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IOT Based Energy Monitoring System

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Abstract: The importance of energy monitoring in the face of increasing electricity demand caused by population growth, urbanization, and industrialization. To get over the limitations of traditional energy monitoring and control methods, this research study proposes an IoT-based energy monitoring system solution utilizing Bluetooth. In order to enable users to actively manage and optimize their energy consumption, the proposed system seeks to deliver real-time energy statistics, user-friendly interfaces, and seamless interaction with a variety of devices and appliances. The system's architecture, features, and advantages in terms of effective energy management, and environmental sustainability are discussed. The usefulness of the suggested approach in enabling users to make knowledgeable decisions about energy use and realize large energy savings is demonstrated by experimental findings and case studies.

Keywords: IOT, Energy Monitoring, Sensors, Energy Consumption, Power consumption

I. INTRODUCTION

According to government statistics, India's power consumption increased by almost 9% year over year in February of this year, reaching 117.84 billion units. The highest supply in a day, or the peak power demand, increased to 209.66 gigawatt (GW) in February 2023 [1]. The inappropriate use of electrical energy in homes and businesses is leading to increased power costs and waste, and future energy shortages are predicted. Electricity power is one of the essential needs for humans, using it wisely is one of the critical responsibilities of humans. But many humans waste many watts of power in their homes, offices, etc. knowingly or without their knowledge. Internet access is becoming more widespread as technology advances more quickly. IOT is therefore rising to the top of the technology list. IOT's primary goal is to improve healthcare. Energy management systems are essential parts of energy conservation in the era of contemporary grids and are crucial in promoting the integration of renewable energy, which safeguards the environment [2]. By keeping an eye on numerous activities, such as energy management, in the home environment, we can develop clever solutions to a wide range of issues and significantly reduce our energy use by employing IOT.

The application of Internet of Things to electrical networks opens up opportunities for small-term, medium-term, and a long-term development processes as smart technology spreads from home appliances to large-scale industry. The findings demonstrate that IoT has real-world application capabilities that will result in technology that is mature and durable [3]. There have been various approaches for monitoring the energy usage in households and industries. The authors of [4] have presented an energy monitoring system that provides precise energy consumption values and computes energy usage for intervals of 1 msec. The suggested architecture is internet-capable and creates a distinctive IP address that enables the user to obtain data on the load's energy usage by utilizing the WIFI module that is built within the ESP8266. In [5] the authors examined ILF (Intelligent load forecasting) methods from a number of angles in their survey, outlining both their benefits and drawbacks. In order to emphasize the important scientific achievements, they first reviewed the ILF area, including its history and uses. A regular energy meter can become a smart energy meter by mounting an electronic meter automation device on it. With the use of customized web pages, smart Apps, and SMS notifications, the user may monitor the meter readings at any time utilizing this meter's Wi-Fi capability [6]. In [7] the authors have suggested that the SEM module, which gives customers and other end users control and surveillance capabilities, is a portion of the overall system. The authors of [8] have created a stable smart home model that can track residential building energy consumption, comfort levels, and safety. The data is transmitted by the model to more complex information and communication technology (ICT) platforms where it may be analyzed and aggregated to offer the user and community many kinds of feedback. The authors of [9] propagated a model which is used to estimate the household's energy usage and even provides a useful reading for the energy unit. As a result, it decreases energy waste and raises awareness among everyone. Even so, the manual intervention will be subtracted. In [10], the authors created a cost-effective Internet of Things (IoT) energy monitoring system that makes use of the Message Queuing Telemetry Transport protocol and Wi-Fi. The created system will offer accurate statistics of energy use and consumption trends.

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There are various reasons why an IoT-based energy monitoring system utilizing Bluetooth technology is necessary. These arguments demonstrate how a system like this can address the shortcomings of traditional energy monitoring techniques. By utilizing Bluetooth in an IoT-based energy monitoring system, users can gain from Bluetooth technology's seamless integration, cost-effectiveness, real-time monitoring capabilities, user-friendly interfaces, and interoperability by. It is an appealing option for creating effective and available energy monitoring solutions because of these benefits.

An internet of things-based energy monitoring system is the suggested solution, allowing for immediate tracking and oversight of consumption of energy in homes and commercial facilities. The system will utilize sensors to gather data on the energy use of each electronic device and the outputs are received and transmitted with the help of the Bluetooth for end users. To collect information about the current and voltage usage of each device, the methodology incorporates an Arduino Uno board in each room where each load is connected to the voltage divider and current sensor. The processed data is then communicated over Bluetooth to the esp32 board, which displays it on an LCD screen.

There are six sections in the paper's flow. The significance of electrical energy, the usage of IoT in contemporary technology, earlier study and methodology, and a concept of the suggested solution were all presented in Section I. The system architecture and methods of the suggested solution are explained in Section II. We covered the hardware components utilized in section III to create the model, and the software components are explained in section IV. Experimental results of the proposed solution are presented in Section V, and the work is wrapped up in the Section VI.

II. SYSTEM ARCHITECTURE

A voltage divider and current sensor coupled to the appropriate relay module, respectively, allow the proposed system to read the current and voltage data from each device. This data is read and processed using an Arduino Uno device. The ESP32 board displays all the properties using the LCD display unit after receiving the processed data over Bluetooth. The transmitter model and the receiver model are the two different variations of this gadget [11].

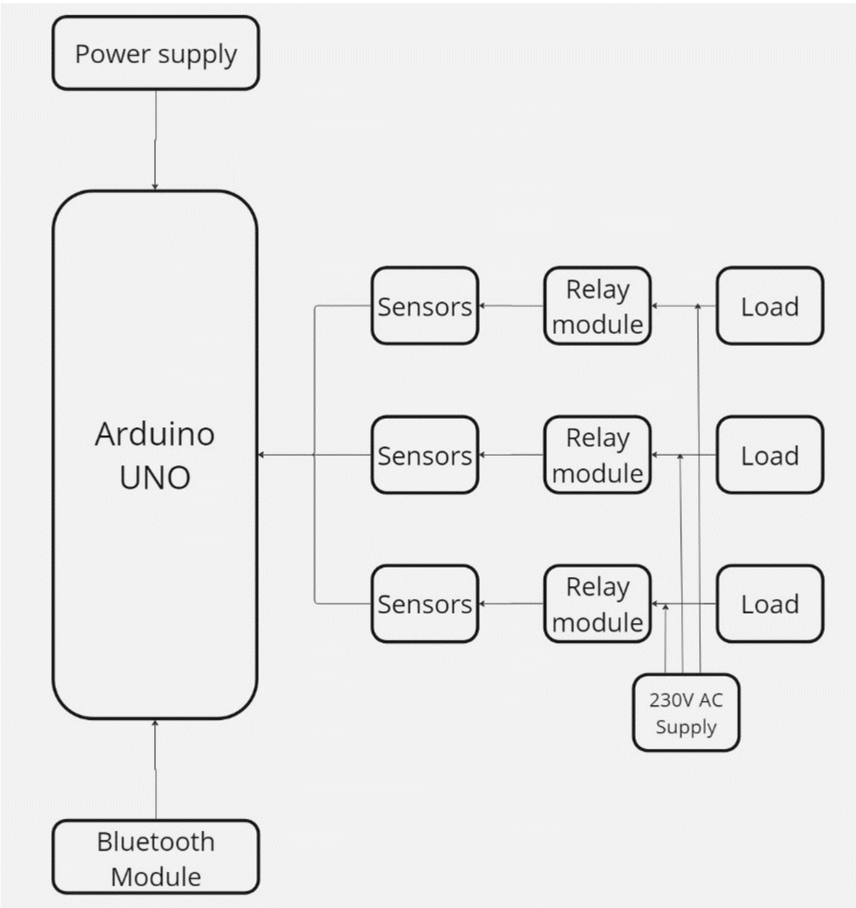

Fig. 1 Transmitter Section

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Fig. 1 shows the transmitter model for the system. This transmitter component is composed of the Arduino Uno board, current sensors, relay module, Bluetooth module, and relay module. On the Arduino UNO board, current sensors are linked to the analogue pins. The sensor data is read and processed by the Arduino UNO. The processed data consists of the current, voltage, and power data of that device. The Bluetooth module transmits this processed data to the receiver model. Fig. 2. Represents the receiver model. The receiver component is composed of the ESP32 board, a 16 x 2 LCD unit, and a Bluetooth module. The ESP32 board is attached to a 16 x 2 LCD display device. The 16 x 2 LCD display unit shows all the processed data that was received via Bluetooth. The transmitter model is installed in every room of a home to keep track of all the electronics and appliances there. To display all of the data from every device in every area, just one receiver model is needed.

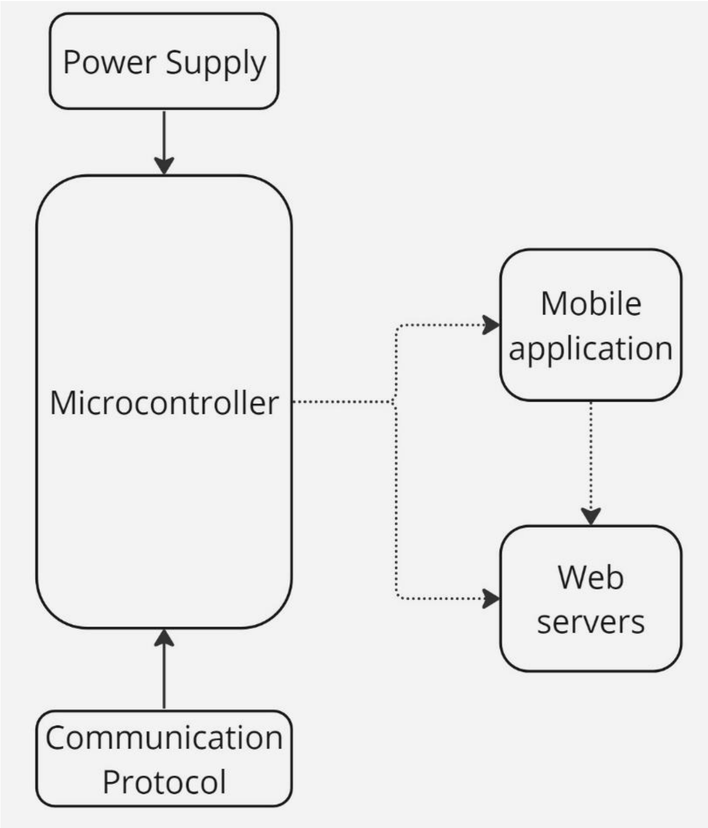

Fig. 2 Receiver Section

Current, voltage, and power are the variables that are calculated and shown on the LCD display unit. The first parameter to be read with the current sensor ACS712 is current (I). It is capable of reading the linked load's current consumption with accuracy.

Current is measured in Ampere and is denoted by ‘A’. The formula for calculating the load's current is

$$I = (SensorValue * 0.5) / 1024.0 / 0.1$$

here,

SensorValue represents the analogue data from the sensor read by the Arduino UNO board. 0.5V is the maximum voltage that can be read by the Arduino UNO board. 1023.0 is the maximum value that can be returned by the analogRead() function of the Arduino IDE platform. We assume that the sensitivity of the ACS712 current sensor is 0.1V/A.

The second parameter to be calculated is the voltage (V). Voltage is measured in volts and is denoted by ‘V’. Voltage of the device is calculated as

$$V = I * R$$

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here,

I is the load's current, while R is the load's resistance.

The last parameter to be measured is the power (P) consumed by each load. Power is measured in Watts and is denoted by 'W'. Power of the device is calculated as,

$$P = V * I$$

here,

V represents the load's voltage, and I represents the load's Current.

III. HARDWARE ASPECTS

The Arduino Uno board, the HC-42 Bluetooth module, the Relay module, the ACS712 current sensor, the ESP32 board, and the 16 x 2 LCD unit are the primary hardware components needed to make the proposed model.

A. Arduino UNO board

The central processor of the Arduino UNO microcontroller board is the ATmega328P. it has 6 analogue pins, a 16 MHz ceramic resonator, 14 digital i/o pins, 6 of which can be used as outputs for PWM, a reset button, a USB port and a power connector. Three different communication protocols are supported by it: UART, I2C, and SPI. It runs between a nominal input voltage of 7 to 12 volts and an I/O voltage of 5 volts. It functions on Linux, Windows, and Mac. It is used by educators and students to construct inexpensive scientific apparatuses, demonstrate chemistry and physics concepts, and begin learning robotics and programming. Interactive prototypes are created by architects and designers, and artists and musicians utilise them for installations and to test out new musical instruments, Fig 3.

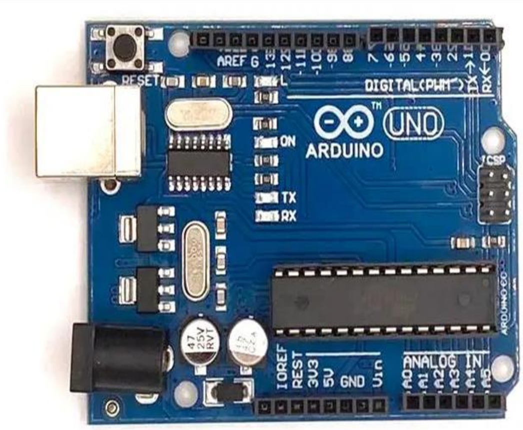

Fig. 3 Arduino UNO

B. HC-42 Bluetooth module

The HC-42 6 pin Bluetooth connectivity 5.0BLE a serial Port Module is the latest type of digital communication chip developed using the Bluetooth BLE V5.0 Bluetooth protocol. The modulation technique is GFSK, and the operating frequency band is 2.4GHz ISM. At 1.8 to 3.6V, it operates. The hc-42's communication interface is UART. 1Mbps / 2Mbps is the air rate. 2.4Ghz frequency band, Fig. 4.

Fig. 4 HC-42 Blueetooth Module

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C. Relay module

Electrical switches known as relays can control higher voltage systems and machinery. Its operating voltage spans 3.3 to 5 volts, *Fig. 5.*

Fig. 5 Relay Module

D. ACS712 current sensor

The ACS712 current sensor is a fully integrated, hall effect-based linear current sensor which has a current conductor of low-resistance and a RMS voltage isolation of 2.1kV. The range of its bandwidth equals to 80kHz. Between 66-185 mV/A is the output sensitivity range., Fig. 6.

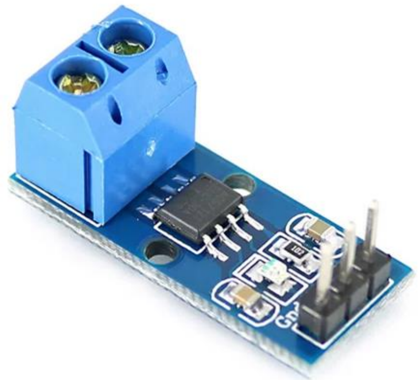

Fig. 6 ACS712 Current Sensor

E. ESP32 BOARD

The Esp32 DevKit v1 is built on the Microcontroller Tensilica 32-bit Single-/Dual-core CPU Xtensa LX6. On this board, 2.4 GHz, 40nm low power Wi-Fi and Bluetooth chips from TSMC are used. It operates on a voltage of 3.3V. It contains 25 Digital I/O Pins (DIO), 2 Analog Output Pins (DAC), and 6 Analogue Input Pins (ADC). It supports three different communication protocols: UART, I2C, and SPI. It runs on a 240 MHz clock speed, *Fig. 7.*

Fig. 7 ESP32 Board

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F. 16 x 2 LCD unit

The 16-pin LCD 16 x 2 includes 8 data pins, 3 control pins, and 5 supply and backlight pins in addition to the remaining 5 pins. This LCD's operating range is from 4.7 to 5.3 volts. With no backlight, the current usage is 1 mA, Fig. 8.

Fig. 8 16 x 2 LCD Unit

IV. SOFTWARE ASPECTS.

The Arduino IDE platform is used in this proposed solution for programming the Arduino UNO Board and the ESP32 Board.

A. Arduino IDE

To writing and uploading programs for Arduino-compatible devices like the ESP8266, the Arduino IDE is a software that is freely available. C and C++ are both supported by the Arduino ecosystem [4]. This supports both Arduino UNO and ESP32 boards.

V. EXPERIMENTAL RESULTS

A prototype of the system includes the necessary hardware and software. The transmitter section and receiver section make up the prototype. The load, an LED bulb, was used and attached at the transmitter end as shown in Fig.9.

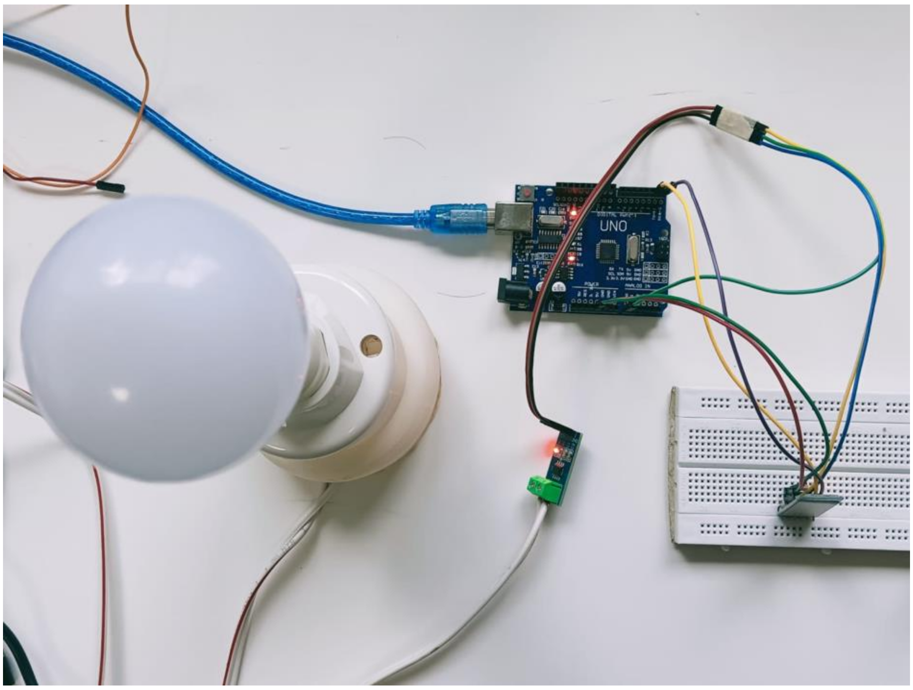

Fig. 9 Transmitter Section

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The bulb illuminates and the current sensor begins to measure current when the AC supply is turned on. As indicated in Fig. 10, the data is transferred and shown in the LCD unit at the receiving end.

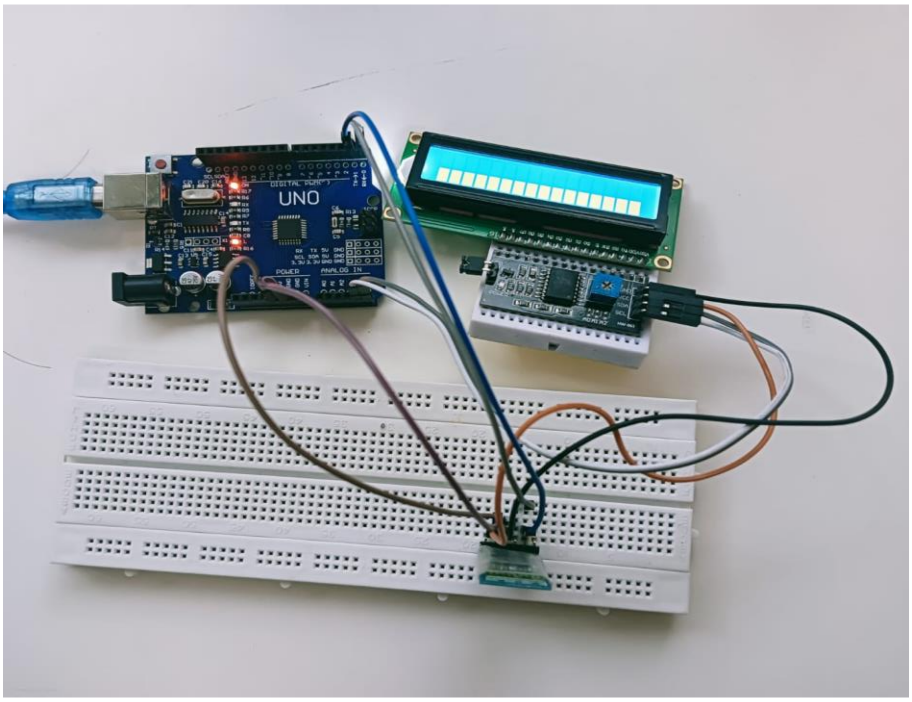

Fig. 10 Receiver Section

As seen in Fig. 11, the 16 x 2 LCD display measures and displays the LED bulb's specifications. It stands in for the model's receiver portion. On the 16 x 2 LCD unit, all the parameters—current, voltage, and power—are shown. According to the display unit, the LED bulb's voltage reading is 110V, its current reading is 826mA, and its power reading is 90.86W. This provided precise current, voltage and power values that enable one to precisely monitor each appliance in a home and determine whether a fault exists when there is abnormal behavior in the energy consumption pattern of the respective device.

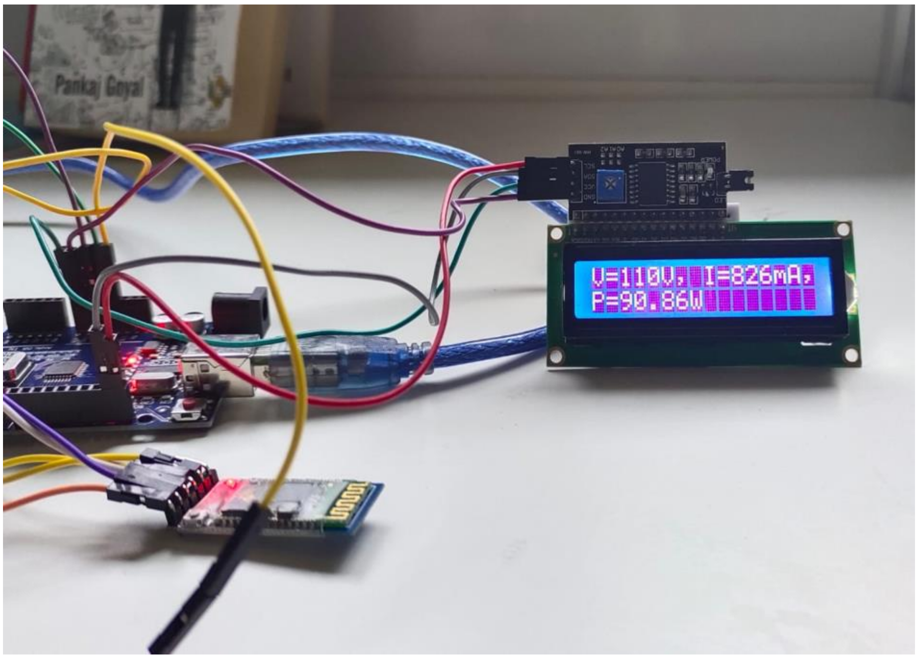

Fig. 11 LCD Output

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VI. CONCLUSION

An IoT-based energy monitoring system has been presented in this study. This system is intended to measure and track the current, voltage, and power consumption of specific devices, and it computes the energy consumption for each interval of 1 microsecond. Current and voltage readings from the device are taken and Bluetooth-transmitted to the main controller, which is built on the ESP32 platform. The information is then shown on an LCD display device. Consequently, a system that is developed can save a lot of energy.

VII. FUTURE SCOPE

Numerous future innovations and improvements in this area can be anticipated as technology develops. Some of the future innovations that can be implemented to this system are.

- Real time monitoring and controlling of each device through mobile application and web servers [12].
- Future prediction of energy usage by each device by analysing past records.
- Generating AI recommendations to reduce energy consumption and detect any faults in the load [13].
- Implementing home automation technologies

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