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TOWARDS SUSTAINABLE ENERGY MANAGEMENT: AN IOE INTEGRATED INTELLIGRID HOME FRAMEWORK

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Abstract

Several technologies currently available for energy monitoring purposes are responsible for the observation, recording, and control of energy consumption in a house or industry, preventing any undesirable losses. As in households, there are various hazards that exist and are not only dangerous for children's, such as electric fires, short circuits, and money loss. Many technologies are available for the consumption, monitoring, and management of energy in houses and industries. Such systems monitor, record, and monitor this type of energy use to reduce losses and effectively control the resources. In houses, there are dangers of electric fires, short-circuiting, and other unnoticed energy wastage that could result in the presence of small children with severe economic losses and safety risks, which could be an energy-related problem without proper surveillance. The industry wants remote operation for continuous control from the main control room and energy monitoring using IOT. The main objective of this study is to design a system that monitors and switches various parameters that are important in a domestic application, using an emerging Internet of Things technology. The proposed system includes numerous sensors that are used for sensing and measuring various parameters to collect data and analyze it, from which it transmits the collected data from nodes to the SQL interface via wireless networks that are used to control and monitor all the processes and energy consumption.

INTRODUCTION

The integration of the IoT with an energy meter innovates monitoring for industrial and domestic applications. This innovative system authorizes users to monitor and control the energy process via IoT-based technology. An efficient system can be used to minimize the loss of energy in developing nations. The system comprises a microcontroller, modules, devices, and voltage-current sensors to provide a real-time user-friendly interface. The device transmits data via a cloud network to provide parameters via IoT improvements for remote monitoring and controlling [1]. This study demonstrates the development and growth of IoT technologies via the connectivity of sensors and devices to provide real-time information. Integration of renewable sources for energy management advancements in IoT and renewable technology. The development of a smart sustainable system improves its efficacy [2]. This study focuses on an IoT-based monitoring system for energy management using the Arduino ESP8266 and other devices. The system efficiently manages the system with ThingSpeak and IoT-based cloud services to manage data via a network. The outcome shows the system functions for smart domestic, grid, and industrial applications [3]. This paper presents computer science integration in grids and power distribution. Advancements in IoT, such as monitoring and automated data analysis, address conventional deficiencies in grids. This study observes a difference in advanced energy systems using SCADA and machine learning algorithms. This study thoroughly discussed the major challenges across the globe for the implementation of IT in grids with renewable energy for effective energy utilization in the future [4]. This study analyzes the possibility of implementing machine learning in a power management system to decrease emissions and protect the atmosphere from climate change challenges. This study thoroughly analyzes artificial intelligence algorithms for optimum energy solutions for sustainability in industrial and domestic sectors. Conventional systems face a lack of efficiency and real-time optimization. The AI-based energy control system significantly reduces emissions for eco-friendly system implementations [5]. This study demonstrated the design of a real-time IoT-based optimum load management system to increase the effective utilization of energy by advancing demand management. Real-time data from sensors provide access to manage peak-hour overloads to decrease the energy shortage. The practical outcome shows the efficiency of the proposed system with an optimal cost. This paper presents the advancement of IoT algorithms to practice energy control [6]. Safety in commercial and public-sector places is one of the biggest challenges worldwide. The hazard-detection system was inspired by the latest IoT technology considered in this study. The system uses an ESP32 CAM, a microcontroller, and sensors. The convolutional neural network classifies the hazard signs as high voltage and flammable to achieve system efficiency. This scheme guarantees efficient energy savings by minimizing the additional load [7]. Innovation and development in Internet of Things technology provides real-time data monitoring for smart urbanization. This study provides development strategies for monitoring different features, including waste management, traffic density management, and energy usage. The main objective of IoT-based systems is to link hardware and software to a cloud network for information management [8]. This study demonstrates an improvement in the efficiency of green energy generation. A combination of Artificial intelligence and IoT technologies can innovate the system. The study outcomes provide technical parameters to enhance the economic and environmental factors. Environmental protection must address global climate change [9]. The rapid increase in population increases the demand for energy. The aim of this study is to estimate the application of IoT in city operations to manage power. The outcome shows a 10% reduction in energy usage and a 15% growth in operating efficacy after implementing the IoT. This study endorses the development of IoT in smart city management to attain energy efficacy and eco-friendly systems [10]. Pakistan is facing a huge energy shortage owing to a sudden increase in its population. The power system framework needs to implement a smart energy and load control system to address load-shedding issues. Energy efficacy reduces economic challenges in a country. The fuel imported for energy generation increases the energy generation costs. This study provides the design and implementation of an energy management system to automatically switch systems during peak hours. The system comprises a transformer, current and voltage sensors, microcontroller, Relay and Wi-Fi module to manage the system [11]. This study provides an energy usage monitoring and control system for domestic solutions. The proposed system measures the energy usage using IoT-based technology. The user notifies and controls the system when the slab reaches a higher limit during the peak hours. These components include the microcontroller, sensors, and cloud data. This study provides energy optimization techniques that reduce the ecological impact [12]. The increase in energy efficacy and implementation of an effective Internet of Energy system provide the development of control. The current energy system is inspired by artificial intelligence and Internet of Things-based technologies for optimum-energy solutions. Real-time information from different sensors and equipment provides energy-usage parameters to recognize the deficiencies of the integrated system. A machine-learning algorithm was utilized to forecast the power demand and optimize the power distribution. The implementation of this system reduces the power usage by 15 %annually [13]. The increase in the demand for and integration of renewable energy for sustainable solutions has led to the development of control schemes. This paper presents solar grid integration with advanced Internet of Things (IoT)-based monitoring and control systems. The system comprises pumps and solar panels integrated with the HTTP protocol to innovate the control management via a cloud network [14]. Conventional systems require efficient and sustainable solutions for their advancement. The main purpose of this study is to provide an energy-efficient system with reduced emissions. Many difficulties have been faced in the transformation of conventional systems into Internet of Things (IoT)-based innovative systems. Smart power management is promising for the latest IoT- and AI-based technologies. The integration of IoT and AI provides a model for predicting energy consumption. The information was collected via sensors and then examined using machine learning models to determine the efficiency of power usage [15]. The Internet of energy-based systems uses multiple sensors for information sharing via cloud-based systems. The main controlling part of the system is to switch the equipment automatically to save power, which causes loss owing to carelessness [16]. This study demonstrates an Internet of Things (IoT)-based power control system to optimize the conventional energy network framework. The descriptive computing pattern provides electricity data, including power, current, and voltages. The cloud network framework transmits electricity data via an based system [17]. Energy deficiency results in an increase in the rates of private generators. This study addresses energy loss by designing a cost-effective IoT-based power control system that provides real-time information. The components include a microcontroller as a major component, and other device sensors and meters analyze the data via the Blynk application. The practical outcome shows that the system perfectly measures and transmits data to consumers [18]. The objective of this study was to efficiently manage energy using an IoT-enabled framework. The other motive of this study was to check the charging discharge, frequency, and temperature parameters of the battery. The IoT infrastructure is a combination of sensor transmission and information analysis for real-time control. The objective of this study is to construct an efficient and sustainable power management system for implementation in developing countries [19]. The increase in the cost and demand for power is a major global challenge. This study provides a smart procedure for tracking and controlling energy. Demand control is a serious issue in improving energy efficacy. IoT is a developing technology for controlling commercial and domestic applications. Each piece of equipment is interlinked with the controller with different sensors and actuators integrated with IoT to collect and manage power usage [20].

MATERIAL AND METHODS

Methodology:

The system uses a mesh topology to facilitate its nodes in that it gives them the freedom to communicate with one another directly if they are within their radio transmission range. This advantage allows easy detection of faults, the nodes that are disconnected from the network for any reason can be easily identified, and the problems can be resolved. The system can be broadly divided into two parts: hardware and software. Microcontroller: This project uses communication and control, which takes information from the network nodes and passes it to the SQL Server user interface. ESP8266 is a Wi-Fi module primarily used for IoT applications, designed to enable wireless communication and Internet connectivity for a wide range of devices. The Figure 1 shows the microcontroller interface.

Voltage Sensor: The ZMPT101B sensor was used for voltage detection. This sensor is ideal for monitoring AC voltage levels and is often used in our system because of its precise voltage measurements for energy monitoring and automation applications.

Microcontroller: The microcontroller ESP8266 utilized to design this prototype. This is the main part of the system that control and manage the overall system via utilizing relays for switching. All the sensors and devices integrated with this system to manage the overall energy operation.

Table 1 Arduino Node MCU Specifications

Name	Specifications	Name
Microcontroller	ESP8266	Microcontroller
Voltage	5V	Voltage
Static Ram	80KB	Static Ram
Speed	80 MHz	Speed

Figure 1. Arduino Node MCU

ZMPT101B is highly sensitive, has a quick response time, and allows easy calibration using an adjustable potentiometer. This prototype has been employed specifically for detecting voltage variations to ensure safe and efficient operation. Current Sensor: The ZMCT103C sensor was used for current detection. This sensor is compatible with AC current level monitoring and is commonly used in applications that require precise current measurements, such as energy monitoring and automation systems. ZMCT103C is highly sensitive, has a quick response time, and allows easy calibration with an adjustable potentiometer. This system has been employed specifically for detecting current variations to ensure safe and efficient operation. The system requires components, modules, and software to access Web server systems. The microcontroller is integrated with the nodes while the SQL server is used on the website. Modules have been used for wireless communication. The implementation of the IoT sensor communicates information with the cloud interface. For the Current measurement, two devices, including an energy meter and current voltage sensors, were utilized. The meter provides the voltage and current parameters. SQL Server software and the mySQL server were designed to create the SQL Server system.Software Setup SQL Server: The Structured Query Language (SQL Server) is utilized in this system to maintain database management. SQL Server software procedures, allocates, and shows the information, support workers, and other personnel to examine the information and make serious conclusions. To observe data collection and handling, information openly to cooperate with devices includes sensors. pumps, loads, and drives. Web Server: The Web Server mySQL server software creates an SQL Server user interface. The SQL Server allows users to maintain more than one user's account on the same computer for different purposes. It also facilitates the provision of log files and maintains records of various activities. User connection details, such as username passwords through which the system is connected to the computer, must be mentioned in the PHP code. The PHP code works as follows:

Request Sequence after the device uploads data, table properties, and table properties the communicated data for the device is selected; and there are three options for direct links with tables. The scheme of this project is presented in Figure 2 and 3.

My SQL: SQL Server Administrator manages all the activities of the SQL Server. Communication lines and input and output channels were defined by the administrator. The values can be text, time, date, or real or float values of up to six decimal places.

Web Page login: This Web application permits the actual consumers to cooperate with the Website interface. This page provides users with access to the interface via a login page integrated with the mySQL and server applications.

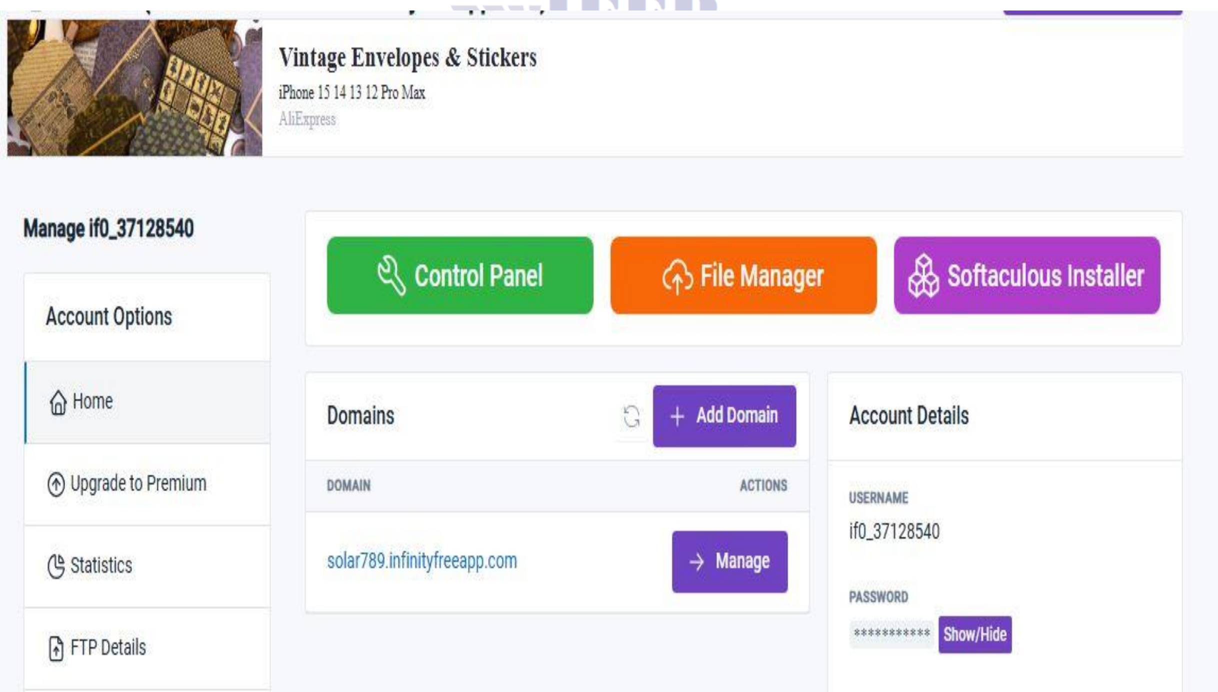

Figure 2: user interface

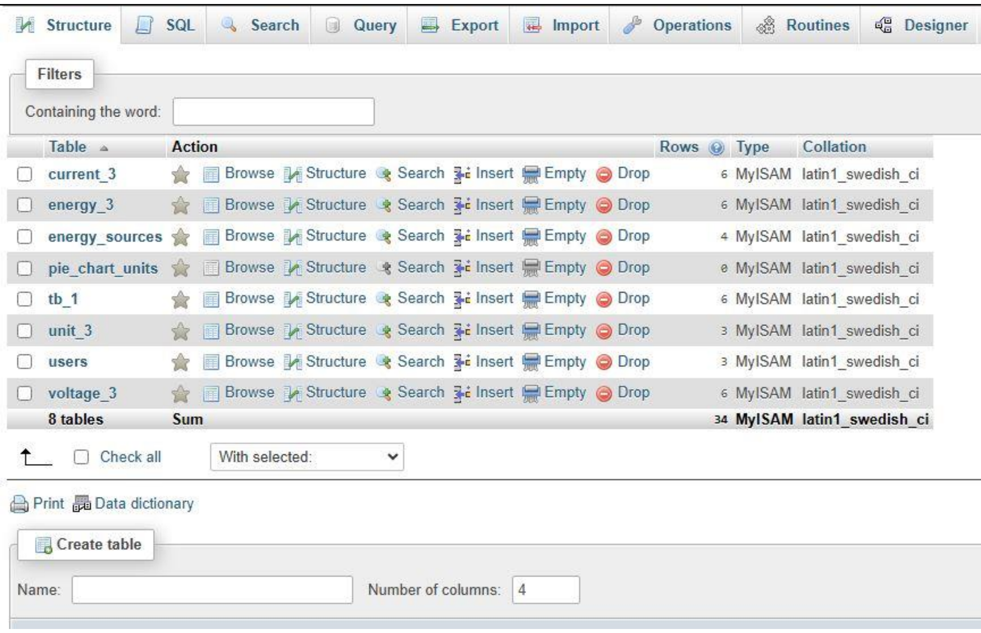

Figure 3: System web structure

System control flow

The system flow of the proposed methodology is illustrated in Figure 4.

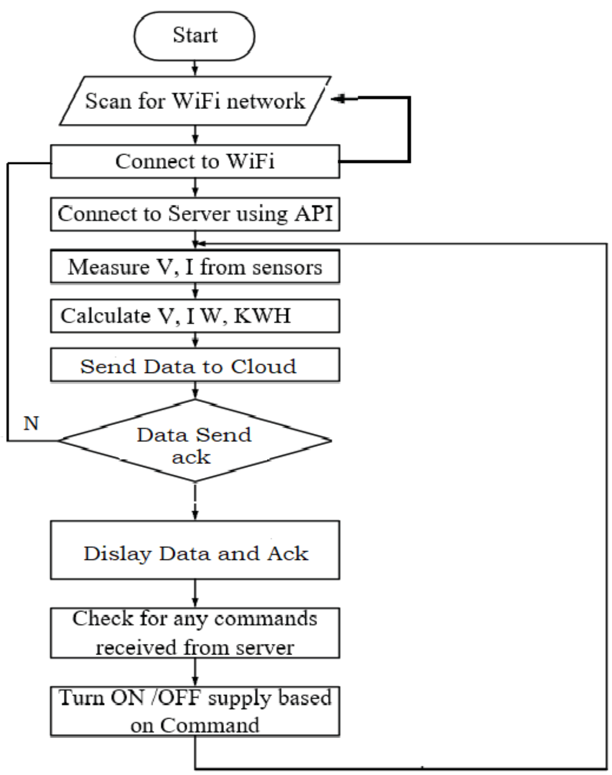

Figure 4: System flow

Schematic Diagram

The layout of the proposed system is shown in Figure 5.

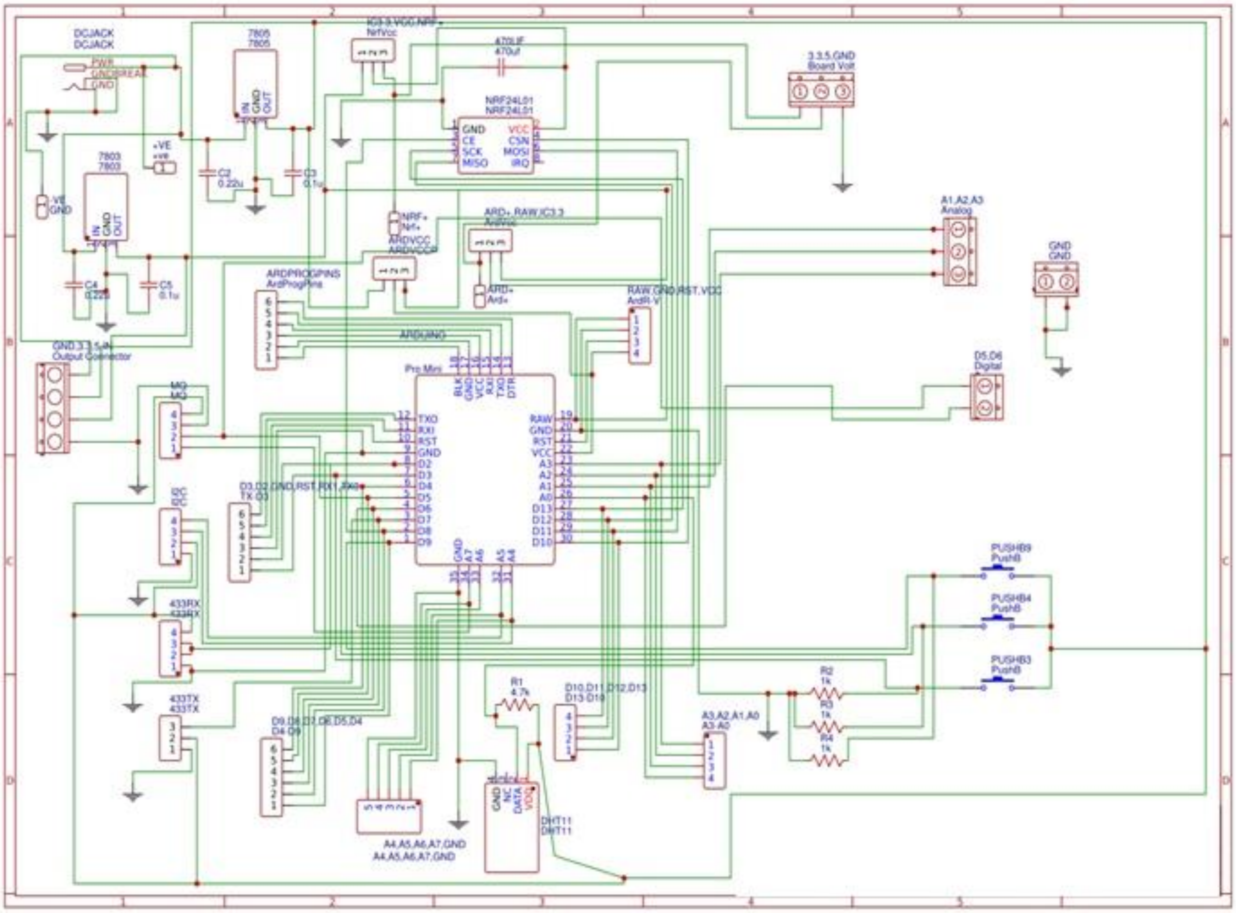

Figure 5: Schematic Layout

Minimize Total Energy Cost with Sustainability Constraint

Mathematical Model:

Minimization

$$\text{Min } Z = \sum_{t=1}^{T} \left(Pt.E^{grid} + C^{maint} + C^{IOE}\right) - (x+a)^n = \sum_{t=1}^{T} R^{sell}.E^{Export}$$ Where

Pt = Price of energy

E_{grid} = Energy purchased

C_{maint} = maintenance cost of IoE System

C_{IoE} = IoE System Cost

R_{sell} = Revenue Sell

R_{sell} = Revenue Export

RESULTS AND DISCUSSION

During the experimental testing phase, the IoT system functioned properly. The range test for the nodes with the website provides results between 90% and 95% with obstacles. The sensors integrated with the network nodes and SQL Server work on the SQL Table, and these registers are declared in the website's

PHP coding. A web server user interface was built for end users to give them maximum details of nodes on a single interface. Furthermore, the SQL Server interface is integrated with the IOT, allowing the network node sensor reading to be viewed on the user interface. The SQL Server system communicates with the website using the PHP protocol. The mySQL server database was also analyzed to verify that the values of the sensors were saved, and a backup was maintained. Demonstration panels for nodes have also been designed, containing node PCBs with acrylic enclosures, sensors, indicators, and actuators.

Subsequently, the final user interface with the node sensor values is shown. When finalizing the entire system, the final hardware functions properly. The entire system requirements were checked, and it was verified that all the systems were tested and verified.

Table 2: Prototype Testing Case 1

Preconditions	**Energy System is powered on**
Actions	Initiate the prototype
Expected Result	System Start
Result	Pass

Table 3: Prototype Testing Case 2

Preconditions	**Circuit and system are loaded**
Actions	Initiate the circuit and sensors
Expected Result	The circuit and sensors operational correctly
Result	Pass

Table 4: Prototype Testing Case 3

Preconditions	**Wireless power transfer system components testing**
Actions	Analysis procedures
Expected Result	System verified
Result	Pass

Table 5: Prototype Testing Case 4

Preconditions	System operation
Actions	Actuate the system
Expected Result	The arrangement functioning accurate and suitable energy management
Result	Pass

System Interface: Figure 6 shows the hardware implementation of the proposed energy system. The hardware setup includes a microcontroller, energy meter, sensors, and bulbs as the load.

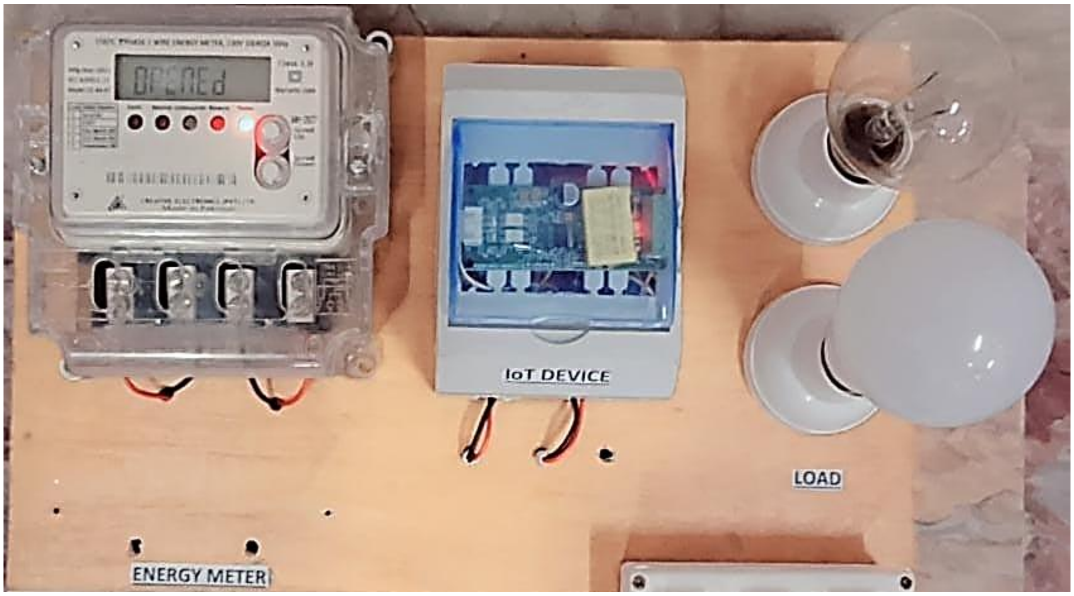

Figure 6. System Interface

CONCLUSION

The smart energy IoE based energy tracker system worked properly, and the parameters were analyzed and matched. The literature review thoroughly discusses previous studies for comparative analysis. An intelligent energy control system can be an active result for saving energy. This study provides innovations in conventional energy systems. Smart energy work can be considered a practice to familiarize oneself with energy management, time management, and energy management. These projects include the main part of the Arduino microcontroller node MCU and the integration of other sensors. Current, voltage, and power sensors are integrated with IoT to transmit data via the cloud and monitor the parameters via a web page. For software implementation, this system uses an Arduino IDE to program the microcontroller, and an SQL data-based system is utilized to store the database record. The proposed system can be implemented in domestic and commercial applications for future implementation of buck energy management.

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