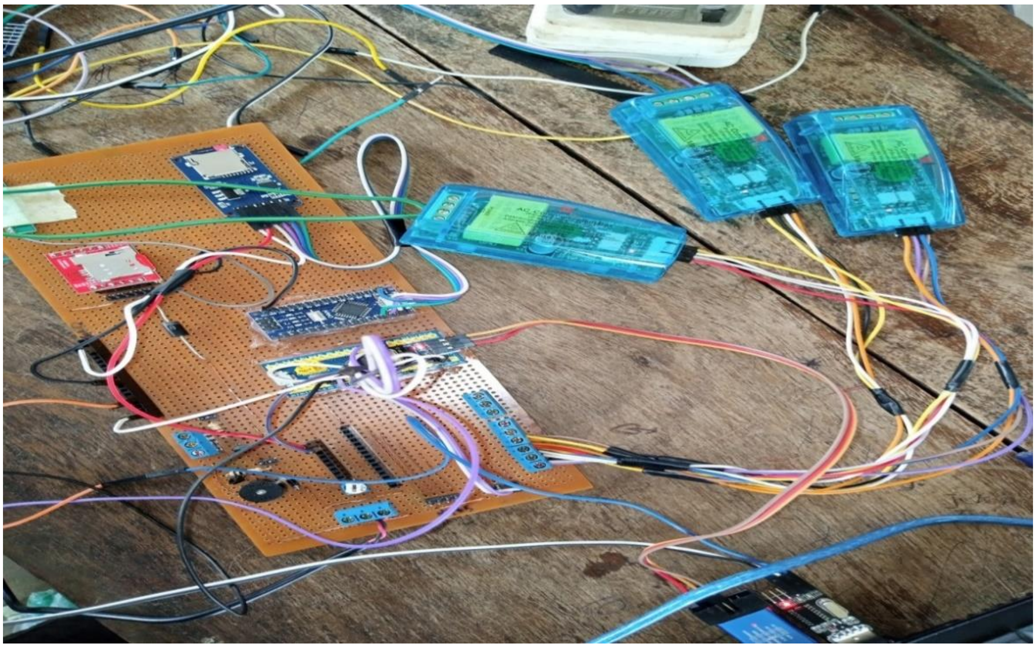

Fig 8: Interfacing the PZEM-004T

IJARCCE ISSN (O) 2278-1021, ISSN (P) 2319-5940

International Journal of Advanced Research in Computer and Communication Engineering

ISO 3297:2007 Certified ⁜ Impact Factor 7.39 ⁜ Vol. 11, Issue 7, July 2022

DOI: 10.17148/IJARCCE.2022.11702

N. IoT sub-system and Unit testing

The internet of things functionality is implemented using the GSM/GPRS module. The internet connectivity is made possible due to the presence of the GPRS and this makes a connection to the internet available using 2G communication. The communication between the GSM module and the ARM microcontroller is done using the GSM sim Arduino library.

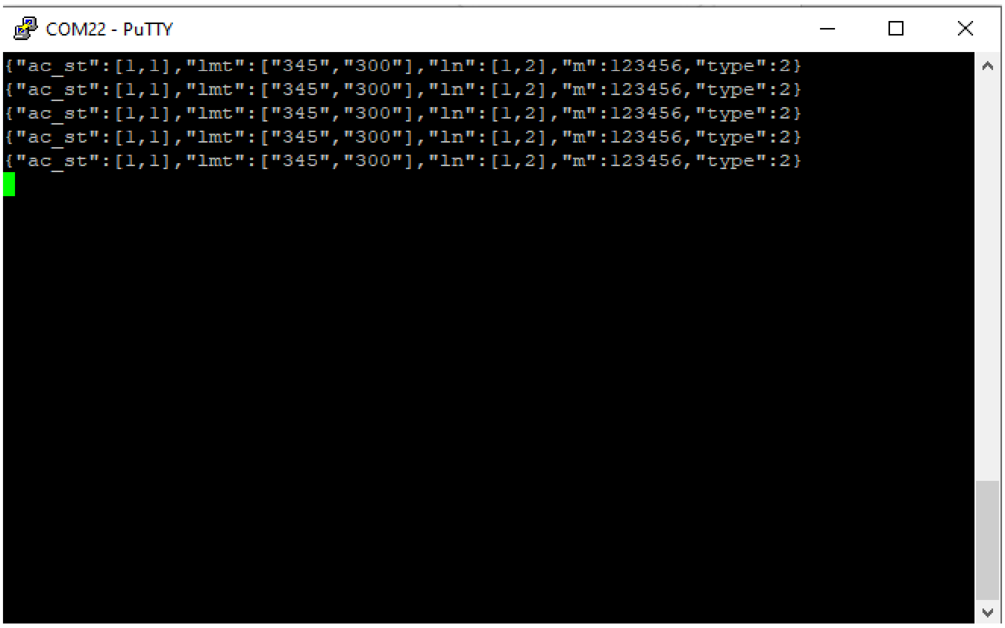

Fig. 9: Administrator Page

The administrator website is designed using JavaScript language. The front-end section of the website is implemented using the Vue JavaScript framework and is utilized in the UI design. The administrator page houses services such as meter registration and line assignment, the addition of a new administrator, room information update, and room power supply control remotely.

O. Result Analysis

1. *IoT Data Transmission and Response:* The data transmitted over the internet is formatted as a JavaScript object notation (JSON) document. The data transmitted is composed of meter identification number, power, current, power factor, and the connected lines representing each room. The response received from the server contains current settings for the hardware system such as room disconnection, the new limit setting for each room.

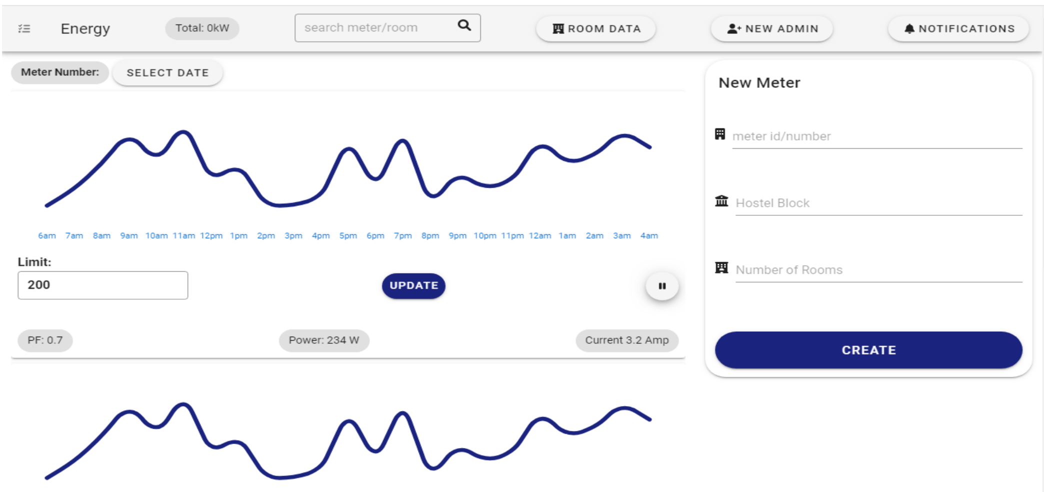

Fig. 10: Response data after hardware post request of energy usage data

IJARCCE ISSN (O) 2278-1021, ISSN (P) 2319-5940

International Journal of Advanced Research in Computer and Communication Engineering

ISO 3297:2007 Certified ∺ Impact Factor 7.39 ∺ Vol. 11, Issue 7, July 2022

DOI: 10.17148/IJARCCE.2022.11702

When the response is received, the JSON data is processed using the ArduinoJson library built for C/C++ programming applications and this ensures memory management in microcontroller hardware facilities. The terms in the JSON response are described in Table 2 below.

Table 2: Server JSON Response

Parameter	Description
AC_ST	Activation Status of each room. 1 signifies an active status whereas 0 signifies an inactive status
LMT	Room limit is used to ensure load usage restrictions. This value can be dynamically updated from the server
LN	Line array signifying the individual lines for each room.
M	This parameter specifies the meter identification number and uniquely identifies each registered meter.

In programming the STM32F103C8 Blue Pill board, the following devices were used;

1. *Arduino IDE:* The Arduino ide was used for code editing and compilation, where codes written in C/C++ programming language were used to write instructions for the microcontroller. To develop programs for the microcontroller, the stm32 core library for the Arduino ide has to be downloaded online.
2. *FTDI programmer:* The FTDI programmer is a USB to TTL converter which was used for the program debugging process. The FTDI is connected to the USART2 port of the microcontroller using female-to-female connectors and communication between the FTDI and the microcontroller was through serial communication.

Fig. 11: PL2303 USB to TTL/USB-TTL/STC Microcontroller Programmer Adapter [19]

3. *ST-LINK V2 Programmer:* This is a stand-alone debugging and programming mini probe for STM32 microcontrollers.

Fig. 12: ST-LINK v2 Compatible Programmer [20]

DOI: 10.17148/IJARCCE.2022.11702

P. *Meter Bypass*

1. *Implementation:* In the implementation of the meter bypass detection section of this solution, other research works suggested capturing the neutral current whenever there is a live channel bypass as shown in the image below,

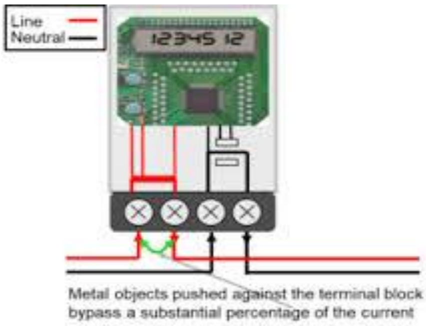

Fig 13: Single-phase meter diagram [10]

To detect meter tampering specifically bypassing current on the live channels, one anti-tamper technique is to measure the current on the neutral channel. For single-phase meters, under ideal conditions, the live and neutral currents should be equal. When there is a large current flowing through the neutral current, then there is a bypass.

2. *Result Analysis:* To implement this solution, the SCT-013-00 100A Current Transformer sensor was clipped over the neutral wire for current data capturing. Although, this sensor seems to be the only available sensor, and also was more sensitive to larger loads as it was designed for 0Ampere to 100Ampere current measuring range. It was also observed that during the bypass test, the PZEM-004T energy metering module captured the load data for this meter bypass configuration. This response by the metering module made meter bypass for this solution a futile venture as the loads connected to the bypass line was still captured for the configuration above, also there was no need for the specialized neutral current measurement using the CT sensor.

IV. CONCLUSION

This project work on Energy Management System using a hostel as a case study focused on achieving energy management in the school hostel by employing monitoring and control technological concepts. This was achieved in our project through an integrated system known as a smart energy meter.

Our project's scope of smart meter includes a metering section responsible for the constant checking of all electrical parameters directly involved in modeling the system such as voltage, current, power, etc. A monitoring section was also incorporated into the smart meter development via IoT based technology. In the monitoring and control section, the parameters measured at regular intervals are logged onto a database and are sent to the internet via the IoT-based technology to be accessed remotely by a preprogrammed administrator website for monitoring and control purposes. Also, important client data was made accessible to the clients (students) via an application that also gives them feedback and complaint logging liberty. The possibility of that bypass which compromises the effectiveness of the developed system was also considered and necessary steps were implemented in the project so as to prevent this.

The project was developed to be deployed for use in the school hostel so as to be able to control and curtail energy mismanagement amongst students; however, its application scope can easily be broadened to solve any related problem at hand in any industry.

REFERENCES

[1]. O.B. Anyaka "Challenges of Deregulation of Electric Power Sector in a Third World Economy", IOSR Journal of Electrical and Electronics Engineering, Volume 9, Issue 3 Ver. III, pp.19-22, 2014.

[2]. K. Bowya, P. Levina and K. Aruna, "GSM based Smart Energy Meter," *International Journal for Modern Trends in Science and Technology*, vol. III, no. 4, pp. 1-7, 2007.

[3]. C.S. Okafor, V.E. Idigo, T.I. Onyeyili, P.C. Obioma, "Design of a Microcontroller-Based Capacitor Switching System for a Power Distribution Network", International Journal of Innovative Science and Research Technology, Vol. 6, Issue 5, 2021.

DOI: 10.17148/IJARCCE.2022.11702

[4]. Z. Sultan, A. Malik, S. F. Ahmed and J. You, "GSM based Smart Wireless Controlled Digital Energy Meter," in *IEEE International Conference on Engineering Technologies and Applied Sciences*, Houston, 2019.

[5]. Enertiv. "What is Energy Management". [Online]. Available: https://www.enertiv.com/resources/faq/what-is-energy-management, January 16, 2019.

[6]. M. K. Hasan , M. M. Ahmed, B. Pandey, H. Gohel, S. Islam , and I. F. Khalid, "Internet of Things-Based Smart Electricity Monitoring and Control System Using Usage Data", Wireless Communications and Mobile Computing Volume 2021, Article ID 6544649, pp. 1 – 16, https://doi.org/10.1155/2021/6544649, 2021.

[7]. N. O. Shokoya, A. K. Raji, "Electricity theft mitigation in the Nigerian power sector", International Journal of Engineering & Technology, 8 (4), pp. 467-472, 2019.

[8]. F. N. Theam, F. A. S. Ahmad, H. Sayuti, M. Marlinah, I. Kamarulazizi, "Energy Consumption in Student Hostels of Universiti Sains Malaysia: Energy Audit and Energy Efficiency Awareness", DOI:10.1007/978-3-319-47895-1_12, 2017.

[9]. C.S. Okafor, V.E. Idigo, O.A. Ezechukwu, T.L. Alumona, "Analytical Evaluation of Voltage Drop along 11/0.415KV Distribution Lines and Within Agu-Awka Injection Substation Distribution Network", Journal of Engineering and Applied Sciences, Volume 16, Number 1, pp. 12-21, 2020.

[10]. M. Prathik, K. Anitha and V. Anitha, "Smart Energy Meter Surveillance Using IoT," 2018 International Conference on Power, Energy, Control and Transmission Systems (ICPECTS), pp. 186-189, doi: 10.1109/ICPECTS.2018.8521650, 2018.

[11]. A. Garrab, A. Bouallegue and F. Ben Abdallah, "A new AMR approach for energy saving in Smart Grids using Smart Meter and partial Power Line Communication," 2012 First International Conference on Renewable Energies and Vehicular Technology, pp. 263-269, doi: 10.1109/REVET.2012.6195281, 2012.

[12]. U. Zafar, S. Bayhan and A. Sanfilippo, "Home Energy Management System Concepts, Configurations, and Technologies for the Smart Grid," in IEEE Access, Vol. 8, pp. 119271-119286, doi: 10.1109/ACCESS.2020.3005244, 2020.

[13]. A. Jain, "Smart and Intelligent GSM based Automatic Meter Reading System," *IEEE annual journal*, vol. 1, No. 1, 2008.

[14]. S. Shete, "GSM Enabled Embedded System for Energy Measurement and Billing," Marseille, 2010.

[15]. N. P. Nikhil, N. K. Sumit, M.B. Dileep, R.K. Vivek and L. S. Ganesh, "Smart Wireless Electronic Energy Meter," *IRJET*, pp. 2662-2665, 2018.

[16]. G. Barone, G. Brusco, D. Menniti, A. Pinnarelli, G. Polizzi, N. Sorrentino, P. Vizza and A. Burgio, "How Smart Metering and Smart Charging may Help a Local Energy Community in Collective Self-Consumption in Presence of Energies," no. 13, 2020.

[17]. H. Zahoor, M. Shahzad, D. Lachhman, H. U. S. Muhammad, A. M. Nasir, H. A. Jawad, H. Raza and B. Ali, "GSM Based On Demand Smart Power Load Management Service Module.," International Journal of Computer Science and Network Security, Vol. 17, No. 9, 2017.

[18]. P. Champ, P. Kittitach, P. Wanchalerm, "Development of An Automatic Meter Reading System Based on ZigBee PRO Smart PowerProfileIEEE802.15.4Standard," 2012.

