

Arduino-based smart energy monitoring and control system

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Abstract - In light of the increasing demand for energy and its efficient utilization, the need has arisen to develop energy management systems. This project seeks to propose an Arduino based Smart Energy Monitoring and Control System aimed at improving the measurement process, prepayment and controlling the electrical loads.

It uses an Arduino microcontroller to enable connectivity among different devices, whereby sensors measure the voltages and current and thus the consumed energy, which is done by computing the number of pulses representing one unit of energy. The method used here is prepayment in which the user pays his/her account balance and then switches off loads when it reaches zero.

Through the Bluetooth module, the consumer can turn the loads on or off remotely and top-up the account via a mobile application. Moreover, ESP8266, which works as a NodeMCU, will upload all the collected information to the thing speak website. On the other hand, the GSM module will provide the alerts of low balances.

Keywords: Smart Energy Monitoring, Prepaid Billing System, Arduino Microcontroller, Internet of Things (IoT), Energy Metering, Wireless Load Control, NodeMCU (ESP8266), Bluetooth Communication, GSM Alerts, Real-Time Monitoring.

1. INTRODUCTION

Nowadays, there is a necessity not only for energy but also for energy-efficient consumption.

The conventional methods of energy management involve the use of regular meters that can perform cumulative energy calculations and follow the post-paid system of billing. This system lacks the potential of performing real-time energy monitoring and control; therefore, the results become the wastage of energy resources and late bills.

Thanks to such innovations as embedded systems and Internet of Things (IoT), a new approach to energy monitoring has appeared. In addition to the real-time control over energy usage, it allows monitoring such parameters as voltage and current. Another innovation in energy monitoring is related to making pre-paid payments based on usage.

It is with this intention that the Arduino Based Smart Energy Monitoring and Control System was designed to integrate these technologies. The system incorporates the use of sensors, processors, and

communication mechanisms, enabling the user to track his/her energy consumption levels, pay in advance for electricity, and regulate loads according to the demand levels. It is for this reason that the Arduino Based Smart Energy Monitoring and Control System is both efficient, cost-effective, and convenient.

1.1. PROPOSED SYSTEM AND METHODOLOGY

Description-The proposed Smart Energy Monitoring and Control System can be seen as an effective and automated approach to analyzing the consumption of electrical energy in real time, implementing the concept of pre-payments for bills, and managing loads.

Firstly, the described system can be considered modular, which means that it is flexible, expandable, and can be applied not only at the household level but also in industries.

There are several components of the system, such as Arduino microcontroller, voltage/current sensor, energy meter with LDR pulse generator, relay board, LCD display, Bluetooth module, NodeMCU (ESP8266), and GSM module. In addition, Arduino microcontroller plays a critical role in the system, making calculations based on the data from different sensors.

In particular, the sensing unit consists of a voltage and current detector, whereas the energy meter generates pulses according to energy consumption. Then, the number of pulses is counted by the LDR sensor, and the quantity of consumed energy is calculated accordingly.

The system that uses prepaid billing is put in place whereby pre-payment is made based on the balance controlled by the consumer himself. This balance is subtracted depending on the quantity of energy being consumed. Once the balance is depleted to zero, then the relay switches off the module.

For the purpose of making the system much more efficient, it utilizes wireless communication techniques. It is possible to use wireless communication since there will be a Bluetooth module that allows for easy management of the gadget as well as balancing it. Additionally, the NodeMCU module ensures that real time information gets uploaded to the Internet of Things server. Lastly, the GSM module ensures that balance as well as updates of the balance can get conveyed.

Lastly, the LCD screen helps ensure that information on voltage, total consumption, units of energy consumed, and total remaining balance are displayed. Therefore, it would be reasonable to argue that the system operates efficiently to fulfill its intended functions.

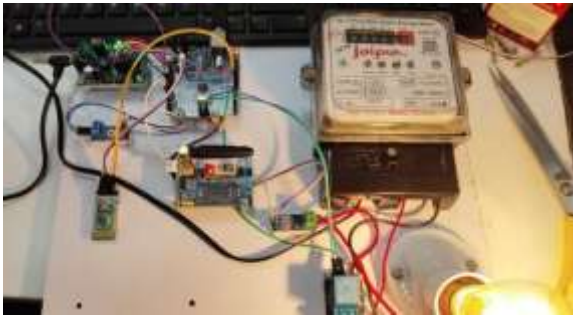


Figure1:

2. LITERATURE SURVEY

Recent advancements in technology have seen energy management systems become popular because of the increased consumption of electricity and the importance of efficient resource management. Traditional energy metering systems only care about measuring the overall energy consumption and generating the bills to be paid for later.

Some researchers have come up with innovative In another study, the author explained how energy monitoring systems can be improved through the adoption of smart grid technology. The author highlighted how energy management systems can be improved through communication technology incorporated into the same system.

Another research paper explored the idea of implementing IoT technology in energy management systems to monitor energy consumption. The paper proved that integrating IoT into energy management systems can increase customer knowledge about their electricity usage.

Likewise, in yet another study, attention was paid to developing an electronic payment meter system based on the use of GSM technology. This study found that provisions had been made regarding checking balances and switching off electricity supplies in case of zero balance, as well as alerting consumers through mobile communications.

Additionally, energy management systems with capabilities for remote device control and real-time monitoring were available. In this regard, the feature of remote device control enabled consumers to remotely switch off devices using their mobile apps.

ways to solve the problem, which involves incorporating embedded systems and wireless communication technology to improve energy monitoring systems. It will help increase efficiency and automate the process.

Furthermore, another research paper discussed energy management systems based on the application of IoT and Arduino. The researchers concluded that effective energy management systems utilizing IoT could be designed using Arduino. Nonetheless, there are flaws with the existing designs, which include the lack of pre-payment billing system

design, the lack of load control mechanisms, inefficiencies in remote monitoring and controlling systems, and others. Moreover, some existing designs depend solely on one form of communication, making them less efficient in other places. Conversely, this proposed IoT-based system shall be enhanced using Arduino, IoT, Bluetooth, as well as GSM technology, hence improving its efficiencies in remotely controlling electrical devices.

3. HARDWARE USED

A) Arduino UNO

The primary microcontroller that is used in this system and functions as the CPU is Arduino UNO. The Arduino UNO microcontroller operates on the basis of ATmega328P and performs various functions, including reading data from sensors, analyzing it, and controlling the entire working of the system. This device provides users with 14 digital input/output ports, out of which 6 supports PWM function and 6 analog input ports. The operating voltage of Arduino UNO is 5V and it runs on a 5V power source using either a USB interface or any external power source within the range of 7V to 12V. The clock speed of Arduino UNO is 16MHz, enabling it to process data efficiently. The primary task performed by Arduino UNO in this system is to read the inputs generated by sensors, analyze energy usage data, and control relay module for load switching.



figure2.Arduinouno

B) voltage sensor

It is worth noting that this particular module will have a significant role to play in detecting the AC voltage of the input sources before the transmission of the analog signal for processing by the microcontroller of the Arduino board. The process of sensing voltage involves the application of voltage dividers because they are very essential in reducing the high voltage into low analog signals which the pin of the Arduino board will detect.



Figure3.voltage sensor

In this respect, the voltage sensors will be critical in ensuring the detection of various voltage levels and any over and under voltages in order to optimize the operations of the electronic components. The analog voltages produced by the voltage sensors will be sent to the microcontroller of the Arduino board where the voltages will be calculated depending on some calibrations. The voltage levels calculated will then be displayed on the LCD screen. They will also be communicated to the IoT server through NodeMCU for computing the level of energy.

C) currentSensor

The The current sensor ACS712 is used in the procedure of measuring the current in the electric load used in the system. The principle of functioning of this type of current sensor is connected with the Hall effect since the current sensor .

current running through the load and calculates the output voltage depending on the magnetic field value. Besides, this type of current sensor makes it possible to ensure the isolation between measuring circuit and loading circuit. Thus, this device allows measuring both AC and DC currents with ranges of 5A, 20A, and 30A. The output voltage of this type of current sensor is within the range from 0V to 5V. Moreover, the current is measured with the help of the ACS712 for alternating and direct currents of 5V.

SAnalog voltage output is then transferred to the Arduino board to calculate the current. Then, calculated current values are summed up with the voltage values to obtain information about the power and energy consumption in the system. Finally, obtained current data is transmitted to the LCD display and IoT platform via NodeMCU. i

Figure 4. current Sensor



D) Energy meter

The energy meter is the meter which offers the chance to calculate the consumption of electrical energy in units of kWh. The energy meter is the electronic meter, which allows more precise calculations in contrast with the mechanical meters. It is possible to employ smart meters due to the recent advances.

Figure5.energy meter



operation principal:

there is a chance to calculate the consumed energy by applying the formula which looks like $P = V * I$. It is required to apply the process of integration through the use of electronics and digital circuits. It should be emphasized that the number of pulses from the energy meter depends on the consumed energy. The number of pulses is calculated using LDR as LED glows within the energy meter. The pulses are calculated using Arduino microcontroller which translates pulses in units of kWh. Information can be displayed using LCD display and transferred by IoT networks.

F) LDRSensor

The Light Dependent Resistor or the LDR sensor is the sensor that is used for detecting the impulses made by the energy meter. This sensor makes use of the photoconductive property where the resistance value changes depending upon whether there is light falling on it or not.

as soon as the light emitting diode of the energy meter blinks, LDR sends signals which are then counted by Arduino.

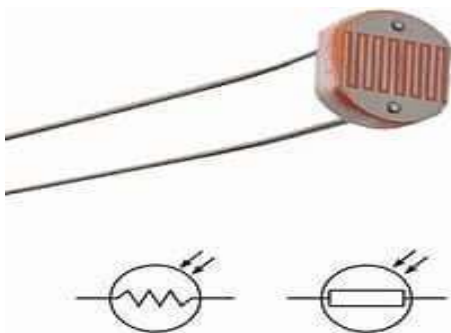


Figure7.LDRSensor

G) LCD Display

The LCD display is used for displaying data in real time to the user. This display is 16×2, which means that it can show 16 characters per row. The data shown in this display includes voltage, current, units of energy consumed, available balance, and status of the load.

Figure10.LCD display



E) Relay module:

The The relay module serves as an automatic switch to control the electric load in the system. The relay module enables the Arduino board to automatically switch ON and OFF the attached appliances in accordance with the system's requirements.

In the current project, the relay module acts to switch off the load once the prepaid amount equals zero and switches it ON after recharging the balance.



Figure9.relay Display

h.) NODE MCU:

The NodeMCU is an IoT module, which operates using the ESP8266 Wi-Fi chipset. This component serves to link the entire system to the Internet for uploading data in real time into an IoT platform like ThingSpeak. The device gathers the data from the Arduino board, sending it over Wi-Fi. The NodeMCU adds more sophistication to the system because it allows remote analysis of the collected data.

Figure 11.NODE MCU



i.) Bluetooth Module (HC-05):

The Bluetooth Module (HC-05) is utilized in the process to facilitate wireless communication between the system and the mobile phone within a short distance range. It helps the end users control electrical appliances and update the pre-paid balance by using a mobile phone app.

The module is connected to the Arduino and uses serial (UART) communication with it. The commands issued from the mobile phone reach the module which further forwards them to the Arduino for carrying out necessary actions like turning ON/OFF of the loads or balancing the account.



Figure 12. bluetooth

j.) GSM Module:

The GSM module is utilized to send alerts to the consumer. Alert messages are sent when there is a problem such as an issue with the battery, status of the system, or any other anomaly.

Figure: 13. GSM module



k.) Power Supply :

The power supply provides all the components in the circuit with the necessary voltage. The power supply used in this experiment is an adjustable one that produces 12 volts, which can be varied according to the voltage needed for the module.

It is crucial to have consistency in the power supply.



Figure 14. power supply

4. SoftwareUsed

A) ArduinoIDE Software

The role of the Arduino IDE in the operation of this system is of utmost importance since it serves as the platform where the coding and upload of the program to the microcontroller takes place. This platform is highly efficient as it helps make the coding process easy and straightforward, including for beginners, in the form of a program in the C/C++ programming language needed for this particular project. The code created by this process will enable the execution of various functions such as data gathering, processing, and energy consumption calculations.

The next step after coding is the compilation of the program using the Arduino IDE, which serves the purpose of detecting and correcting errors within the program and translating it into a format that the microcontroller can understand. Once this step is completed, the code is then uploaded to the Arduino UNO through the USB port. The microcontroller then executes the program repeatedly and controls the relay module based on the gathered data and processed informat.

Embedded C : language is used for writing codes for operating an Arduino microcontroller. This language is specifically designed for embedding into the microcontroller to enable communication between the software and hardware. Through the Embedded C language, all logical operations have been

Tack other actions. performed in the program. This language allows the program to collect information from different sensors, such as voltage and current sensors, manipulate information,

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```
int cnt;
High_peak = 0;
Low_peak = 1024;

for (cnt = 0; cnt < SAMPLES; cnt++)
{
float ACS_Value = analogRead(currentSensor);

if (ACS_Value > High_peak)
High_peak = ACS_Value;

if (ACS_Value < Low_peak)
Low_peak = ACS_Value;
}

Amps_Peak_Peak = High_peak - Low_peak;
}

// ***** SETUP *****
void setup() {
Serial.begin(9600);
bluetooth.begin(9600);

lcd.begin(16, 2);
lcd.print("Energy Monitor");
delay(2000);
lcd.clear();
}
```

c) ThingSpeak (IoT Platform) : ThingSpeak acts as an IoT platform that is used to collect data related to the system online. NodeMCU transfers data, which include voltage, current, and energy consumed, to ThingSpeak through the internet using Wi-Fi. Data collected will be stored, and graphs and charts showing the data will be generated. With this, the user can monitor the electricity consumption.

1. . FutureScope

Future improvements that can be made include incorporation of a mobile application to make the operation easy. Internet connectivity should also be improved to facilitate access to any kind of information.

Better quality sensors can be incorporated for enhanced accuracy. Incorporation of solar energy would reduce electrical consumption. Certain security aspects could also be introduced to enhance safety. These improvements would make the system perform more effectively.

```
int cnt;
High_peak = 0;
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}

// ***** SETUP *****
void setup() {
Serial.begin(9600);
bluetooth.begin(9600);

lcd.begin(16, 2);
lcd.print("Energy Monitor");
delay(2000);
lcd.clear();
}

pinMode(relayPin, OUTPUT);
pinMode(currentSensor, INPUT);

digitalWrite(relayPin, HIGH);
}

// ***** LOOP *****
void loop() {

// ***** SYSTEM LOCK *****
if (overloadTriggered) {
digitalWrite(relayPin, LOW);

lcd.setCursor(0, 0);
lcd.print("!! OVERLOAD !!");
lcd.setCursor(0, 1);
lcd.print("RESET REQUIRED");

Serial.println("SYSTEM LOCKED - MANUAL RESET REQUIRED");
delay(1000);
return;
}

// ***** BLUETOOTH *****
if (bluetooth.available()) {
char command = bluetooth.read();

if (command == '1') digitalWrite(relayPin, HIGH);
if (command == '0') digitalWrite(relayPin, LOW);
}

// ***** NEW ACS712 RMS CURRENT METHOD *****
read_Amps();
Amps_RMS = Amps_Peak_Peak * 0.3536 * 0.01;
double currentValue = Amps_RMS;

// ***** VOLTAGE *****
int adcVoltage = analogRead(voltagePin);
double voltageValue = (adcVoltage / 1024.0) * 25.0;

// ***** LDR UNIT COUNT *****
int ldrValue = analogRead(ldrPin);
int currentLdrState = (ldrValue > ldrThreshold) ? 1 : 0;

if (currentLdrState == 1 && lastLdrState == 0)
unitCount++;
}
```

2. CONCLUSION

To conclude, the designing and implementation of the proposed Smart Energy Monitoring and Control System have been done successfully. The proposed system efficiently integrates the ideas of embedded systems and Internet of Things (IoT) to provide real time monitoring, prepayment billing and smart load control. Sensors such as voltage, current and energy meters are used in the system to monitor the usage of electricity. The major controlling device used is Arduino UNO that functions continuously to calculate energy usage. Using the prepayment principle, the system automatically deducts the balance according to the units used and disconnects the loads when there is no balance left. Apart from its basic functions, this system provides advanced functions like wireless load control and remote monitoring using the communication devices like Bluetooth, NodeMCU and GSM. Besides providing wireless functionality due to IoT, the proposed system uses LCD screen to show relevant data to the user. The proposed system is affordable, durable and user-friendly. Automation has been incorporated in the system making the process energy efficient.

3. REFERENCES

- [1] V. C. Gungor and F. C. Lambert, "A survey on communication networks for electric system automation," *Computer Networks*, vol. 50, no. 7, pp. 877–897, May 2006.
- [2] S. N. Patel and A. Jain, "Design and Implementation of Smart Energy Meter for IoT Applications," *International Journal of Engineering Research & Technology (IJERT)*, vol. 6, no. 5, pp. 1–5, 2017.
- [3] K. Muralidharan and S. Rajasekaran, "GSM Based Prepaid Energy Meter with Remote Monitoring," *International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering*, vol. 4, no. 3, pp. 1200–1205, 2015.
- [4] A. Kumar and P. Singh, "IoT Based Energy Monitoring and Control System," *International Journal of Innovative Research in Science, Engineering and Technology*, vol. 7, no. 4, pp. 3500–3506, 2018.
- [5] R. Singh and S. Verma, "Development of Arduino Based Smart Electricity Meter," *International Journal of Engineering Science and Computing*, vol. 9, no. 6, pp. 23000–23004, 2019.
- [6] A. Zanella, N. Bui, A. Castellani, L. Vangelista, and M. Zorzi, "Internet of Things for Smart Cities," *IEEE Internet of Things Journal*, vol. 1, no. 1, pp. 22–32, Feb. 2014.

- [7] H. Karl and A. Willig, *Protocols and Architectures for Wireless Sensor Networks*. Wiley, 2005.