Design and Installation of an IOT-Based Computer Laboratory Power Management

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Abstract—*Constant rise in energy consumption caused by population growth and the daily introduction of new gadgets and appliances had created significant hurdles for consumers trying to manage their energy usage. According to IEA, global electricity demand is expected to rise at a faster rate over the next three years, growing by an average of 3.4% annually through 2026. The increasing demand for energy efficiency in educational institutions has prompted the exploration of innovative solutions for power management. This study presents the design and installation of an Internet of Things (IoT)-based power management system tailored for a computer lab environment. The proposed system integrates IoT devices to monitor and manage the power usage of computer laboratory. An android application were developed to remotely control and monitor devices like air conditioners and lights. Moreover, this study focuses on evaluating the effectiveness of the designed device. Furthermore, quantitative data were gathered using a validated, self-made evaluation questionnaire to determine users-experience, functionality and effectiveness of the application. Users rated the functionality of the system with a weighted mean of 4.71 that offers accuracy in monitoring power consumption and compatibility of wide range devices. The users- experience was also highly rated, with a mean score of 4.84, reflecting satisfaction with the user-friendly interface and easy controls. Effectiveness gathered a rating at 4.90, allowing users to manage power usage which is beneficial to the environment and conserves energy. This study contributes to the growing body of knowledge on IoT applications in energy management and offers a scalable model for similar institutional settings.*

Keywords— *Arduino, Internet of Things, Home Automation, Microcontrollers, Power Management.*

I. INTRODUCTION

Energy consumption has been on the rise in the Philippines and poses multifaceted challenges as the population grows as more and more individuals use new gadgets and appliances. According to a Department of Energy (DOE) report, since 2005, the Philippines' energy usage has been rising. Since 2014, the rate of rise has also been increasing. It has also been projected that the energy consumption of the country will grow substantially in the coming years with primary energy supply projected to nearly triple by 2050, growing at an average rate of 3%. 9% per year [1]. The increase in consumption puts a strain on the country's power grid making it more difficult for people to manage their energy usage. This results in electricity bills and an increased occurrence of power outages [2]. These issues are made worse by the nation's reliance on non-renewable energy sources, underscoring the pressing need for creative energy management solutions. To guarantee a steady and sustainable energy supply going forward, the increasing demand also calls for large expenditures in energy infrastructure.

There is also an increased concern on energy conservation in the educational sector. It's critical that educational establishments consider how much energy they utilize. Educational institutions, especially universities, are significant energy consumers, primarily due to the need to maintain a conducive learning environment and support various academic activities. Finding locations where energy could be saved is made easier by conducting period inspections of energy usage. Schools and colleges can focus on areas of concern by using reliable information about the times of day, week, or month when energy usage is high, which can be obtained from readings on electricity meters [3]. Air conditioning, lighting are major energy consumers in educational buildings. Implementing energy-efficient practices can significantly reduce consumption. Simple actions like turning off lights, computers, and equipment when not in use can make a difference. As these institutions strive to balance their educational objectives with environmental responsibilities, the need for innovative power management solutions becomes critical [4] [5]. This says that energy efficiency in educational facilities is not only a way to minimize expenses but also a tool to promote sustainable behaviour and minimize the negative impact on the environment.
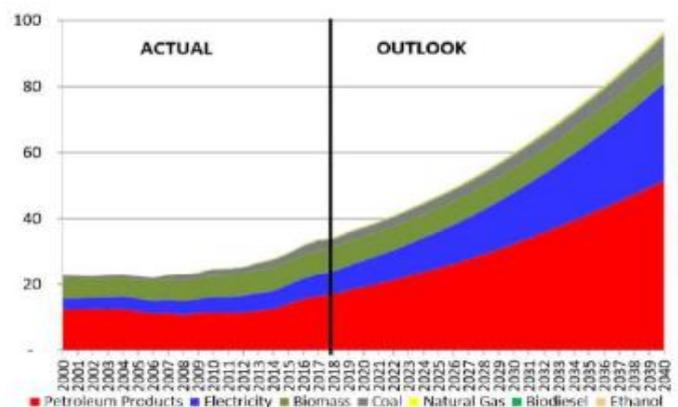

Figure 1. Total Energy Consumption of the Philippines by the DOE.

A potential system that can be used to integrate Internet-of-Things (IoT) devices in tracking and controlling power usage with the aim of improving the energy use in computer laboratory is also described as a method to disciple the energy consumption [6] of an institution. The IoT refers to a network of physical devices, vehicles, appliances, and other objects

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embedded with electronics, software, sensors, actuators, and network connectivity that enable these objects to collect and exchange data. So, these "smart" devices receive data and communicate with each other and other internet-enabled devices IoT includes everything from simple home-based components to heavy industrial machines that are borderless. Few Internet of Things (IoT) technologies that track building energy consumption have the educational sector in mind [7]. In a computer lab environment for instance, the utilization of the system will help in conserving energy thus cutting down on the expenditures on energy bills. This approach not only seeks to cut costs but also aligns to the green agenda of institutions of learning and therefore, promotes a sustainable and environmentally friendly campus.
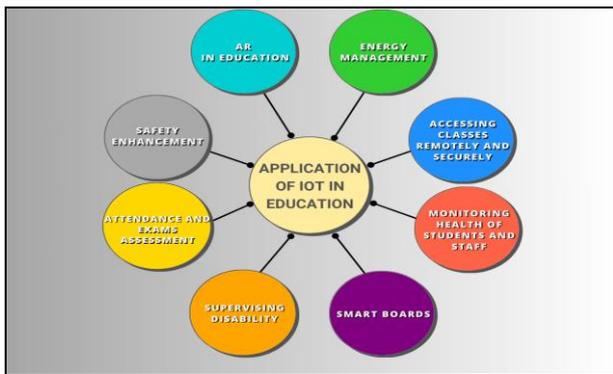

Figure 2. Application of IOT in the sector of Education.

The primary purpose of this research study is to address the pressing energy challenges faced by educational institutions, particularly computer labs. By leveraging an innovative Internet of Things (IoT)-based power management system, this project aims to enhance energy efficiency, and create a sustainable environment within the institutions. The potential benefits include reduced energy bills, time cost and efficient energy environment. Implementing this technology demonstrates a commitment to sustainability, enhancing the institution's reputation and attracting environmentally conscious individuals.

II. RELATED LITERATURE

The positive outlook of changing energy usage and efficiency has drawn a lot of attention to the application of IoT in energy management. Through the use of related devices and sensors, users of IoT systems can monitor and manage energy [8]. Therefore, the main goal of this technology is to empower consumers and decision-makers to more effectively manage and make wise choices regarding energy consumption.

According to [9] IoT technology energy management has been revolutionized by ensuring real time monitoring and control through interconnected devices and sensors. In schools, for example, research has shown that these systems reduce consumption rates of electricity as well as increase user satisfaction. This means that they can help us with managing computers, lighting and air conditioning equipment. The aim is to save a lot of energy through an implementation of internet-of-things enabled power management system in the computer lab and also create a remote access capability which will be friendly to users. This occurs with the fact that research has identified need for new ideas in the area of energy management while at the same time showing how IoT could drive sustainable practices in educational sphere towards self-sufficiency regarding energy use.

In the context of the paper of [10], IoT technology has been used by smart farming in recent years to transform agricultural methods. Farm management may be greatly improved with an IoT-based agriculture stick that has smart sensors for real-time temperature and moisture monitoring. Such a system facilitates real-time monitoring and decision-making by utilizing solar technology for sustainable power supply, cloud computing for data storage and analysis, and Arduino for sensor integration. By giving farmers accurate and timely data, this innovation hopes to maximize resource utilization, increase crop output, and support sustainable agricultural methods. This method closely resembles the study on Internet of Things (IoT)-based power management systems, illustrating the adaptability and influence of IoT in various domains including education and agriculture.

An author [11] also shown that the implementation of IoT-based energy management systems in smart homes results in significant energy savings and enhanced user satisfaction. For instance, users report high levels of satisfaction with the system's functionality and ease of use, particularly appreciating the accuracy of real-time monitoring and the intuitive user interfaces. These findings highlight the potential of IoT technologies to transform energy management in residential settings, making homes smarter and more energy-efficient. Furthermore, future research in this field is expected to focus on improving system scalability, enhancing data analytics capabilities, and integrating renewable energy sources such as solar power. These advancements will further bolster the effectiveness of IoT-based energy management systems, paving the way for more sustainable and energy-efficient smart homes.

This literature review provides a comprehensive background for our study on the design and installation of an IoT-based computer laboratory power management system. By drawing parallels with smart home energy management systems, we can leverage similar technologies and methodologies to optimize energy usage in educational institutions, thereby contributing to energy efficiency and sustainability.

III. METHODOLOGY

A. Objectives of the Study

This project aims to implement a newly and advanced way of power management by integrating IoT using Arduino technology, thereby optimizing user's time, conserving energy, and reducing laboratory electricity consumption. This project also aims to design and develop Arduino-based control modules equipped with sensors enable real-time monitoring and control of power sources and enhancing operational efficiency. This expanded functionality will empower users to remotely control these devices from any location within the school area with internet connectivity, enhancing convenience

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and flexibility. This project seeks to optimize user comfort, streamline operations, and facilitate efficient management of computer laboratories. Additionally, an assessment of the IoT integration's environmental impact will be conducted, ensuring that the department's activities are in line with aims to give sustainability and efficiency. Finally, the project will evaluate scalability and offer suggestions for possible future extensions. The department's overall aims of efficiency, cost-effectiveness, and environmental responsibility are all in line with these particular objectives, which together seek to demonstrate the effectiveness and advantages of IoT integration.

B. Components

In the current IoT era, a great deal of new research is being done on the creation of smart IoT-based products to support an IOT-Based Computer Laboratory Power Management. This section discusses the Design and Installation of an IOT-Based Computer Laboratory Power Management.

In this section, various components i.e. Modules and Sensors being used for IOT-Based Computer Laboratory Power Management development is discussed:

ESP8266 NodeMCU

ESP8266 NodeMCU an open-source software and hardware development environment built around an inexpensive System-on-a-Chip (SoC) called the ESP8266.

Technical Specifications: The ESP8266, designed and manufactured by Espressif Systems, contains the crucial elements of a computer: CPU, RAM, networking (WiFi), and even a modern operating system and SDK. That makes it an excellent choice for Internet of Things (IoT) projects of all kinds.

Figure 3. ESP8266 NodeMCU.

Passive Infrared Sensor

PIR (Passive Infrared) is a small and efficient device that is used in motion detecting purposes. This is attained since it operates by detecting infrared light emitted from objects in its frontal view as a security system, automatic lighting, among other applications. PIR sensor is affordable and compatible with almost all the types of microcontrollers and other systems.

Technical Specifications: With a detection range of up to 7 meters and a detection angle of 110 degrees, operates at a voltage range of 4.5V to 20V, provides a digital (High/Low) output signal, has a stabilization time of less than 1 minute after power-up, functions within an operating temperature

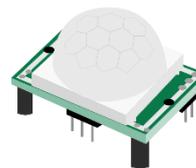range of -20°C to +50°C, and consumes less than 50µA of current.

Figure 4. Passive Infrared Sensor.

Solid State Relay

The Solid State Relay (SSR) is a reliable and efficient switching device designed for controlling high-power loads, featuring an operating voltage range of 3V to 32V DC for the input side, an output voltage range of 24V to 380V AC, a maximum load current of 40A, zero-crossing detection for minimizing electrical noise, an isolation voltage of 2500V AC, and a rapid switching time of less than 10 milliseconds.

Figure 5. Solid Sate Relay (SSR) 40A

220V AC 120mm

220V AC 120mm blower exhaust cooling fan, designed for efficient heat dissipation in various application, features an operating voltage of 220V AC, a fan size of 120mm, high airflow capacity, low noise operation, durable construction for long-term reliability, and is suitable for use in electronic enclosures, equipment cabinets, and other cooling applications.

Figure 6. 220V AC 120mm blower exhaust cooling fan.

AC LED Bulbs

AC LED bulbs are designed to provide dependable and energy-efficient illumination. They are also compatible with standard light sockets and are perfect for residential, commercial, and industrial lighting applications. With an operating voltage range of 110V to 240V AC, wattage options ranging from 5W to 100W, a lifespan of up to 25,000 hours, and color temperatures ranging from warm white (2700K) to cool daylight (6500K).

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Figure 7. AC LED Bulbs.

C. Installation

The installation phase of the IoT-based power management system in a computer laboratory involves several critical steps to ensure proper functioning and integration of all components. First, a thorough site preparation is conducted, including an assessment to determine optimal placements for IoT devices such as sensors, smart plugs, and controllers. This assessment also identifies necessary upgrades to the electrical and network infrastructure to support the new devices, ensuring safety compliance and enhancing network connectivity. Next, the installation of devices begins with strategically placing energy monitoring sensors to track power usage of individual computers and other equipment. Smart plugs are then connected to devices requiring power management, allowing for remote control and real-time monitoring of power consumption. Finally, central controllers are set up to manage and coordinate the communication between all IoT devices, ensuring seamless integration and functionality of the power management system. This comprehensive installation process is crucial for the successful deployment and operation of the IoT-based power management system in the computer laboratory.

The IoT based Computer Laboratory Power Management incorporates ESP8266 nodeMCU for monitoring of Air Conditioner and laboratory lighting and sends the data to the BLYNK environment via Internet Wi-Fi. In this IoT project, 3 values are measured: Laboratory air conditioner and lighting manual, automation controls and time scheduling.
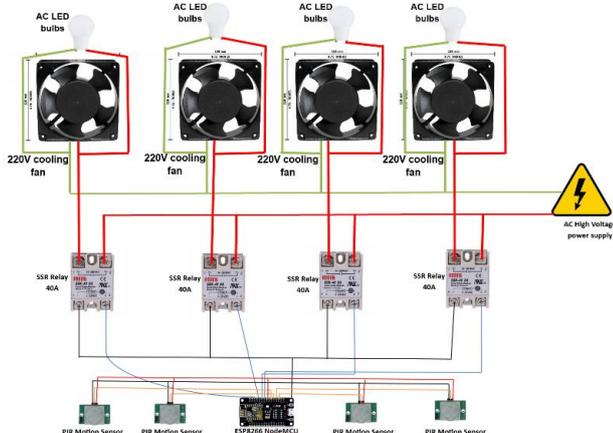

Figure 8. Circuit Diagram of the IOT-Based Computer Laboratory Power Management.

Live Implementation and Real-Time Monitoring

The general operation of the system is covered in this section. The animated view of the IOT-Based Computer

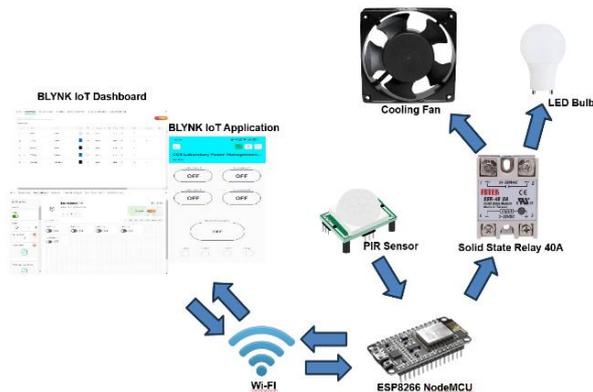Laboratory Power Management is displayed in the diagram below.

Figure 9. Overall working system of "IOT-Based Computer Laboratory Power Management".

The following diagram shows the complete details of IOT-Based Computer Laboratory Power Management being developed:
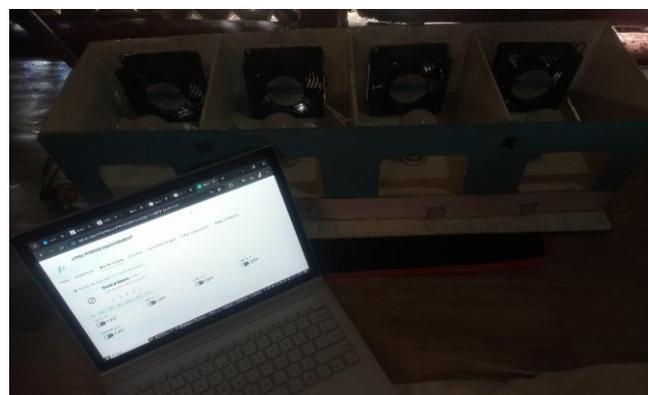

Figure 10. Prototype Model

Figure 11. Prototype model with BLYNK IoT Dashboard controller.

D. Research Methods

A validated, self-made assessment questionnaire was used to collect quantitative data from end users of the target research setting in order to assess the application's effectiveness, functionality, and design. The produced systems were assessed using a 5-point Likert scale, with 5 being the best and 1 being the lowest. The scale's descriptions are as

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follows: 5 is for outstanding, 4 is good, 3 is satisfactory, 2 is poor, and 1 is unsatisfactory.

TABLE I. LIKERT'S SCALE METHOD

Rating	Weighted Mean	Interpretation
5	4.51-5.00	Outstanding
4	3.51-4.50	Very Satisfactory
3	2.51-3.50	Satisfactory
2	1.51-2.50	Poor
1	0-1.50	Unsatisfactory

IV. RESULTS AND DISCUSSION

This section contains the results and discussion of our study on the creation and implementation of an Internet of Things-based computer lab power management system, which was assessed using a self-created questionnaire. The findings shed light on how well the system was received by users and how effective it was; they also show how the system affected user satisfaction, operational ease, and energy efficiency in educational settings.

In the functionality aspect of the project, the proponents aimed to fulfill the objectives and ideas behind the development of the IoT Based Power Management system using Android App Support. The project objectives were designed to meet the needs and requirements of the end users effectively. With the indicators on the questionnaires are composed of (1) The system accurately monitors power consumption in real time; (2) The system effectively identifies energy consuming devices; (3) I trust the accuracy of the data provided by the system; (4) The mobile app allows me to remotely control devices connected to the system; (5) I find the remote-control feature convenient for managing the device; (6) The system responds promptly to commands sent through the mobile app; (7) The system seamlessly integrates with different IoT devices; (9) The mobile app is compatible with a wide range of smartphones/tablets; (10) I encounter no compatibility issues when using the system; (11) The system effectively communicates with all connected devices; (12) The system consistently operates without technical glitches or errors; (13) Overall, I am satisfied with the functionality of the system. Figure 12 shows that the functionality of the developed application garnered a total grand mean of 4.71 which interprets that the applications has an outstanding function to the end-users.
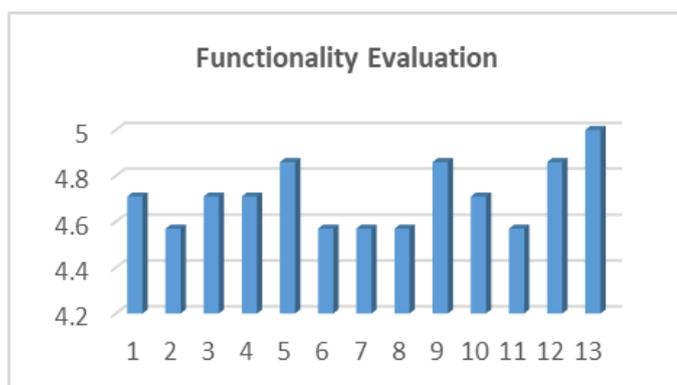

Figure 12. Evaluated functionality of the IOT application.

In the user experience aspect of the project, the proponents aimed to fulfill the objectives and ideas behind the development of the IoT Based Power Management system using Android App Support. The project objectives were designed to meet the needs and requirements of the end users effectively. With the indicators on the questionnaires are composed of (1) The mobile app interface is user-friendly; (2) The process of connecting devices to the mobile app is straightforward; (3) Navigating through different functionalities of the mobile app; (4) The mobile app provides clear instructions on how to use each feature; (5) Overall, I find the mobile app experience satisfactory.

Figure 13. Evaluated user-experience of the IOT application.

In the effectiveness aspect of the project, the proponents aimed to fulfill the objectives and ideas behind the development of the IoT Based Power Management system using Android App Support. The project objectives were designed to meet the needs and requirements of the end users effectively. With the indicators on the questionnaires are composed of (1) The IoT-based Power Management system has the potential to help reduce the overall energy consumption of the CCS Laboratory; (2) I believe that using the IoT-based Power Management system has a positive impact on the environment; (3) I would recommend the system to others based on its potential environmental benefits; (4) I would continue using the system in the future; (5) The system meets my expectations in terms of managing power usage effectively; (7) Overall, I am satisfied with the overall effectiveness of the IoT-based Power Management system.
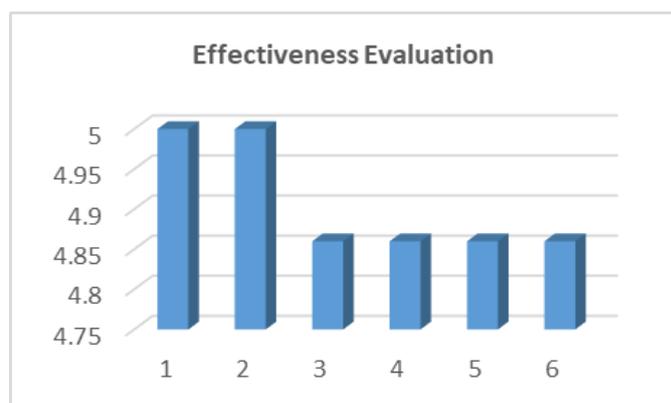

Figure 13. Evaluated effectiveness of the IOT application.

The implementation of the IoT-based power management system for the computer laboratory yielded highly positive results across various evaluation metrics. The system's functionality received a grand mean score of 4.71, indicating that it met the required operational standards effectively. Users reported a high level of satisfaction with the system, as evidenced by the user experience score of 4.84. This suggests that the system was intuitive, easy to use, and well-received by its users. Most notably, the system's effectiveness in reducing energy consumption and optimizing power management was rated at an impressive 4.90. These scores collectively highlight the system's capability to deliver on its promises of enhancing energy efficiency and providing a seamless user experience. The high ratings across functionality, user experience, and effectiveness demonstrate the potential of IoT solutions in achieving sustainable energy management in educational environments.

V.   CONCLUSION AND RECOMMENDATIONS

The study successfully designed and implemented an IoT-based power management system for a computer laboratory, achieving notable success across multiple dimensions. The system's functionality received a grand mean score of 4.71, user experience scored 4.84, and effectiveness achieved an impressive 4.90. These high scores indicate that the system not only operates effectively and efficiently but also provides a high level of user satisfaction. The significant reduction in energy consumption and the positive feedback from users validate the potential of IoT solutions in enhancing energy management in educational settings. The high effectiveness score reflects the system's capability to meet its intended goals, while the excellent user experience rating underscores its ease of use and user-friendly design. Overall, the results confirm that implementing an IoT-based power management system in computer laboratories leads to significant energy savings, improved operational efficiency, and enhanced user engagement.

Given the positive outcomes, it is recommended to extend the implementation of the IoT-based power management system to other computer laboratories and relevant facilities within the institution. Further research should focus on integrating advanced features such as predictive analytics for proactive energy management and automated fault detection to enhance system reliability. Additionally, continuous user training and engagement initiatives should be implemented to ensure users are well-informed about the system's benefits and functionalities, thereby maximizing its effectiveness and user

satisfaction. Regular evaluations and updates to the system based on user feedback will also help maintain and improve its performance over time. Furthermore, exploring partnerships with other educational institutions to share best practices and experiences can foster broader adoption of IoT-based energy management solutions, contributing to a more sustainable and energy-efficient academic environment.

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