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# IoT Based Smart Control of Load for Demand Side Management

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**ABSTRACT-** One of the most significant gifts that science has bestowed upon humanity is electricity. It has also assimilated into contemporary life, and it is impossible to imagine existence without it. In our daily lives, electricity serves a variety of purposes. Based on World Bank report, the quantity of lost earnings due to electrical outages is projected at 5.47%. Especially in India, these losses are even more. Energy meter in India doesn't provide two-way communication. However, domestic consumers and farmers cannot control their loads remotely. Another challenge in today's system is electricity consumers are unaware of their electricity consumption patterns and tariff accounting process. Every time a consumer cannot go outside of the house and check their reading in energy meter. To overcome these challenges, IoT technology has been used. IoT is a new technology that connects users to physical devices. The proposed work uses ESP32 based hardware circuits to control the 220V AC supply power outlet. The main aim of this paper is to develop a sophisticated system that allow remote control of load, real-time monitoring, creating awareness in customers and ultimately to save energy.

**Keywords:** Internet of Things (IoT), Sensors, Tariff, ESP32.

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## 1. INTRODUCTION

More than USD 1.6 trillion was invested in energy supply in 2013, according to the IEA (The International Energy Agency) 2014 fact book. In a similar vein, 130 billion USD were spent in an effort to increase energy efficiency. It is anticipated that annual investment would rise to over USD 2 trillion by 2035, representing an increase in global investment of USD 48 trillion from 2014 to 2035, of which USD 40 trillion will go toward energy supply and the remaining USD 2 trillion toward energy efficiency [1-3]. Based on U.S. Department of Energy's National Renewable Energy Laboratory (NREL), the electrical system energy loss is 46% for residential areas, and 52.1% for commercial entities, mostly from conversion losses [4, 5].

By ever-growing technologies and ever ending needs, consumption of electricity is also increasing day by day. Even though most of the process in our system is not automated like users cannot control their load remotely. To save time and energy, the system has to allow remote control of the load. There is no interactive system between consumer and electricity provider like consumers are unaware of their electricity consumption patterns. If a consumer knows about their consumption patterns, they can try to reduce their electricity consumption. In some countries, tariff accounting places according to demand patterns (Such as at high demand, high prices are allowed, and vice versa). So, the system has to allow real-time monitoring of consumption. Thus, it provides two-way communication between electricity consumers and suppliers.

To achieve this objective, the latest technology IoT [6] is used in this paper. In this work, the home appliances are connected with cloud servers via IoT devices. Remote control of load is achieved by using IoT with the help of a mobile application. It sends electrical parameter information such as voltage supplied to load, current consumed by the load, power drawn, energy consumed and tariff analysis to the cloud [7]. It is a consumer-friendly system, in which consumer can control their load anywhere through his/her mobile app. In the mobile application itself, the electrical parameter information is also available and graphical analysis of energy consumed and tariff.

Numerous researchers used a computerized energy meter with a power line carrier (PLC) [8, 9]. The authority received the bills and consumed units via PLC (power line carrier), a kind of communication. The PLC, or power line carrier, transmits data across a power line at a specific frequency, often between 500 kHz and 1 MHz. PLC was utilised in the earlier transmission system to connect the substations. A filtering system was required in the communication system in order to use PLC. Furthermore, employing a PLC had made harmonic distortion difficult.

## 2. PROPOSED SYSTEM

*Figure 1* depicts the overall overview of the proposed system. Heart of the proposed system is the controller. The purpose of the controller in this work is collection of data, processing of data and sending data to the cloud. The ESP32 or Node MCU 32 is the controller used in this work. It is a dual-core controller. CPU in ESP32 is low-power Xtensa 32-bit LX6 microprocessors. The microcontroller that boasts Wi-Fi, Bluetooth, Ethernet, and Low Power support all in a single chip. The current and voltage sensor gives the current drawn and the voltage across load to the controller [10-11]. Relay acts as a switch and is controlled by controller commands from an APP. Whole methodology will be discussed on the following sections in this paper.

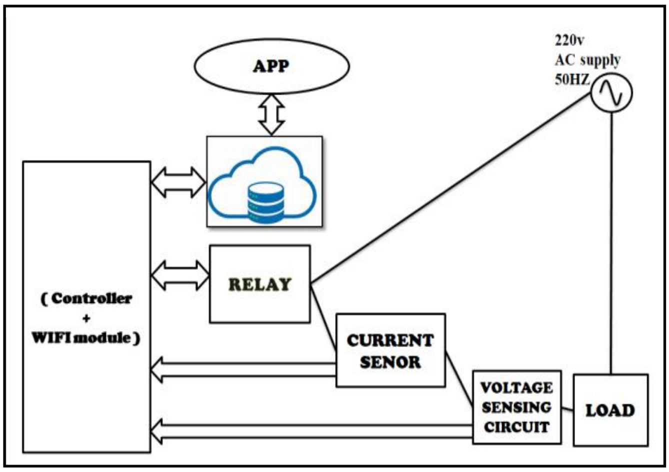


**Figure 1:** Block Diagram of Proposed Work

In order to measure voltage, a conventional circuit is developed according to the input of the load and controller requirements. The input given to the load is 230V AC of 50Hz frequency. The controller voltage rating is 3.3V DC. To measure the voltage across the load using Node MCU 32, a compatible circuit is designed as shown in *figure 2*.

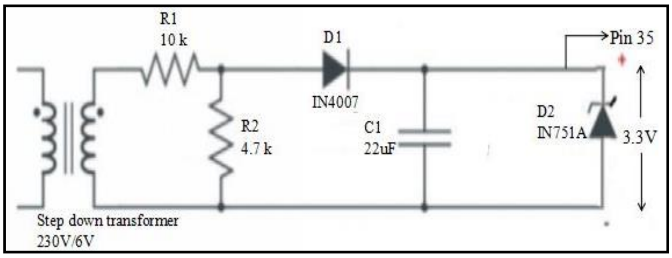


**Figure 2:** Voltage Sensing Circuit

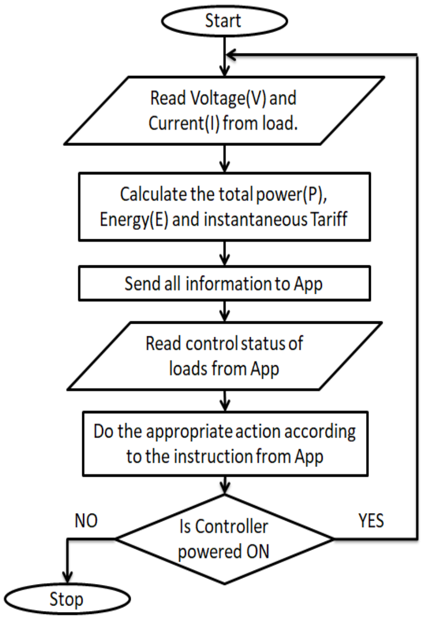


**Figure 3:** Flow Chart of the System

First, give the supply to the system and connect local Wi-Fi to the ESP32 controller. Now controlling the load is done through the app remotely. The Controller reads voltage and current from the user. From that, it calculates power (W), energy (kWh) and instantaneous tariff and sends all the information to the app. The Controller read the control status of loads from the App. Then the controller does the appropriate action according to the instruction from the App. This process continues until the controller gets power supply as shown in *figure 3* [12-15].

## 3. SIMULATION

To implement proposed system simulation, Proteus software is used. For the design of electrical and electronic circuits, Lab Center Electronics created the simulation and design programme called Proteus. Line diagram of simulation design for smart control of load and tariff analysis is shown in the *figure 4*.

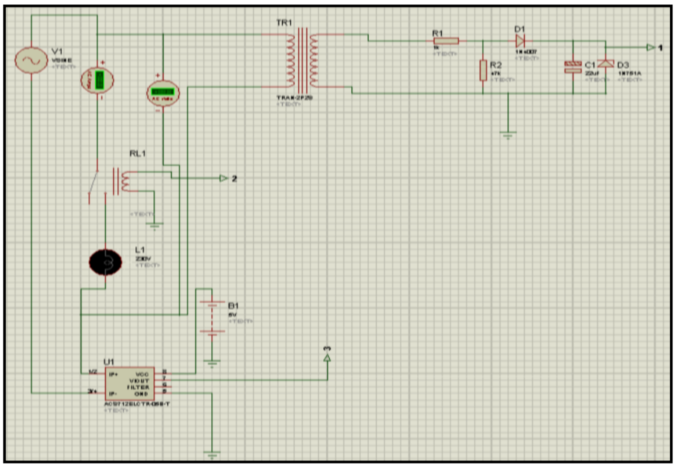


**Figure 4:** Line Diagram

The *Figure 4* shows simulation on load side contains supply, load, relay, voltage sensing circuit and current sensor.

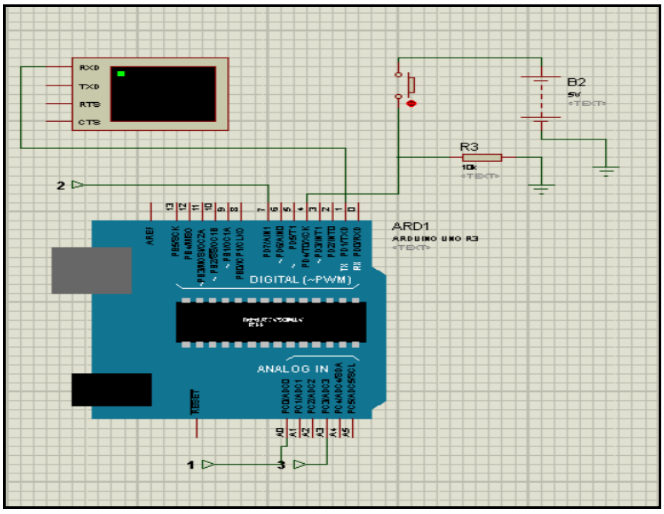

**Figure 5:** Line diagram 2

The *Figure 5* shows simulation on controller side contains virtual terminal, button (To control load), and Arduino. Controller operates in low voltage and current but load consumes higher voltage and current when compare to the rating of the controller. So proper conversion mechanism is needed for reading purposes. The current sensor used is ACS712. For voltage reading a circuit is built. The load is controlled by the relay and button circuit. The button replaces the App in simulation. The software used to dump code is Arduino IDE.

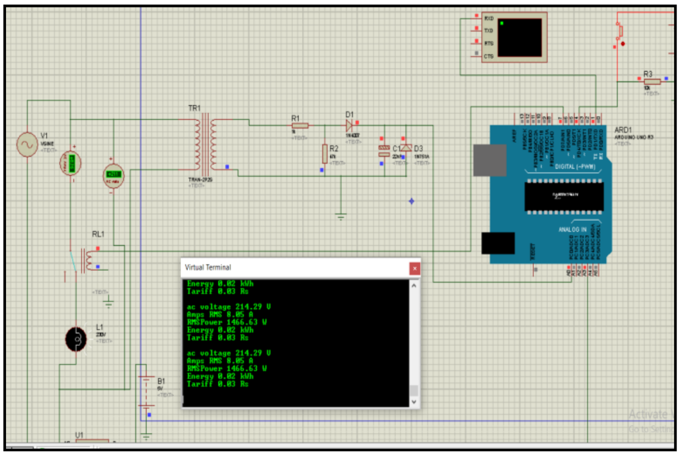

**Figure 6:** When the button turns ON, the results are shown in virtual terminal

In this simulation control of load, real-time monitoring of electrical parameter is achieved and results are shown above *figure 6*.

# 4. HARDWARE MODEL

The hardware is ESP32 based circuit to control loads of 220V AC power outlet. For current sensing ACS712 board is used. For voltage reading a conventional circuit is built as shown in *Figure 7*. The loads used in this work are resistive loads but same work can be implemented for reactive loads also with some small modification. Arduino IDE is used to upload code in ESP32.

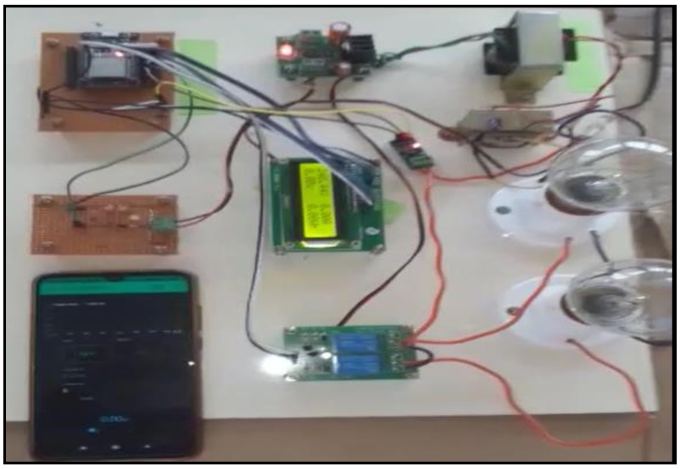

**Figure 7:** Hardware assembly

## 4.1 Creating an account in blynk and add a device

To develop APP for the work, blynk application is used. An add-on called Blynk runs on top of a hardware programme. It takes care of all the data transfer and connection procedures between your hardware, Blynk Cloud, and your app. Get the Blynk app for your phone. To upload code to ESP32 controller Arduino IDE is used, to implement blynk part code its corresponding library added in Arduino IDE.

- To get ESP32 hardware online and connect it to Blynk Cloud, it needs a device authentication token.
- Once you download the app, an authentication token is generated for every device.
- Add authentication token in code and upload it to device.

## 4.2. Uploading the Code into ESP32 Controller

In Arduino IDE

- Go to Tools > Board, identify the ESP32 section and select ESP32 board then
- Go to Tools > Port and select COM port.
- Click on the upload button.

Sometimes error occurs when uploading code; it means that ESP32 is not in correct mode.

Error message as: Failed to connect to ESP32: Timed out... Connecting...

To upload code, follow the next steps:

- Hold-down the "BOOT" button in ESP32 board.
- After you see the "Connecting…." message in Arduino IDE, release the finger from the "BOOT" button.
- After that, the "Done uploading" message is shown.
- Press the "ENABLE" button to restart the ESP32 and run the new uploaded sketch.

## 4.3 Build the APP interface

There are different ways to control hardware using blynk. Blynk allows different communication ways to communicate with the boards such as Ethernet, Bluetooth, Wi-Fi, GSM, 3G, LTE or

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even by using USB. While coding add the Wi-Fi credentials of local Wi-Fi network so it communicates using Wi-Fi.

- After installing Blynk app from play-store, open it.
- Register the mail-id and create a password.
- To the registered mail-id, authentication token is mailed.
- Add that authentication token in code of the project.
- Then select "New Project" in blynk.
- A work area is created, in that add the required widgets.
- Select appropriate pins for each and every widget for proper communication according to the code.

Connect local Wi-Fi network to ESP32 controller. Initial set-up process takes place. Open mobile APP with registered login and password. It shows device online condition. By control terminal in APP, the user is controlled remotely. The changes in electrical parameters are updated in APP automatically. The tariff accounting process also takes place simultaneously.
Final APP Interface is shown in *figure 8*.

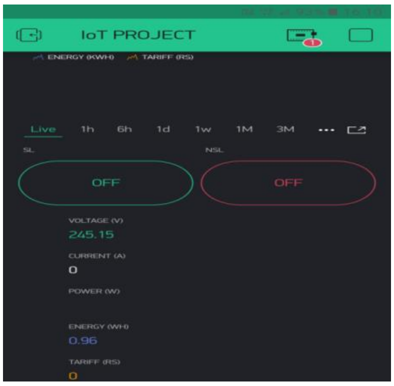


**Figure 8:** Final App Interface

## 5. RESULTS

When load1 is turned ON as shown in *figure 9*. If user turns ON load 1 through app, the signal from app is taken by controller. According to commands given by user controller give signal to respective relay, so that load and supply get connected. It leads change in electrical parameter information all these updates are modified is app automatically.

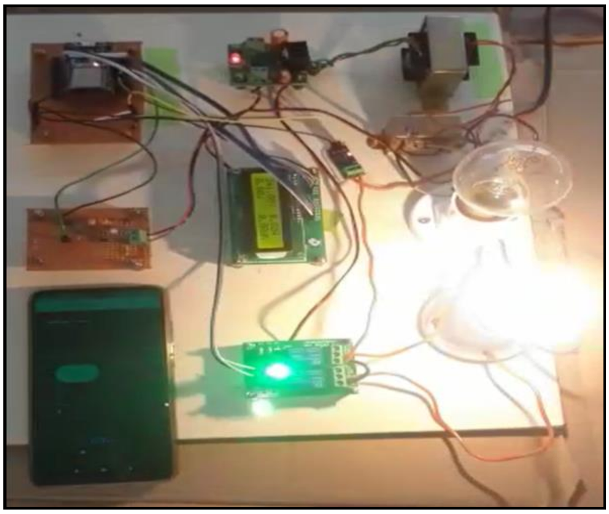

**Figure 9:** Load 1 is ON

**Table 1: The observation In LCD and App (Load 1 ON)**

| OBSERVATIONS | READING |
|---|---|
| **Voltage** | 240.20V |
| **Current** | 0.24A |
| **Power** | 48.92W |
| **Energy** | 0.05Wh |
| **Tariff** | 0.00Rs |

When both loads are ON as shown in *figure 10*. Here both the loads turned ON up to 4 hours.

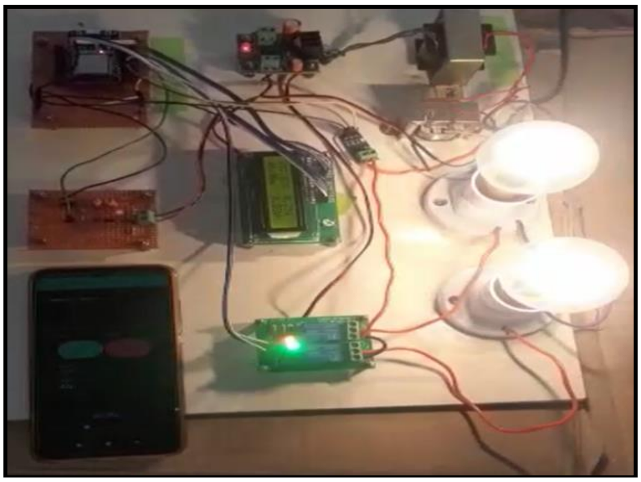

**Figure 10:** Both Loads are ON

**Table 2: The observation in LCD and App (both Loads ON)**

| OBSERVATIONS | READING |
|---|---|
| **Voltage** | 242.15V |
| **Current** | 0.47A |
| **Power** | 91.08W |
| **Energy** | 344.80Wh |
| **Tariff** | 0.50Rs |

## 6. CONCLUSION

This "IoT Based Smart Control of Load Remotely with Tariff Analysis for Demand Side Management" is an ESP32 Microcontroller kit-based hardware model. By using this system consumer or farmer can control his distant loads from anywhere through a mobile App. These save time of a consumer and lot of hard work for farmer. Also, controller sends electrical parameter information such as voltage supplied to load, current consumed by the load, power drawn, energy consumed and tariff analysis. So, system that allows real-time monitoring of consumption. Most of the consumers are unaware of their tariff accounting process and the importance of energy. So, the system create self-awareness in consumers to save energy thus it leads to demand side management. Every time consumer cannot go outside and check their energy reading. The system simplifies the purposes and provide consumer friendly system.

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