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Research Article

Enhancing Energy Efficiency with Smart Building Energy Management System Using Machine Learning and IOT

M.Sahaya Sheela[1*], S.Gopalakrishnan[2], I.Parvin Begum[3], J. Jasmine Hephzipah[4], M Gopianand[5], D. Harika[6]

[1]*Department of Department of Electronics and Communication Engineering , Vel Tech Rangarajan Dr. Sagunthala R&D Institute of Science and Technology, Chennai, Tamil Nadu, India.*

[2]*Department of Information Technology, Hindustan Institute of Technology and Science, Kelambakkam, Tamil Nadu 603103, India.*

[3]*Department of Computer applications , B.S.Abdur Rahman Crescent Institute of Science and Technology , Vandalur, Tamil Nadu 600048, India.*

[4]*Department of Electronics and Communication Engineering, R.M.K. Engineering College, Kavaraipettai, Tamil Nadu 601206, India,*

[5]*Department of Computer Applications, PSNA College of Engineering and Technology, Dindigul 624622.Tamil Nadu, India.*

[6]*Department of Electronics and Communication Engineering, Mohan Babu University (Erstwhile Sree Vidyanikethan Engineering College), Tirupati-517102.India.*

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ABSTRACT

The energy management system designed on the networking platform has been interfaced with controller to control the electrical device using the Wireless communication has been used as the most reliable and efficient technology in short-range communication. In this method IoT-based energy management could significantly contribute to energy conservation of home appliances device. This model analyses an IoT-based smart energy meter that automatically tracks residential energy consumption using current and voltage sensors. Input values senses unit that detects and controls the electrical devices used for daily actions. The ESP32 is used due to its built-in Wi-Fi facility, allowing data collection and exchange from electronic hardware to a cloud platform. The virtual android app displays the value of voltage, current, power, and unit consumed on a mobile screen, enhancing the efficiency of the system. The developed coding system to enhance system performance and provide more accurate results and ESP32 controller to interface non-invasive CT and voltage sensors, delivering data to a Blynk server over the internet. Model show the system accurately records voltage, current, dynamic power, and increasing power consumption and outcome accordingly, the home concerned person can turn ON/OFF the device based on such information if customer based user information.

1. INTRODUCTION

Energy management refers to the automation of the house or its activities involve the control of lights, fans, appliances, and other systems to improve convenience, comfort, electricity savings, and security. The concept of energy management has grown over many existences, and devices have recently entered the market; however, no personal solution has yet broken through to become widespread[1].

**Corresponding author. Email: hisheelu@gmail.com*

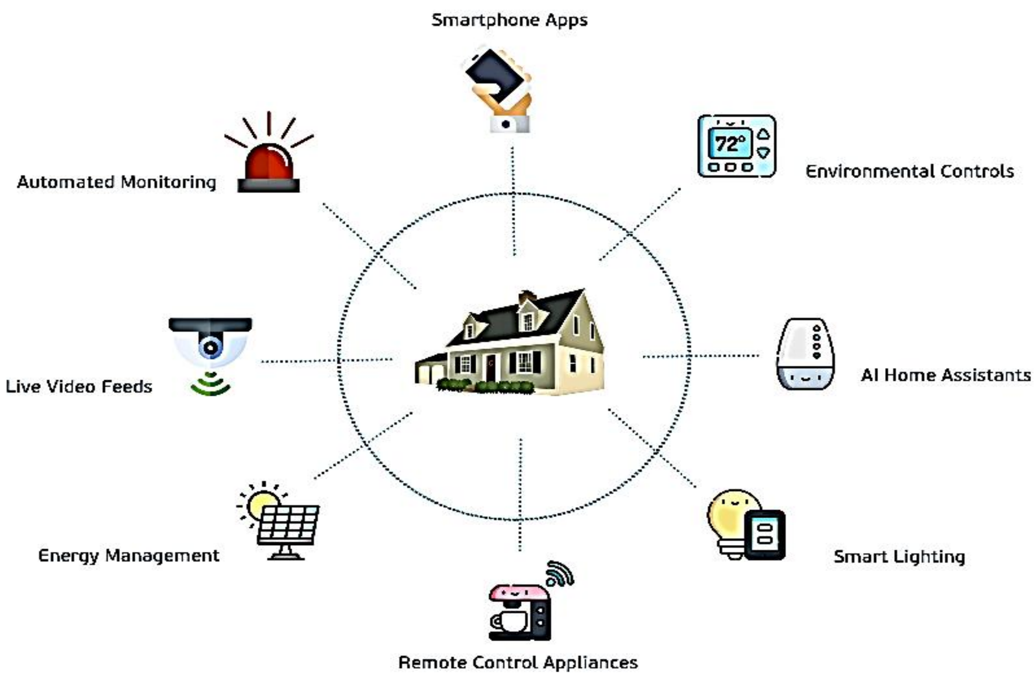

Fig. 1. Application of Smart Home management

Energy management also benefits the elderly and disabled who have moved into their homes by eliminating the need to go from one spot to another only to turn on or off appliances, open the door, and so forth. This can also provide a remote interface to home kitchen appliances or the automation system over the internet, allowing control

A smart building is one that uses technology to exchange information about what occurs in it at its basic level. Construct connections between systems to maximize the efficiency of the structure. Then, these data are employed to automate a range of procedures, including heating and ventilation, climate control, and safety. Smart workplaces and smart homes, libraries, healthcare facilities, and other smart hospitals and a variety of other SBs that can offer automated services that can bring a variety of value assistance and services (such as reducing energy waste) to safeguard the tenants' convenience, health, and safety.

1.1 Objective

1. To integrate all devices with networking communication and device-to-device communication into a discrete-time model
2. To create a system to plan all building electrical equipment in order to achieve energy savings in accordance with real-time voltage and current measurements for consumers.
3. To track and estimate bills and increase consumer understanding of energy consumption among residential and commercial users.
4. To achieve this, a monitor device shows the real-time estimated energy used by each connected component and the real-time estimated bill of the entire consumption.

2. LITERATURE SURVEY

Machine learning can be used to automate numerous operations, Smart buildings make it easier to manage tasks such as temperature, safety, and maintenance using computers and mobile devices. The Internet of Things (IoT) is used by smart buildings to link various building systems. Smart buildings are becoming vital parts of larger system integration as the Internet of Things develops. The Internet of Things (IoT) is essential for smart buildings and provides features that boost security for people by using potent tech-based critical approaches. This study presents the HEMS-IoT smart home energy management system, which is built on big data and machine learning for home comfort, safety, and energy savings. [1].

Because of advancements in energy conversion, new communication techniques, and information technology, smart houses are becoming a reality. The Internet of Things (IoT) is an amalgam of diverse technologies from several application domains that are employed to connect objects over the Internet, enabling the identification, observation, and management of multiple objects from a distance. Options that promise to improve energy efficiency include big data, machine learning, and energy management systems integrated with the Internet of Things. Blynk API and the J48 machine learning algorithm to comprehend user behaviors and energy usage. [2].

Demand-oriented systems frequently include smart Internet of Things (IoT)-capable devices in an ecosystem designed to maximize energy efficiency and have been proposed for smart home energy management systems. However, these technologies are only applicable to already-intelligent devices and are not suitable for many locations where most appliances are not yet IoT-capable. The argument for paying consideration to non-smart equipment and providing a way for incorporating them into the energy-saving environment of the IoT [3].

The energy consumption is statistics on maximum demand's hourly consumption collected at the smart commercial tenants that have been chosen for Internet of Things (IoT)-enabled construction has been analyzed using a arithmetic technique using the formula, the mean, and the variance. K-nearest Neighbor On the consumption data, the (k-NN) approach has been used. Using three distinct values of the closest distance for the prediction method. The predicted data were divided into various testing and training ratios of 70% and 30%, respectively [4].

Therefore, a continuous energy system is required to create a national performance indicator. Thus, a better system known as the smart grid is installed to improve the energy management system. Addressing demand-side management in smart buildings promotes effective energy management. The use of optimization techniques, such as genetic algorithms, helps to reduce the added process of energy consumption in smart buildings. This is accomplished using an optimization technique and machine learning. This facilitates efficient appliance scheduling. The scheduling of priorities is used to accomplish this. The total performance was measured using sensors and the Internet of Things. The act of detecting exterior physical parameters such as temperature, humidity, wetness, and heat [5].

Using gradient boosting machine techniques, such as the Light Gradient Boosting Machine (Light GBM), Category Boosting (Cat Boost), and Adaptive Boosting (Ada Boost), the energy consumption of certain public buildings was estimated. The key predictors developed by each technique were compared, and the Light Gradient Boosting Machine approach (Light GBM) produced the best-performing model with the lowest root mean squared error of 1.119. The experiment employed R-squared, mean absolute error, and root mean squared error as assessment measures. As part of the idea of "smart cities," the model may be used to create an intelligent machine learning-based energy management system for public buildings. [6].

Due to the rising population and their aspirations for comfort, there has been a tremendous rise in global energy consumption over the past few decades. Building energy management has become a crucial topic in today's society for decreasing energy waste because buildings account for 40% of the world's energy. The deployment of energy-efficient management systems requires the ability to predict the amount of energy consumed in SB and plan for that use. Approach for calculating the energy consumption of buildings and providing recommendations for reducing energy consumption and costs. Information such as temperature, humidity, and air quality is used by the systems. Machine learning is used to analyze these data and predict the number of energy smart buildings will use [7].

Due to the increased use of BLE technology, conventional ZigBee-based energy efficiency management solutions are less flexible in smart homes. This study provides a detailed comparison of the energy-saving management capabilities of ZigBee and BLE in smart homes. A BLE-based smart home energy management system is recommended. The BLE technology's fast transmission rate and high degree of interaction are taken advantage of by this system. Additionally, the study creates new concepts like "rules-based" smart home energy management systems, "smart app terminals for energy efficiency management," and "smart home." [8].

Energy specialists and managers are thus looking at these building energy demand profiles to optimize and boost the energy efficiency in the structure itself first and subsequently in the grid. This paper aims to present various algorithms that predict the electrical power use of structures, a case study of a hotel building in Shanghai, and to describe the approach needed and the comparative study between them using machine learning algorithms in Rapid Miner software, such as support vector machine (SVM), artificial neural network (ANN), selection tree (DT), and random forest (RF). [9].

A method for a smart residential energy management system that employs machine learning is suggested in this study. With rooftop solar and locally energized local storage, the proposed system shifts pre-prioritized prospective loads between the grid and residential premises using machine learning algorithms. Using a load-shifting algorithm, it is also possible to reduce electricity expenditure in residential buildings while maintaining a steady power supply. The system also includes features that predict average solar power using artificial neural networks and optimize solar power generation and energy storage using reinforcement learning. In the end, residential premises have less reliance on the grid [10].

Using cutting-edge technologies, this study focuses on building energy management and conservation. Machine learning and the Internet of Things (IoT) are used to automate building equipment and track energy consumption. The work discusses energy management and conservation using advanced IOT technologies such as sensors and actuators in buildings. For efficient use of electricity in the building, the appliances are sensed using various sensors and monitored by Arduino. The Smart Home Bluetooth-controlled Android app was created using MIT App Inventor. Local automation is performed using Bluetooth and the MIT App Inventor to monitor and manage the building’s electrical equipment from handheld devices. Customers are observed using electricity carelessly [11].

Building management systems need to be able to anticipate occupancy in real time with greater accuracy as Internet of Things (IoT) sensors become more sophisticated and are used in smart building automation applications. This saves power and maintains the comfort of the people. The experimental conclusions show that GRU outclasses the LSTM network because it uses 13.57% less power and has a reduced error of 1.21%.[12].

This study develops a novel energy-efficient thermal comfort model for environmental conditioning systems in smart structures, with the goal of reducing energy consumption and improving occupants' thermal comfort. Our provide a system architecture for a thermal comfort system that would reduce energy consumption and increase occupant comfort while taking into consideration outliers in groups like people of different ages. Using the ASHRAE RP-884 database, data were gathered during the sensing phase. Then, using various machine learning methods, we apply a machine learning approach to forecast the Thermal Sensation Vote (TSV) of the thermal comfort model [13] - [14].

Energy consumption forecasts are useful for consumer expenditure planning, comfort control in smart buildings, and energy budgeting for smart grids. Energy management is a fundamental requirement for building management systems in smart buildings. To achieve this, energy forecasting is essential. In general, machine learning techniques are used to predict energy use. However, massive amounts of data are required for machine learning algorithms to perform successfully. The collection of these data from data slaveholders may influence privacy breaches. A distributed system framework called federated learning can reduce privacy concerns. Therefore, federated learning has been developed for mobile edge devices such as automobiles, smartphones, and other mobile devices [15].

An efficient smart grid can integrate any type of generating source into the system, offering end users dependable, useful, intact, and high-quality electricity. The most important use case for the smart grid is the Home Energy Management System (HEMS). Energy forecasting is crucial in HEMS because of the non-uniform and extremely dynamic loading circumstances and the changeable generation availability. This article provides a quick introduction to load forecasting and HEMS approaches. A unique approach based on Long Short-Term Memory (LSTM) and Deep Neural Network (DNN) for estimating periodic power usage. The load is predicted for the next seven days. [16].

3. MATERIALS AND METHODS

The method uses the wireless input signal that is received from the Android handset to manage electrical loads. It gets harder for the elderly and disabled to continually turn on and off electricity switches by manually. A smart house is a structure with advanced technology installed that enables communication between several systems and appliances.

A computer-aided system that operates automatically and is set up by a computer in a building or house is known as smart home lighting management. One way to give control orders is to touch a button on the equipment, or users may use automated systems that can sense their surroundings on their own. The user may keep an eye on the condition of the house in real time data to the usage of remote monitoring devices. In the design of electronics and power supplies, converting AC (alternating current) to DC (direct current) at a particular voltage is a frequent problem. You can use a power supply or converter to change AC 230 volts to DC 5 volts. DC 5v to connect the esp32 controller.

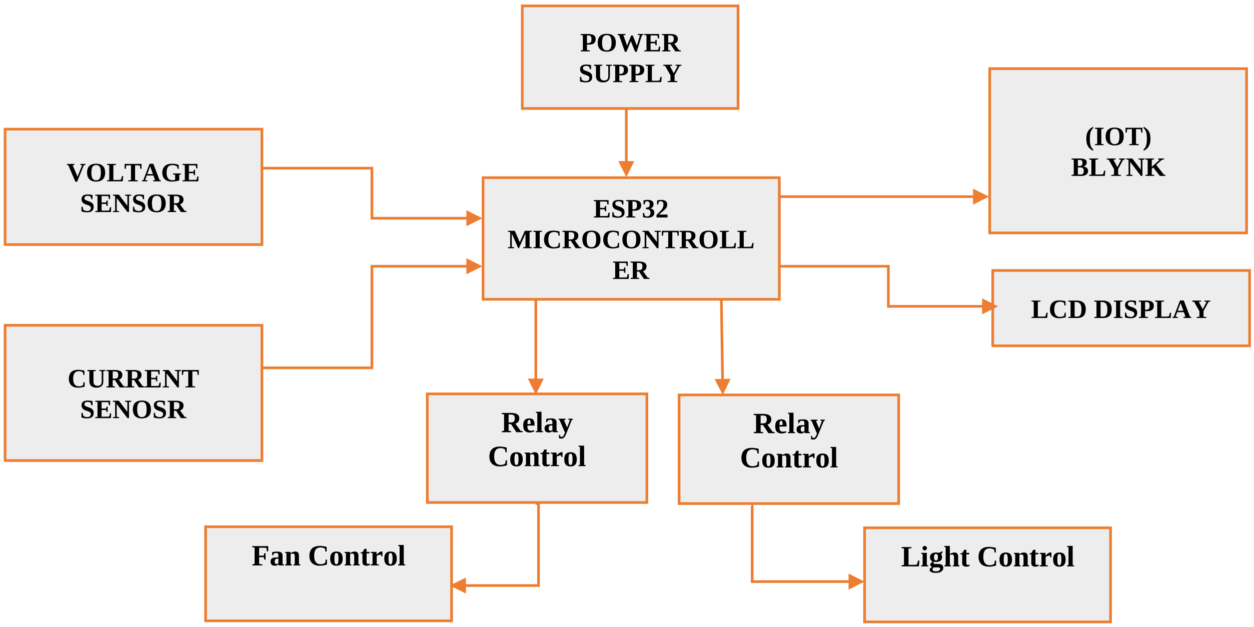

Fig. 2. Block diagram of Proposed Energy Management

A pre-made AC to DC power supply with the required specs is available for purchase. These power supplies are widely accessible and are offered in a variety of configurations, such as wall adapters, desktop power supplies, and DIN rail-mounted devices. Make sure that the power supply you select has a 5V DC output rating and an input rating that is compatible with your AC voltage (in this case, 230V AC). If you only need a 5V DC for charging or powering USB devices, you can use a USB power adapter. These adapters typically accept a wide range of input voltages, including 230V AC, and provide a 5V DC output via a USB port.

3.1 Esp32 Controller

The ESP32 is a versatile controller that can connect to Wi-Fi or other communication protocols, making it suitable for IoT applications. Numerous tools and technologies to track, manage, and optimize a building's energy use for sustainability and efficiency. This system can make use of an ESP32 controller to manage energy-related operations, interface with sensors and actuators, and gather data. The main elements and procedures for building a BEMS using an ESP32 controller are listed. Various sensors can be used to monitor parameters like temperature, humidity, occupancy, light levels, and energy consumption. Examples include temperature sensors, occupancy sensors (PIR or ultrasonic), light sensors, and current/voltage sensors for monitoring electrical loads.

3.2 Voltage Sensor

Fig. 3. Module of voltage sensor with example display output

A voltage sensor is a crucial device used in various applications, including industrial controls and power systems. This type of sensor is often used with controllers, as they can easily measure changes in electromagnetic fields around them using built-in analog-to-digital converters (ADCs). Voltage sensors are divided into two types: voltage-sensitive resistors (VSRs) and operational amplifiers (op-amps). VSRs are used in electronic circuits to detect small voltage changes, like battery life or solar panel output. Op-amps are used for tasks like motor driving or LED control, and are commonly found in controllers like ESP32 Controller boards.

3.3 Current Sensor

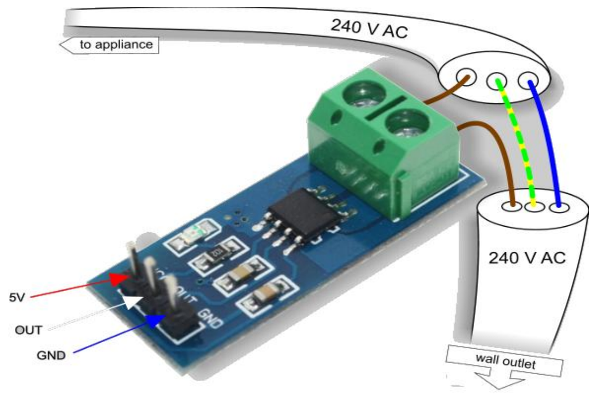

Fig. 4. Current sensor Configuration

A current sensor measures the electric current passing through a conductor, converting it into a quantifiable output such as voltage, current, or digital signal. These sensors are used for monitoring, control, or protection, and can measure large currents due to their coreless structure. Magnetic current sensors detect the generated magnetic field around the current path, allowing for the measurement of current. They are different from shunt approaches in that they may be isolated inside the sensor itself and do not require an isolation amplifier or isolation ADC. This approach is appealing because it detects current flowing to resistors with relatively low resistance standards, hence addressing the drawbacks of shunt resistor isolation amplifier/isolation ADC.

3.4 Blynk IOT

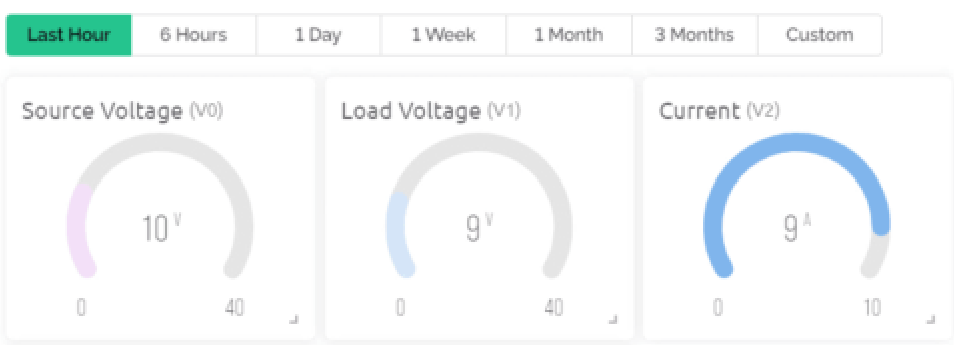

Fig. 5. Blynk IOT application

Blynk is an Internet of Things platform that works with iOS and Android devices to enable internet-based remote control of Node MCU. It enables users to work with widgets to construct graphical interfaces, or HMIs. Blynk can store, envision, and display sensor data. It was created with the Internet of Things in mind. The platform is made up of three main parts: the Blynk App, which lets users modify interfaces using pre-made widgets; the Blynk Server, which manages all smartphone-to-hardware communication; and the Blynk Libraries, which facilitate command processing and communication for common hardware platforms. Data is moved to the Blynk Cloud when a button is touched, and it then somehow makes its way to the installed devices. The system is able to manage thousands of connections.

3.4 LCD Display

Fig. 6. Model calculation of LCD output

Liquid crystal display, (LCD) demonstration module found in many gadgets, including calculators and cell phones. Its main applications are seven segments and multi-segment light-emitting diodes. LCDs are programmable and affordable and provide countless options for unique animations and characters. The data register and command register are the two registers found in a 16 2-LCD. The data register is set to '1', while the command register is set to '0'. Register select (RS) is used to switch between registers. This system can multitask; therefore, it will take less time to control loads, regulate loads, and keep an eye out for motion and fire. For the preservation of the user's energy: People occasionally become exhausted from their work and lose part of their vitality. Because this mechanism operates autonomously, humans do not need to exert more effort.

4. RESULT AND DISCUSSION

The outcome of Internet of Things (IoT) for controlling smart houses by using sensors and the Blynk application to control appliances in the house. Two loads a fan, a light are used as examples of this proposed work, through the internal controls, a user may effortlessly operate these appliances due to our logical interface.

Over the internet, this embedded device will receive orders from users. Loads are managed using relays. The controller operates these loads by processing commands from the user over the internet. As an outcome, the technology enables effective online energy management. With the aid of the technology, the loads will be automatically controlled. Execution: There are several parts to the Internet of Things (IoT) smart energy management system, including those that follow: Sensor Unit: The voltage and current passing through the electric power lines are measured by the sensors in this module. The embedded device receives the data about these sensors and processes it. Controller: This component transfers information to the wireless part after processing it from the sensor unit.

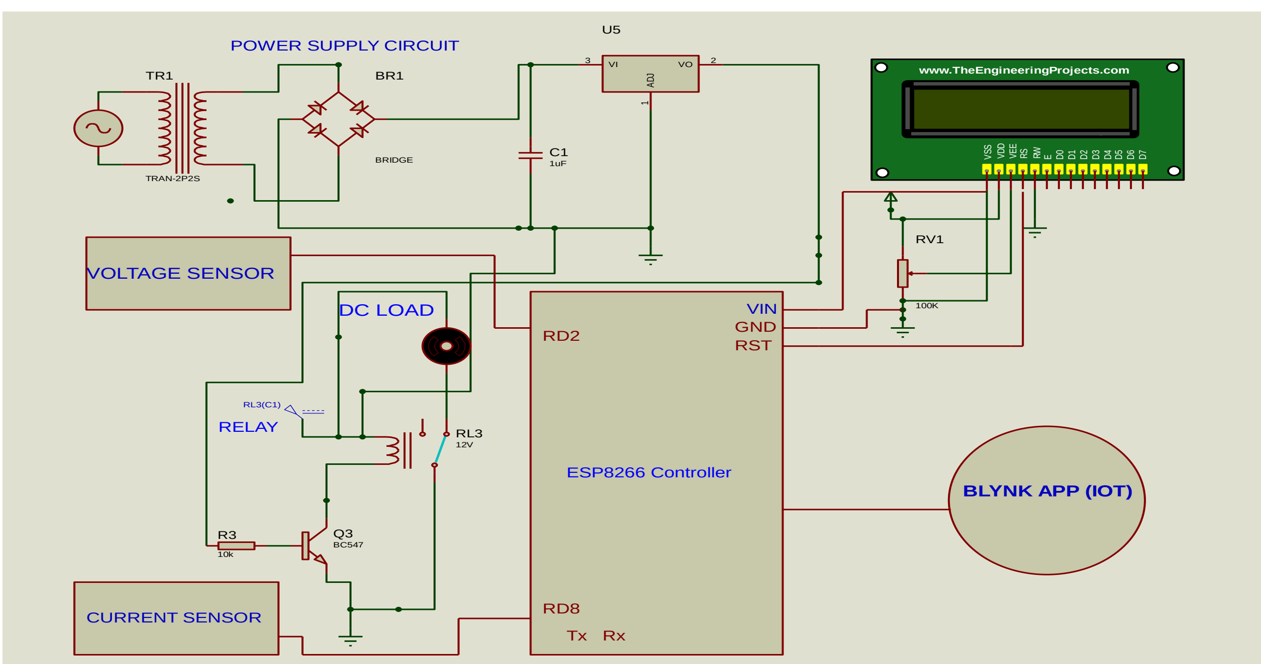

Fig. 7. Circuit diagram of smart energy management

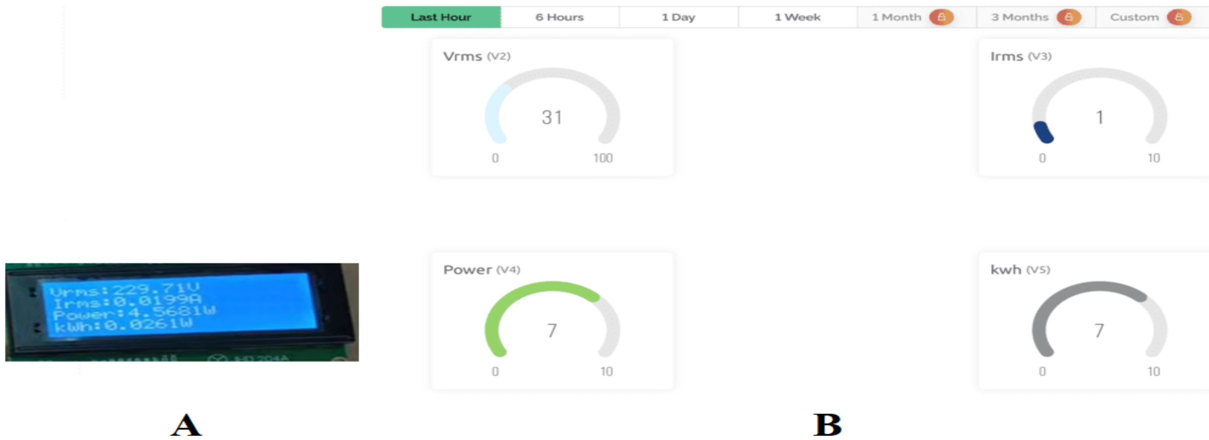

Fig. 8. (A) Output in the LCD display (B) Output in the Blynk application

Figure 8. Shows the real-time electrical parameters like current, voltage, power, and the unit consumed in the LCD display, and the parameters are shown on the mobile device through the Blynk IoT application for the portable monitoring of the electrical parameters.

5. CONCLUSION

The smart energy monitoring system is automated, using an ESP32 controller to interface with a current transformer and voltage sensor. The data is then retrieved via the blynk cloud for web clients. Experiments show the system effectively monitors voltage and current, power and kilo watt hours. This model aims to design and implement a smart energy meter system using an ESP32 controller in homes and public spaces, measuring voltage, current, energy, and power using a voltage and current sensor. This system that measures both mains voltage and current used by a consumer.

The voltage sensor's calibration parameters allow for high accuracy. It can measure current up to 30 amps and voltages up to 250 volts. The technological aspects of the ESP32 development are described on the same page, including Wi-Fi 802.The 11 b/g/n connection and 18 ADC channel with 12-bit resolution make it suitable for this IoT project. The equipment measures voltage, current, power use, and hourly consumption. The measured values appear on either the Blynk mobile application via Wi-Fi or the LCD display. The tool also offers a graph that shows electricity values over a 12-month period. This graph can be saved in CSV format for further examination or consumption. In future Internet of Things (IoT) refers to machine-to-machine communication. Additionally, an IoT-based energy management system in which a controller receives readings from environmental indicators including temperature and light intensity sensors. The Arduino controller is configured to regulate the appliance consumption in accordance with detected readings. Along with regulating appliance use, each appliance's current draw is calculated using Hall Sensors, and the additionally added remotely sent to a Raspberry Pi 3 via a Wi-Fi component.

Conflicts Of Interest

The paper's disclosure section confirms the author's lack of any conflicts of interest.

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