Energy Optimization through IoT-Enabled Monitoring and Control Mechanisms

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Abstract: **The aim of this study was to design a cloud-integrated IoT controller device for controlling, managing, and monitoring loads in university classrooms. The outcome of this study will help address the issue of lights operating with needless energy use. The controller was built using a controller Nod MCU ESP32 with Wi-Fi capabilities, PZEM 004T, and a Relay based switch to control load transferring, and scheduling via a web portal. The created web portal not only functions as a controller but and organized scheme to establish suitable class scheduling and a controlling scheme that shows the duration of usage and the overall quantity of power used by the classroom loads. This work comprises both hardware and software integration, where the program is assembled utilizing Arduino IDE, while the web portal is constructed utilizing PHP language.**

Keywords: **Internet of Things, Energy Optimization, Controlling Mechanism.**

INTRODUCTION

The Internet has transformed the technique to work and interconnect by linking us via IoT also purposes to integrate via additional level by attaching numerous equipment's and utilize IoT for the human-machine interface via web applications. The aim of this cloud-based prototype system is to monitor real-time electrical parameters and control and schedule the loads of university classrooms. This study resolves the problematic of unnecessary energy utilization in classrooms. This IoT integrated study, utilized a low-cost Node MCU ESP32 and Pzem 004t with a 100A CT. A system that uses a web portal to control, monitor, and schedule different rooms through the Internet from any place around the world saves electric power and provides better security services through an Internet connection without breaking any convention usability. Class schedules can be set through the web portal to permit the area to function the lights for a specified period, and loads can also be controlled separately through the web portal, other than the given schedule [1-5]. The Internet of Things exists widely utilized in industrial automation, smart power monitoring, and some other uses.

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Although there are numerous advantages to IoT integration in the SG area, it still faces some difficulties that must be overcome for optimal operation. This study demonstrates sustainable goals for IoT integrated schemes. The power monitoring system described in this study is based on the Internet of Things (IoT) and can measure and examine electrical parameters such as voltage, current, power, and load power utilization [6-9].

Owing to its low cost and standing as an extremely Oil depending generation increase the cost and emissions. IoT for tracking industry energy consumption, Raspberry Pi was chosen for this study work. To gather statistics numerous electrical measured values from the current power meters' access through a laptop or mobile device, a Raspberry Pi was used in system. The observing system has been useful for the industry for the daily power pattern, which is required to enable power saving measures to lower energy usage [10-14]. Energy monitoring is essential for creating effective electrical grids utilizing Internet of Things (IoT), which allows for the remote monitoring of electrical system data. This study describes the construction of a two-channel electrical parameter-observing system. The parameters were collected by the PZEM 004T V3.0 sensors, and the information were sent via cloud based technology. The data are kept on a micro SD card, and an LCD is used to obtain local readings. on a micro SD card, and local readings were performed using the LCD. Two distinct applications—one for the web and the other for mobile devices—are used for remote monitoring. The Gen 2 Vue Energy Monitor, a commercial product with IoT characteristics, was used to validate this suggestion [15-18]. The term smart home refers to the next generation of housing implementation, which aims to distribute a range of facilities both outer and interior the home using networked devices that are integrated and connected across all their varied applications and underlying intelligence. These smart devices can communicate with one another as of the continuous accessibility of network connections. The Internet of Things (IoT) now encompasses innovative homebased outcomes for the implementation of system. The objective of this study is to demonstrate how an IoT-based innovative house can be power efficient by examining a home model. The domestic safety system comprised a camera and motion detector for observation [19-21]. Energy optimization demonstrates the latest IoT-based technologies to identify and meet global energy challenges. This study integrates the latest instruments, controllers, and tools to deliver real parameters monitoring and switch schemes for an optimal power solution. The designed system reduces greenhouse gas emissions with predictions for further sustainable system implementation [22].

MATERIAL AND METHODS

A. PHP hypertext preprocessor

PHP codes vary with HTML codes and can be utilized in arrangements with numerous web structures. Its characters are displayed on the server. The main objective of PHP is to permit web developers to generate pages, as shown in Figure 1.

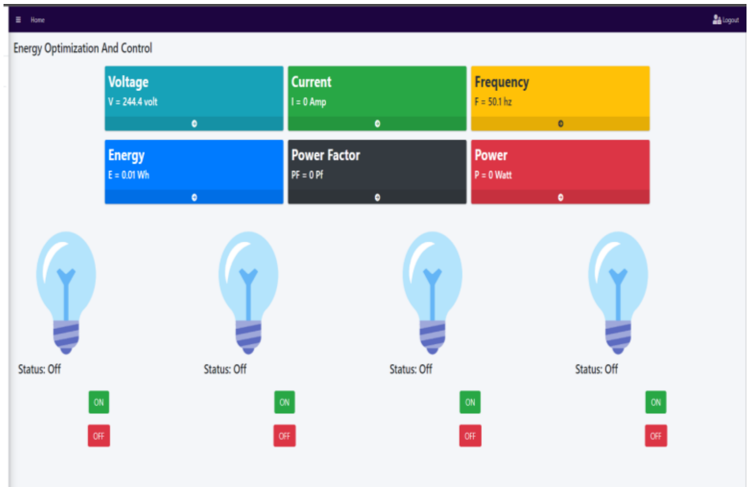

Figure 1: Load monitor, control and schedule the load.

B. Arduino Assembly

We configured the Arduino board by programming its assembly, in which we just linked the ICSP cable in the circuit serial programmer to compose the panel, although it can restore the board. Unlike other Arduinos, dissimilar Arduino does not have an integrated debugger, similar to other programming platforms. Users can also use third-party applications or a serial monitor to check and debug the active activities of the Arduino. The serial monitor can be designed using the Serial class, which restores the variables' comments and standards. In most cases, Arduino models consume serial pins 0 and 1, which are linked to the USB port. Arduino is distant additional than just a simple microcontroller. With an extensive IDE and a massive array of hardware configurations, Arduino is an accurate platform. The variability of its libraries and its instinctive design varieties make it a preferred choice for new users and skilled makers.

C. Charger

The charger shown in Figure 2 is connected to the DC devices that are responsible for stepping down the 220 V to 5 V.

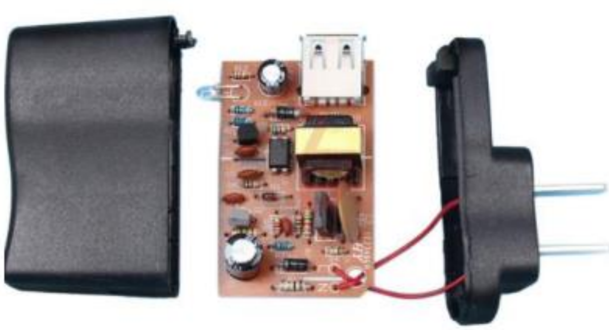

Figure 2: Charger (5 volt)

D. Four Channel Relay.

The four-channel Relay Shown in Figure 3 is a switch that stays functioned by an electromagnetic triggered by a distinct short-frequency signal from the microcontroller.

Figure 3: 4-Channel Relay

E. LCD

A liquid-crystal display (LCD) is a display for electronic parameters display shown in Figure 4.

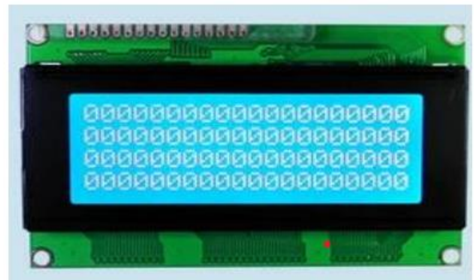

Figure 4: LCD

F. Nod MCU ESP32

The microcontroller Node MCU shown in Figure 5 provides IoT platform, and ESP32 is an economical, less energy consuming microcontrollers with combined Wi-Fi and Bluetooth. The ESP32 accessible in dual-core and single-core arrangements, has a clock rate of up to 240 MHz, with RF technology comprises of processor, power amplifiers, less noise amplifiers.

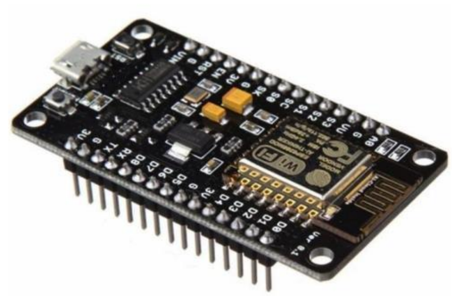

Figure 5: Nod MCU ESP32

G. PZEM 004T

PZEM-004T, as Shown in Figure 6, the AC communication module without a display function is mostly utilized for calculating power, frequency, power factor, voltage and current.

Figure 6: PZEM 004T

METHODOLOGY

This study proposes a design of a low-cost system, as shown in Figure 7, to reduce energy consumption, control, and schedule using the Internet of Things (IoT). This new innovation allows us to control and observer for electrical devices over the Internet. This research was based on a prototype with four switches with a load to demonstrate how to manage university classrooms. The controller used in this study was the Node MCU ESP32 (Node Microcontroller Unit). This microcontroller was interfaced with relay modules, which instructed the commands to be switched to the classroom via the Internet. This system also proposes an energy consumption detection system, as shown on the web portal. This microcontroller sends complete instructions to operate these loads and displays the status of the classroom on the web portal.

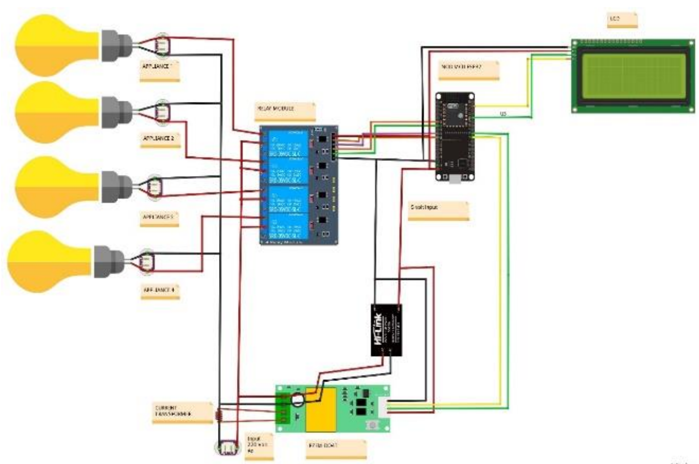

Figure 7: Schematic diagram of the proposed framework

This study also includes the PZEM-004T sensor integrated with a microcontroller to calculate energy consumption using a local cloud host database to provide an organized system through which the web portal and microcontroller communicate. Data from this sensor were transferred to the server every 10 s. This sensor is utilized to store information in a microcontroller. This web portal calculates the electrical energy parameters. The sensor was found to be the most suitable for the scope of this research work, bundled with a 100A current transformer coil that monitors voltage, current, power, frequency, energy, and power factors. The utilization of a Node MCU microcontroller that supports built-in WI-FI connectivity and creates IoT application implementation easy. It is a low-level control microcontroller with an open-source hardware and software development environment programmed using the Arduino IDE. With the help of a laptop or any mobile device as a local server using Xampp software. After access, controlled the schedule and monitored the load. The data transmit to the microcontroller, and the command is sent to the relay, which controls the loads accordingly. Data from the microcontroller are pushed to the server using HTTP and real-time data are viewed through the web portal from any location. Web development is performed using the PHP language. By comparing electrical parameter readings, such as voltage, current, and frequency, as the power factor values vary depending on the connected load, it is possible to determine the accuracy of this prototype.

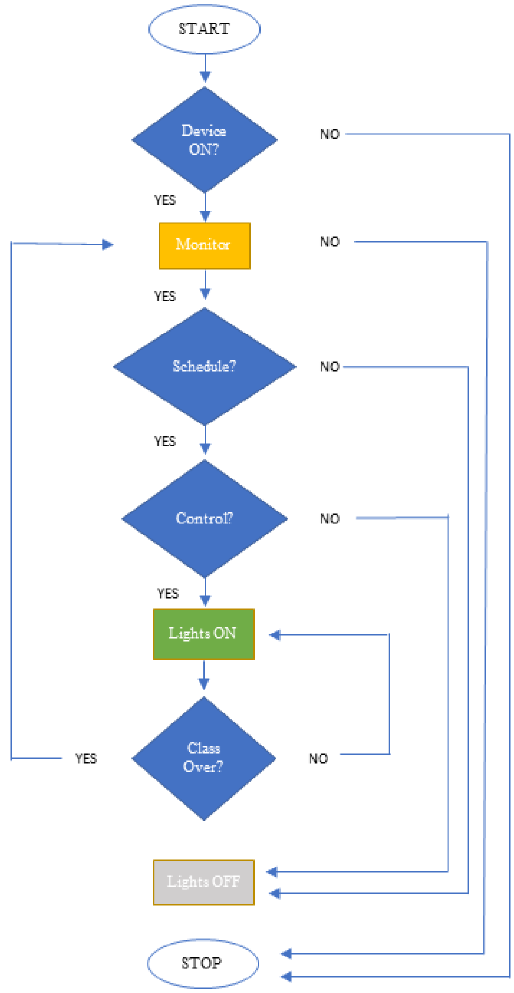

Figure 8: System flow

HARDWARE SETUP

Node MCU ESP32 microcontroller is powered with USB 5V/1A. The four relay modules and PZEM-004T were integrated with the microcontroller. The GND and VCC of the components were connected to the GND and VCC pins of the microcontroller. The PZEM-004T sensor inputs were interfaced with two general-purpose I/O pins, GPIO5(D1) and GPIO2(D4). The V_{CC}, Ground, and switch using relay module. This relay is used and connected to the controller so that the user may switch on or off the loads of classrooms, as shown in Figure 9.

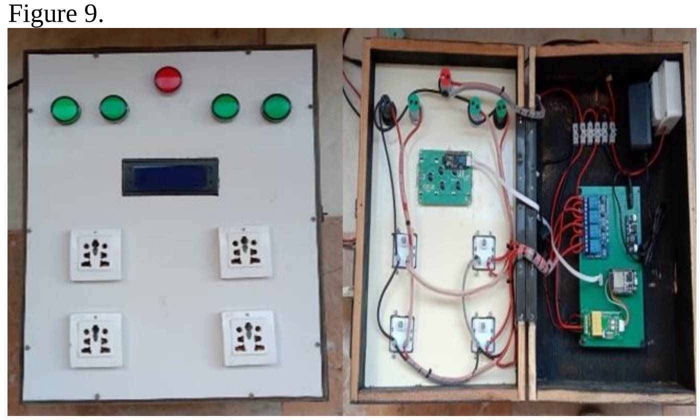

Figure 9: Hardware Setup

RESULTS AND DISCUSSION

The outcomes demonstrate that the IoT-based energy optimization and control system successfully achieved its objectives of monitoring, scheduling, and controlling classroom loads while reducing energy consumption. The integration of the NodeMCU ESP32 with the PZEM-004T sensor and relay module provided a low-cost, scalable solution for real-time energy management. The web portal, developed using PHP and hosted via Xampp, offers an intuitive interface for administrators to manage classroom operations with the potential of IoT in smart classroom management. The accuracy of the monitoring system, validated against manual measurements, underscores the reliability of the PZEM-004T sensor for measuring critical electrical parameters. The scheduling functionality was robust, enabling precise control over load activation, which is crucial for preventing energy wastage during unoccupied periods. The control feature further enhances flexibility by allowing manual interventions without disrupting scheduled operations. However, this system has limitations. Reliance on a local server (XAMPP) restricts scalability for large-scale deployments, as it may face performance bottlenecks with increased user access or data volume. Additionally, the prototype was tested with a limited number of loads (four relays), which may not fully represent the complexity of a deployment across an entire university. Network reliability also poses a challenge, as interruptions in Wi-Fi connectivity can disrupt communication between the Node MCU and the server. The observed energy savings of 83.3% in the controlled tests highlight the system's potential for economic and environmental benefits. By automating load management, the system reduces manual oversight, which is particularly valuable for large institutions such as hospitals. Future improvements could include integrating machine learning algorithms to predict classroom occupancy and dynamically optimize schedules, as proposed in the conclusion section.

WEB APPLICATION RESULT

A. Login Webpage

Any browser, such as Internet Explorer, Chrome, or Firefox, can b used to access the webpage server, as shown in Figure 10.

Figure 10: Login page(Energy Optimization and Control Scheme

B. Monitoring

This page opens when log in to this webpage, which shows the real-time simulation results of the hardware, which displays the frequency, current, power, power factor, and voltage, as shown in figure 11.

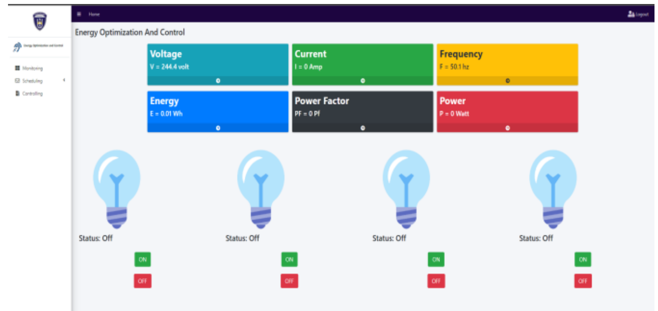

Figure 11: Web Application Results

C. Scheduling

University classroom loads can be scheduled using a web portal. The user can indicate the room number, date, and time with the beginning and end of the class. Users can update the schedule anytime from any location and can add new schedules and loads for expansion. The web application can be accessed using any web browser. The figures 12-14 shows the four-room schedule weekly.

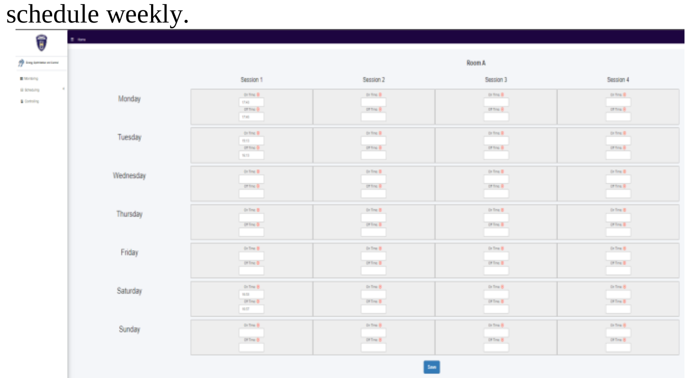

Figure 12: Web portal Results of Room 1

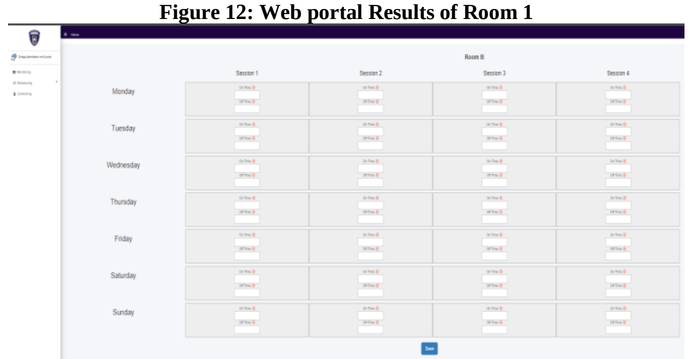

Figure 13: Web portal Results of Room 2

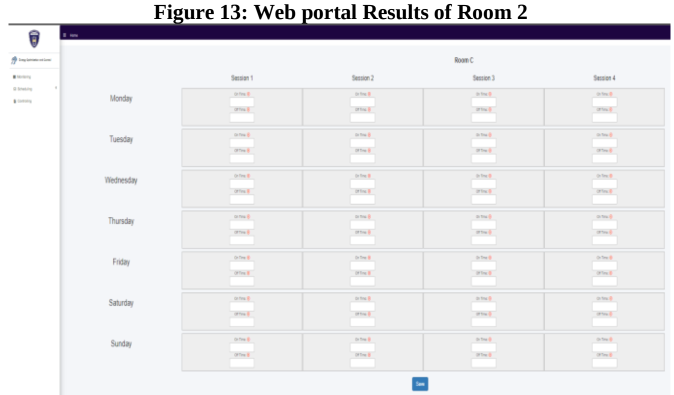

Figure 14: Web portal Results of Room 3

D. Test Cases

Table 1: Test Case 1

Preconditions	Energy Controlling System is powered on
Actions	Activate the microcontroller
Expected Result	Displays it on the connected screen.
Result	Pass

Table 2: Test Case 2

Preconditions	Energy Controlling System Sensors loaded
Actions	Activate the system sensors properly
Expected Result	Displays the electrical parameters.
Result	Pass

Table 3: Test Case 3

Preconditions	Energy Controlling System Working Properly
Actions	Activate the system properly and testing
Expected Result	System working efficiently.
Result	Pass

CONCLUSION AND FUTURE WORK

In this study, the use of IoT for university classrooms can be highly beneficial because it is flexible and accessible from any location. The implementation of this research will be economically beneficial to universities with less effort. In this prototype, the load is controlled by a local cloud-based web portal. This prototype design is portable and feasible, inspired by advanced classroom management with a secure IoT-based system. The main goal of this research is to provide a scenario of IoT technology integrated with automation by providing the user with complete control. The results showed that with a minimal amount of hardware, this technology can be used to improve university classroom management. This prototype can implement automatic control by adding sensors, such as a light-dependent resistor (LDR) that can sense daylight, a passive infrared (PIR) sensor that detects motion and can be used for alarm for security purposes, and a DHT11 sensor that senses temperature and adjusts the air conditioner accordingly. Further implementation of this prototype-based research work is to implement machine learning and artificial intelligence.

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