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IoT-Based Power Monitoring System

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Abstract

Today, in many smart systems, the Internet of Things (IoT) plays an important role. It is mostly used in power monitoring, household applications, and industrial applications. In that, power is the most important thing that is to be monitored, controlled, and properly utilized. In this paper, a system is designed for monitoring and controlling the streetlights of a particular area. With the help of light-dependent resistor (LDR), power consumption is possible. Customers and system operators can view real-time energy use patterns with an intuitive web-based dashboard. Users can obtain important insights into their electricity consumption through graphical representations and historical data analysis, which facilitates more efficient load management, energy conservation, and cost optimization. By giving end users comprehensive and easily accessible information, the suggested smart energy meter improves energy use transparency. Additionally, it supports the shift to intelligent energy management systems by enhancing energy efficiency and facilitating informed decision-making. The design, which makes use of IoT technology, is a major step toward the modernization of smart grids and sustainable energy management systems. It also marks a substantial improvement in smart metering infrastructure. Users can view energy statistics from any location with internet connectivity thanks to the system's remote monitoring capabilities. This system is used to measure electrical quantities such as voltage, current, power, frequency, and power factor. By using a Wi-Fi module, all these quantities are transmitted to ThingSpeak. ThingSpeak is a server- or software-based application used to store and automatically update this data.

Keywords: Arduino, IoT, LDR, PZEM-004T meter, and Wi-Fi module

INTRODUCTION

Electricity theft is the main problem, so large amounts of power and money are wasted every year, which is why power consumption is a necessity of time. Renewable energy sources and non-renewable energy sources are both used for the generation of electricity, but some of the sources from non-renewable energy are consumed rapidly, and day by day, it is available in less quantity [1–4].

An Internet of Things (IoT) system that connects smart devices and provides accurate data, and is embedded with sensors, software, and other technologies to other devices, is called an IoT. Energy monitoring is the smartest thing using IoT; while using IoT, the system can be controlled remotely or using sensors from anywhere. An ESP8266 Wi-Fi module was used in this project to transmit data to the ThingSpeak server. In this system, a light-dependent resistor (LDR) was used to automatically turn ON and OFF streetlights, and a PZEM004T meter was used to measure electrical quantities. This system also displays all these quantities on a 16 × 2 LCD and uses IoT with the internet. Regular household devices can also be controlled and monitored using this system [5–7].

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Power monitoring and control using IoT is a wireless system that is widely used and convenient. Energy consumption will be lower using this system than using other conventional technologies. Arduino Uno is used in this project to connect the LDR, Wi-Fi module, and other sensors, which turn a complex system into an easy one. Using an LDR, a bulb glows only at night; switches are not required for ON and OFF purposes, which reduces energy consumption. The electrical parameters that are available at the ThingSpeak server using the ESP8266 Wi-Fi module are useful for analysis and study purposes, and most importantly, they avoid paperwork. Data can be accessed from anywhere [8–12].

LITERATURE SURVEY

In this study, a low-cost power monitoring system and control that reduces power consumption and consequently saves power were described. It measures electrical parameters smartly and then manages the whole system. A web server was used to store data, which was accessed by the operator from anywhere using the ThingSpeak server. Based on the literature survey, this system is also useful for household devices remotely or using the IoT [13–15].

This study focuses on monitoring, controlling, and switching of streetlights. The system is designed such that it controls the streetlight without the help of an operating person. Using an LDR, the intensity of the lights is determined, and the operation of the streetlight is performed. An LDR, also known as a photoresistor, works based on the principle of photoconductivity. It operates lamps by identifying darkness and dimness. Lamps are off during the day, while lamps are on at night. IoT prefers real-time monitoring and energy quality control and detects abnormal conditions. Based on the literature survey, ThingSpeak server shows the data in various formats, such as graph, numerical, and time formats, which are suitable for various conditions [16–18].

Arduino Uno

The Arduino Uno is a microcontroller board based on the ATmega328P microcontroller, developed by Arduino.cc. Burning and uploading programs to an Arduino is easier than to a microcontroller. Arduino uses an Integrated Development Environment (IDE) software that is an integrated development environment. Programs can be written for Arduinos using C and C++.

It has six analog input pins, a USB interface, a 16 MHz frequency crystal oscillator, and 14 digital I/O pins. These pins are used to connect various external sensors and electronic devices. In 14 I/O pins, 6 pins are Pulse Width Modulation outputs.

METHODOLOGY

Block Diagram

This system monitors electrical energy usage and automatically controls a lamp using a microcontroller. The Arduino Uno processes data from the energy meter and LDR sensor to control the
relay for load switching. It also displays information on an LCD and transmits data to a server via the ESP8266 module. Overall, the system integrates energy monitoring, automatic lighting control, and remote access, as shown in Figure 1.

The embedded features of the board can be directly connected to a computer or laptop using a USB cable. By using a USB cable, we can transfer or upload code from our computer to the Arduino using the IDE software. If a USB cable is not available, we can use an AC to DC adapter. When the board does not work properly or hangs, a reset pin is provided to reset the board, and the program starts from the initial point.

The Arduino requires a 5 V supply, which can be obtained from an AC to DC adapter or a USB cable. It also has other pins like

1. PWM provides an 8-bit output and is available on board at pins 3, 5, 6, 9, 10, and 11.

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2. *Rx and Tx:* It is at no 0 and 1 serially. The Rx pin is used to receive the data, and the Tx pin is used to transmit the data. Both are called serial communication pins.
3. *GND:* This pin is provided to connect to the ground. More than one ground pin is available on the Arduino for connection.
4. *Vin:* It is the input voltage pin available on Arduino; supply is provided through the power jack.
5. *LED:* It is available on the Arduino Board at pin no. 13. It works on high and low values, and according to the situation, it turns ON and OFF (Figure 2).

PZEM004T Meter

PZEM004T meter is the best solution to measure the electrical AC quantities like voltage, current, power, energy, frequency, power factor, and using an IoT platform, the measurement values can be sent to the server online using the internet and can be accessed from anywhere.

The PZEM004T meter was upgraded from version 1.0 to version 3.0. This updated version is suitable for measuring all electrical parameters mentioned above. It is available with a current transformer coil that senses the current and does not require any measurement circuit (Figure 3).

Measuring parameters and their range are as follows

1. Voltage
   - The measuring range is from 80 to 260 V.
   - Accuracy is 0.5%.
2. Current
   - There is a different measurement range of current available in the PZEM004T meter, like 0–10 A, 0–100 A, etc., suitable for our requirement.
   - Measurement of current starts from 0.01 to 0.02.
   - Accuracy is 0.5%.
3. Frequency
   - Frequency measurements are available from 45 Hz to 65 Hz.
   - Accuracy is 0.5%.
4. Active power
   - Measurement range is 0–2.3 kW for the 10 A kit, and for the 100 A kit, the range is 0–23 kW.
   - Accuracy is 0.5%.
5. Energy
   - Measurement of energy is available from 0 to 9999 kWh.
   - Accuracy is 0.5%.
6. Power factor
   - Measurement range is 0.00–1.00.
   - Accuracy is 1%.

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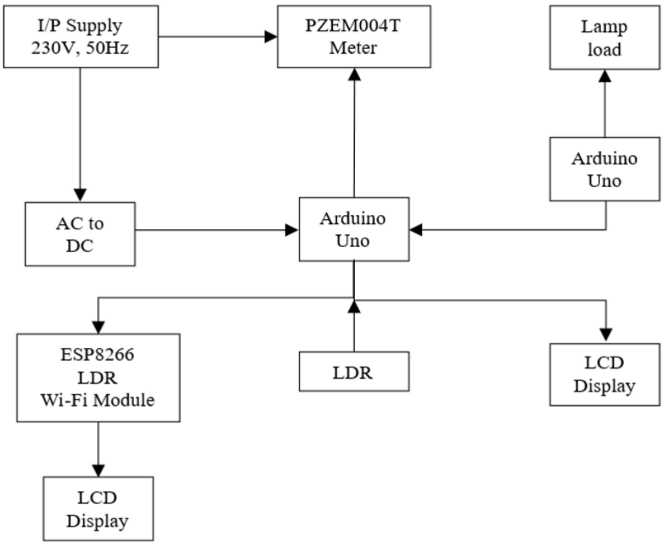


Figure 1. Block diagram of smart energy monitoring system.

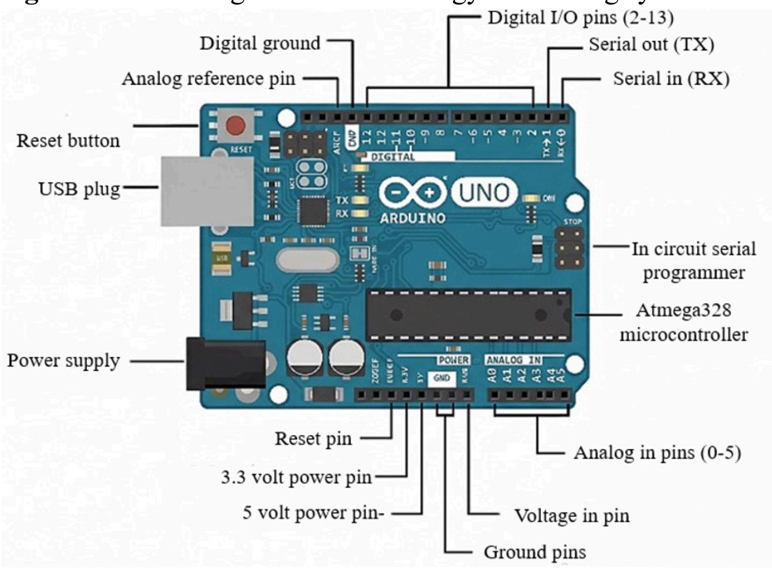
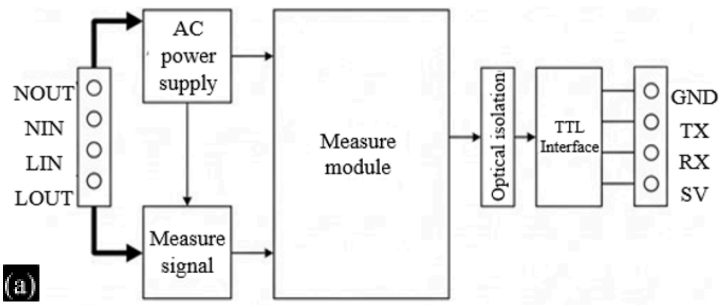


Figure 2. Arduino Uno image.



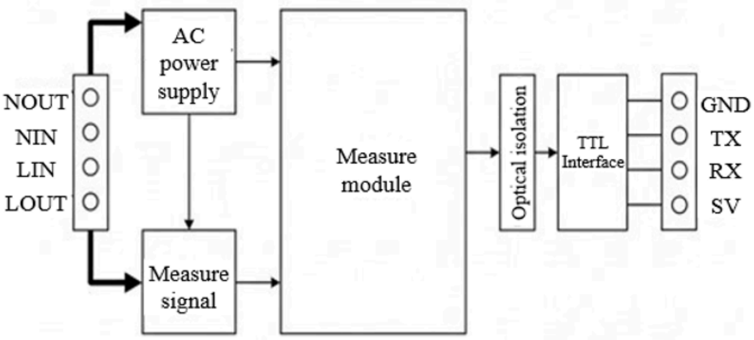


Figure 3. (a) and (b) Block diagram and wiring diagram of the PZEM004T meter; Function block diagram, Wiring diagram.

Some precautions that should be observed while using this meter include the following: use it only in indoor applications, ensure that connections are accurate and do not make faulty connections for wiring, and do not exceed the rated value of the load.

The PZEM004T meter is also known as a multifunction meter or an AC digital multifunction smart meter.

It can easily interface with Arduino and microcontrollers and has serial communication. This meter has automatic measurement and overload warning alarm functions. The measured quantities are transmitted to a 16 × 2 LCD using Arduino functions.

It has dimensions of 3.1 cm × 7.4 cm, and a 33 m bundled current transformer coil (Figure 4).

Light-Dependent Resistor

A LDR is also known as a photoresistor, photoconductor, and cadmium sulfide (CdS) cell. It works on the function of resistivity; hence, they are light-sensitive devices. LDR is made up of semiconductor material. LDR works on the principle of photoconductivity.

When light falls on the device, its resistance is decreased, and increased at night, which means at dark time. At night, when the dark resistance of LDR is very high and called dark resistance. Its high value is 1012 ohm. LDR is a non-linear device. LDRs are less sensitive than photodiodes and phototransistors.

Working Principle of LDR

LDR works on the principle of photoconductivity. When light falls on its surface, the material's conductivity reduces, and electrons in the valence band are excited to the conduction band of the device. These photons in the incident light must have energy greater than the band gap of the semiconductor material, then electrons from the valence band jump to the conduction band (Figure 5).

LDRs are classified as intrinsic photoresistors and extrinsic photoresistors. They have simple construction and are mostly used in street lighting and garden lighting. They are used in electrical and electronic projects. Some of their applications are streetlights, garden lights, smoke alarms, and light sensors.

TECHNOLOGIES USED

ESP8266 Wi-Fi Module

The ESP8266 Wi-Fi module is a technology-based device. It is developed by Espress if Systems. It is mostly used in IoT-based applications. It is used to send the data to a web server. It is a low-cost device that is available easily and easy to use (Figure 6).

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Figure 4. Current coil of PZEM004T meter.

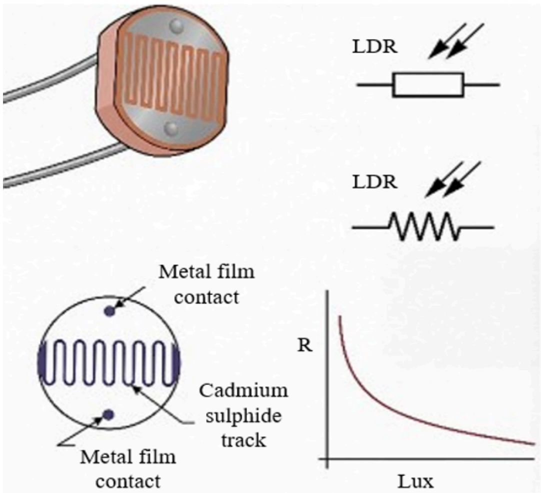

Figure 5. LDR symbol and basic structure.

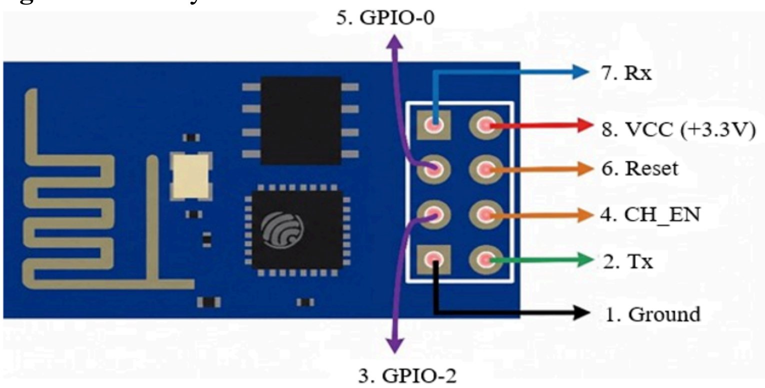

Figure 6. Basic structure of the ESP8266 Wi-Fi module.

ESP8266 consists of 8 pins as follows:
Pin 1. Tx
Pin 2. Rx
Pin 3. GPIO 0
Pin 4. CH_PD
Pin 5. GPIO 2
Pin 6. VCC
Pin 7. RESET
Pin 8. GND

Where, Tx and Rx are used for communication, GPIO pins are general-purpose I/O interface pins, and GND and VCC are used as power pins.

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It is a microchip with a full-stack TCP/IP and microcontroller capability. ESP8266-01 communicates with the Arduino with the help of Attention Commands. The baud rate is 115200. The operating voltage range of this Wi-Fi module is 3.0–3.6 V, and the average operating current is 80 mA. A specific program is used to interface the Wi-Fi module with the Arduino. It uses serial communication or a Universal Asynchronous Receiver/Transmitter interface (UART) interface for connectivity to the Arduino Uno. It hosts Wi-Fi networking functions from another application. The ESP8266 operates at 3.3 V only; its maximum voltage range is 3.6 V, and any voltage range beyond 3.7 V can damage the device. It is mostly used in IoT-based projects (Figure 7).

There are many Wi-Fi modules available in the market, so we must choose the device according to our requirements. It can upload data offline, so there is no need for the internet. The internet requires only viewing the data that is posted on the ThingSpeak server. For that purpose, the specific Service Set Identifier (SSID) and password should be written in the program (Figure 8).

ThingSpeak Server

ThingSpeak server is an IoT-based platform in which we can visualize and analyze live data in the cloud. Using ThingSpeak, we can send data privately and analyze and visualize it anytime, anywhere. It collects data from different fields by making different channels, and these channels we can see privately as well as publicly, both options are available there. ThingSpeak works with Matrix Laboratory (MATLAB), Arduino, ESP8266 Wi-Fi module, Beckhoff, Raspberry Pi, and others. In ThingSpeak, data is automatically updated when any operation is performed regarding its application. We can record any data values with the help of sensors by interfacing with a Wi-Fi module, and we can also download data sheets of those values, so pen paperwork is avoided. Real-time data collection, data updating, and data processing are some features of ThingSpeak. In ThingSpeak, the channel is the most important element, where you can view your data. Each channel has 8 fields for storing data, latitude, longitude, elevation, status, etc. options are available. ThingSpeak has an IoT platform with MATLAB analytics.

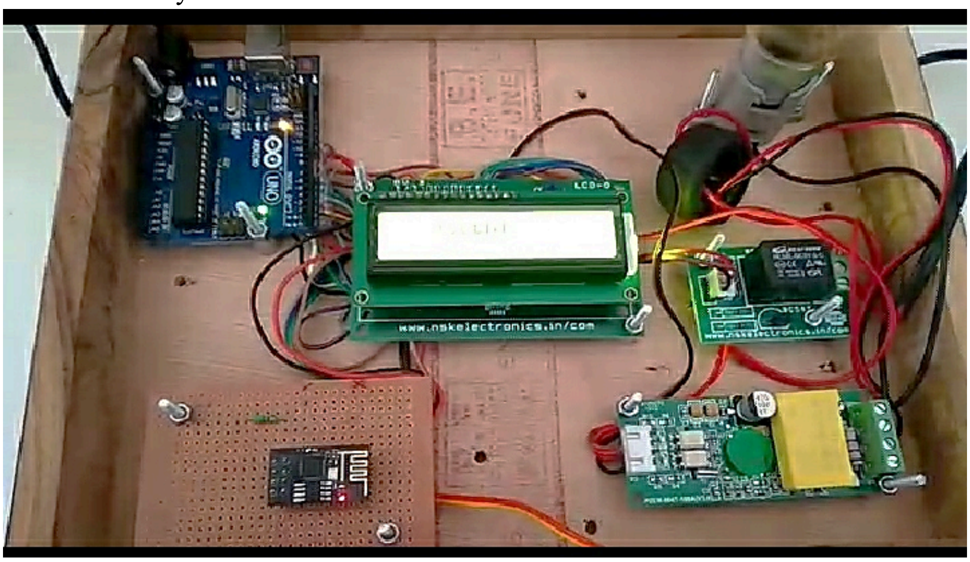

Figure 7. System kit.

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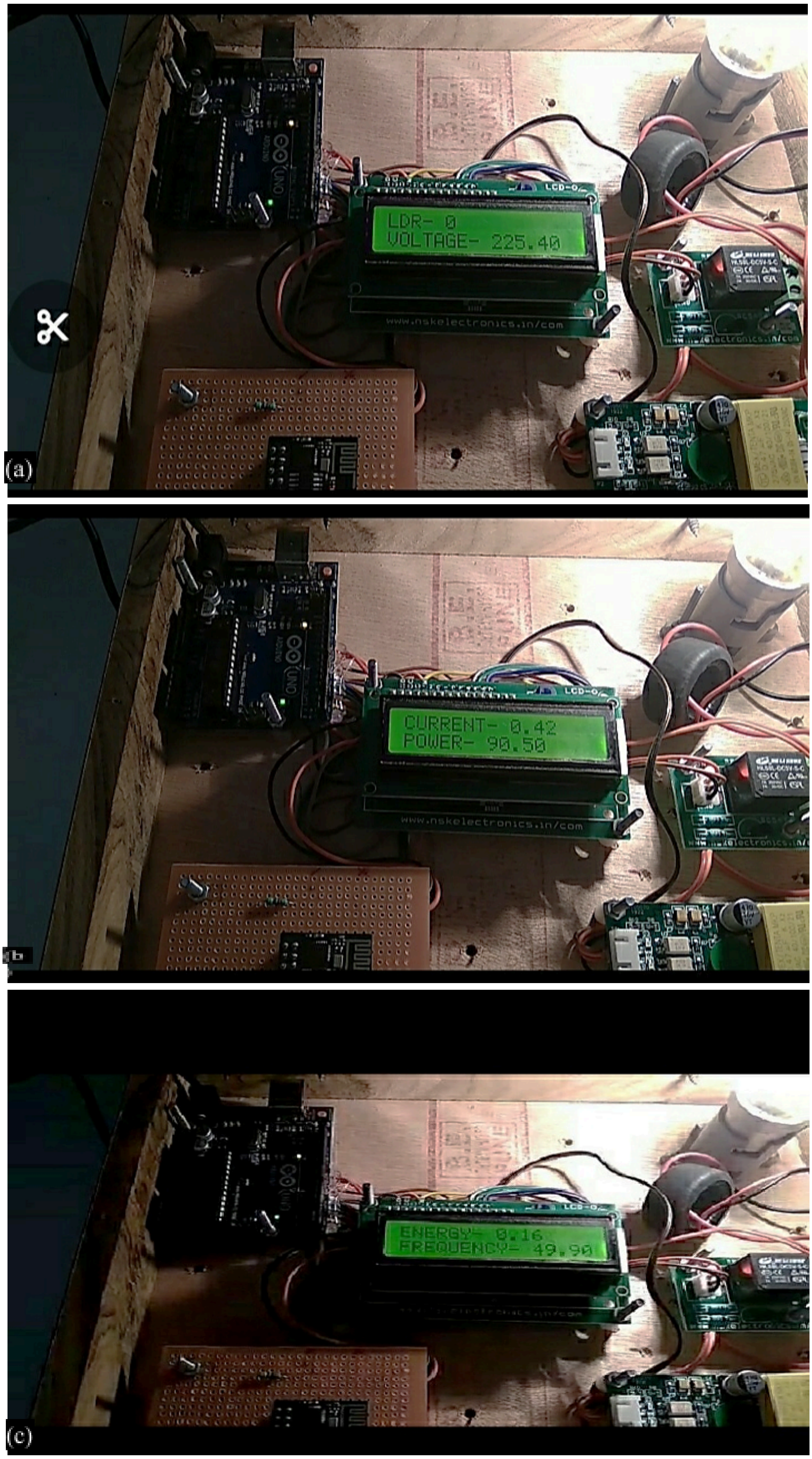

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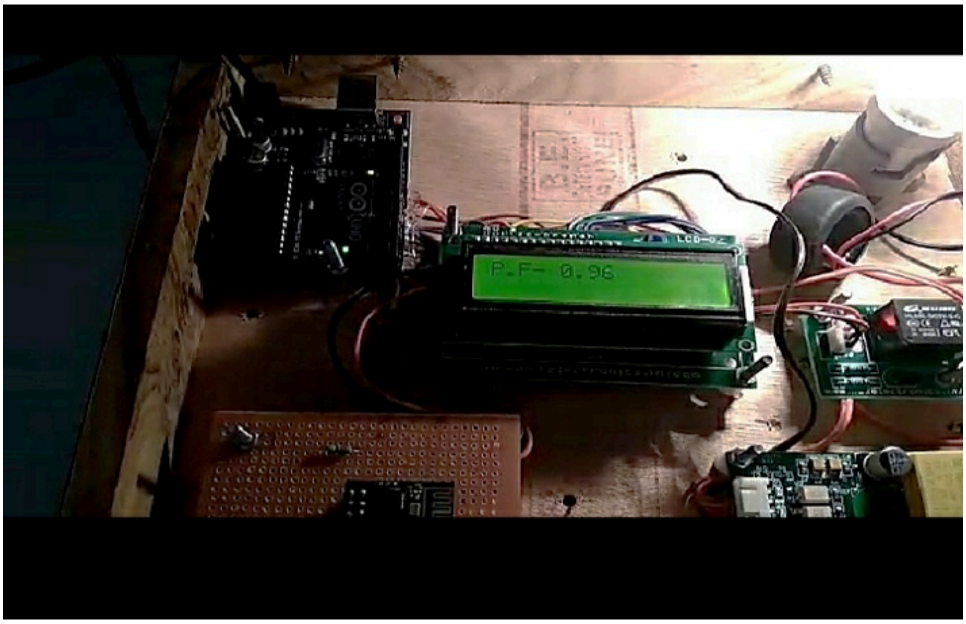

Figure 8. (a) to (d) IoT-based smart energy meter prototype displaying real-time voltage.

ThingSpeak also comprises time zone management, read/write API keys, and JavaScript-based charts, in which read/write API keys are used to read and write data. We can see stored data in the ThingSpeak server in different formats, like graphical, numerical, and time zone, and it also indicates location.

RESULTS

Results were obtained when the bulb was ON.

CONCLUSIONS

The system monitors and controls the power consumption of appliances automatically using an IoT platform through a wireless network. It protects the load from high voltages. The system is designed such that it consumes low power, has a low cost, and is portable in size. This system makes the entire process smart because it automatically displays all function values on a display board through an Arduino and on a ThingSpeak server. This project was also installed at the domestic level to identify electricity theft. This project avoids the calculation of electrical parameters and saves time and paperwork.

REFERENCES

1. Khan F, Siddiqui MAB, Rehman AU, Khan J., Asad MTS, Asad A. IoT based power monitoring system for smart grid applications. 2020 International Conference on Engineering and Emerging Technologies (ICEET), Lahore, Pakistan. 2020. p. 1–5. doi:10.1109/ICEET48479.2020.9048229.
2. Gopal M, Chandra Prakash T., Venkata Ramakrishna N, Yadav BP. IoT based solar power monitoring system. IOP Conf Ser Mater Sci Eng. 2020;981:032037. doi:10.1088/1757-899X/981/3/032037.
3. Krishna Rao C, Sahoo SK, Yanine FF. An IoT-based intelligent smart energy monitoring system for solar PV power generation. Energy Harvest Syst. 2024;11(1):20230015. doi:10.1515/ehs-2023-0015.
4. Nayyef IM, Husein AA. Design and implementation of IoT based smart power monitoring and management system using WSNS. Int J. Embed Syst Appl. 2018;8(4):1–16. doi:10.5121/ijesa.2018.8401.
5. Zhao L, Matsuo IB, Zhou Y, Lee WJ. Design of an industrial IoT-based monitoring system for power substations. IEEE Trans Ind Appl. 2019;55(6):5666–5674. doi:10.1109/TIA.2019.2940668.

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6. Rani DP, Suresh D, Kapula PR, Akram CHM, Hemalatha N, Soni PK. IoT based smart solar energy monitoring systems. Mater Today Proc. 2023;80(Pt 3):3540–3545. doi:10.1016/j.matpr.2021.07.293.
7. Mudaliar MD, Sivakumar N. IoT based real time energy monitoring system using Raspberry Pi. Internet Things. 2020;12:100292. doi:10.1016/j.iot.2020.100292.
8. Patil SM, Vijayalashmi M, Tapaskar R. IoT based solar energy monitoring system. 2017 International Conference on Energy, Communication, Data Analytics and Soft Computing (ICECDS), Chennai, India. 2017. p. 1574–1579. doi:10.1109/ICECDS.2017.8389711.
9. Ghosh S. Neuro-fuzzy-based IoT assisted power monitoring system for smart grid. IEEE Access. 2021;9:168587–168599. doi:10.1109/ACCESS.2021.3137812.
10. Nuhin MI, Shariar MA, Khan JM, Kongkon TN, Imam MH. Design of an IoT based power monitoring system model for a grid connected solar PV. Int J Adv Technol Eng Explor. 2022;9(92):923–940. doi:10.19101/IJATEE.2021.875084.
11. Khandel H, Pandey S, Reynolds D. IoT based power consumption monitoring and controlling system. Int Res J Eng Technol. 2018;5(7):2211–2218.
12. Kamble A, Mulani AO. Home automation using Google Assistant. Purakala. 2023;32(1):1071–1077.
13. Premananda BS, Pai SS, Shashank B, Bhat SS. Design and implementation of 8-bit Vedic multiplier. Int J Adv Res Electr Electron Instrum Eng. 2013;2(12):5877–5882.
14. Gadade B, Mulani AO, Harale AD. IoT based smart school bus and student monitoring system. Natl Campano. 2024;28(1):730–737.
15. Mulani DAO. A comprehensive survey on semi-automatic solar-powered pesticide sprayers for farming. J Energy Eng Thermodyn. 2024;42:21–28. doi:10.55529/jeet.42.21.28.
16. Salunkhe SS, Mulani AO. Solar mount design using high-density polyethylene. Natl Campano. 2024;28(1):1483–1493.
17. Mulani AO, Jadhav MM, Seth M. Painless machine learning approach to estimate blood glucose level with non-invasive devices. In: Kolhe ML, Karande KJ, Deshmukh SG, editors. Artificial Intelligence, Internet of Things (IoT) and Smart Materials for Energy Applications. Boca Raton: CRC Press; 2022. p. 83–100. doi:10.1201/9781003220176–6.
18. Pol RS, Mulani AO, Bhalerao MV. Cloud based memory efficient biometric attendance system using face recognition. Stoch Model Appl. 2021;25(2):403–417.

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