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Load Demand Response Controller

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Abstract

This project aims to design a system which helps electricity consumers to monitor and control their electrical loads. In this system, the energy meter is connected to an optocoupler which provides optical isolation and transfers electrical signals between the energy meter and Arduino UNO. This system has a step-down transformer and Regulated Power Supply (RPS) to provide supply to Arduino UNO and to the loads through electromagnetic relays. The electromagnetic relays act like a switch for the operation of the loads. The system is enabled with an Arduino UNO which acts like a control device. A Wi-Fi module ESP8266 is used to link the Arduino UNO to the internet. All of the data is processed by Arduino, and the Wi-Fi module communicates the energy consumption values to the Blynk application. Through Blynk application, the energy consumption values and load turn on/turn off options are available. From the Blynk application, relays can be operated as switches. The energy consumption is calculated by the Arduino UNO and when the peak load consumption is reached, the Wi-Fi module will send an email to the consumer's email id notifying them to turn off the unwanted loads.

Keywords – Energy consumption, Energy meter, Arduino UNO, ESP8266, Blynk app.

I. INTRODUCTION

One of the world's greatest issues now is the energy crisis. Almost 80% of energy is generated by fossil fuels, which are non-renewable resources. New environmental rules, the depletion of fossil fuels, and increased energy usage are all contributing to a significant increase in energy prices. Energy conservation is now one of the most essential issues for the development of smart grids, lowering energy usage and, as a result, addressing the current high electricity costs. One approach to addressing the energy crisis is to decrease or regulate our daily energy consumption through proper monitoring and minimising energy waste. The monitoring and management of energy consumption by the consumer like households, industries or factories is called Demand Response Management.

Demand Response Management (DSM) refers to initiatives and technologies that encourage consumers to optimize their energy usage by giving them the opportunity to play a significant role in grid operation by reducing or shifting their electricity usage during peak periods in response to time-based rates or other forms of financial incentives. This, in turn, will serve to stabilize the grid and give flexibility in the wholesale and ancillary electricity markets. Demand response programs are viewed as an increasingly significant resource alternative by the electric power business, whose capabilities and potential impacts are being enhanced by grid modernization projects. Demand Response Management (DRM) is an important component of current and future smart grids, actively lowering peak demand and power fluctuation. This idea proposes monitoring different loads depending on energy use from remote places in order to control peak load demand.

II. LITERATURE SURVEY

Demand response management is a critical component of smart grid systems, allowing for more effective use of electrical resources and lowering peak demand. This invention is not credited to a single person. It is the outcome of collaborative efforts of energy management and grid optimization researchers, policymakers, and industry specialists. Numerous studies have been conducted to explore various techniques and strategies for demand response management especially focusing on load shifting, where the energy consumption patterns of consumers match the availability of renewable energy sources or minimize electricity costs during peak hours. Several studies have explored combining advanced metering infrastructure (AMI) and real-time pricing systems to encourage users to switch loads. Other research has looked into the use of predictive modelling and optimization algorithms to forecast energy consumption patterns and adjust power usage using techniques like demand forecasting and load scheduling. Furthermore, research has looked into the impact of consumer behavior, incentives, and societal variables on the acceptance and success of load demand response programs in order to promote sustainable and efficient energy usage.

III. ENERGY METER

An Energy meter is a device that measures the quantity of electrical energy consumed by a home, a business, or a gadget that is powered by electricity. Energy meters are normally calibrated in billing units (most often kilowatt hour), and readings of energy consumption are made on a regular basis to determine billing cycles and energy used throughout a cycle. Some meters may also measure demand, which is the maximum amount of electricity used which is the desirable time to save energy. Meters in some areas have relays that turn off non-essential equipment. There are two types of energy meters on the market. The first is the traditional energy meter, which operates on the concept of mutual induction. This meter has a free wheel, which is a rotating aluminum wheel, but it has a lot of energy losses. The second is Electronic digital energy meter, which we are employing here and which is interfaced with the microcontroller. This meter has no moving parts and hence has less energy losses. The electronic digital energy meter consists of an LED blinking based on energy consumption of the user. Here we use a 230 V, 1 PH, 3200 imp/KWH energy meter which means for 1 KWH of energy consumption, the LED in energy meter flashes for 3200 times.

Energy meter

IV. ARDUINO UNO

A microcontroller board called Arduino UNO is based on the ATmega328P. It contains 6 analogue inputs, a 16 MHz ceramic resonator, 14 digital input/output pins (six of which can be used as PWM outputs), a USB port, a power jack, an ICSP header, and a reset button. To get it going, all it needs is a USB connection to a computer, or it can be powered by a battery or an AC-to-DC adaptor. The programming language used is called IDE, or integrated development environment. It is compatible with offline and online platforms.

Arduino UNO

V. Wi-Fi MODULE ESP8266

The ESP8266 Wi-Fi Module is a self-contained SOC with an integrated TCP/IP protocol stack that can provide access to your Wi-Fi network to any microcontroller. It has a powerful enough on-board processing and storage capability to interact with sensors and other application-specific devices via its GPIOs with minimal programming and load during runtime. The ESP8266 may host applications or offload entire Wi-Fi networking tasks from another application processor.

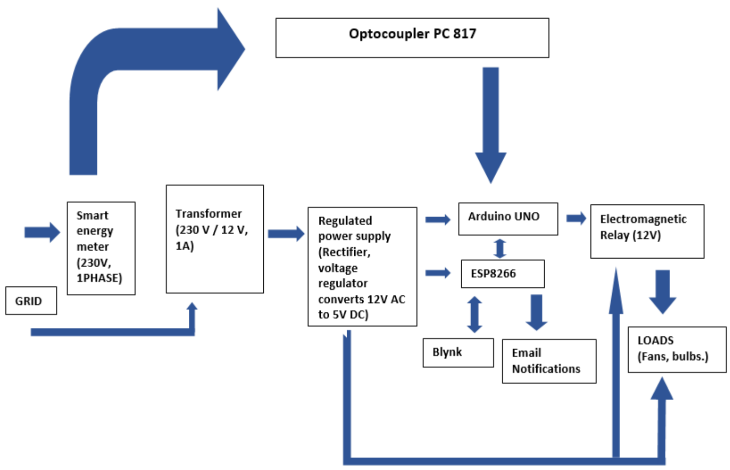
Wi-Fi module ESP8266

VI. BLYNK APP

Blynk is a user-friendly smartphone application that allows users to control and monitor a variety of electronics and Internet of Things (IOT) devices. It has an extensive library of pre-built widgets and drag-and-drop design tools to build interactive and responsive interfaces. Furthermore, Blynk offers secure cloud connectivity, enabling users to remotely access their devices and receive real-time data updates from anywhere in the world. Blynk app, in conjunction with the ESP8266 module, offers an exceptional solution for efficient energy management control by connecting to energy meter and access real-time data on smartphones or tablets. This enables users to track and set up personalized energy management control systems to analyze energy usage patterns, identify areas of inefficiency, and make informed decisions to optimize energy consumption.

VII. BLOCK DIAGRAM OF RESPONSE CONTROLLER

LOAD DEMAND RESPONSE CONTROLLER



VIII. WORKING OF LOAD DEMAND RESPONSE CONTROLLER

This load demand response controller contains both hardware and software elements. The project's hardware comprises of electrical circuits connected to several components. The Arduino IDE is used to write the software code that is utilized in the Arduino UNO and Wi-Fi module ESP8266 to control the system. The Blynk app is used to connect loads and consumers.

In the hardware module, grid supply is provided to the energy meter and step-down transformer. The energy meter consists of an LED panel through which the energy consumption is calculated (3200 impressions are equal to 1 KWH). Energy meter is connected to an optocoupler to provide optical isolation and read the pulses in the form of electrical current signals convert them into optical signals. The electric pulses given to the optocoupler are converted into light signals through infrared LED. When the light hits the photosensitive device, it switches on and starts to conduct electrical signals. These electrical signals are given to the Arduino at digital pin 2 to create an interrupt and calculate the energy consumption.

A 230V supply is provided to a Regulated Power Supply (RPS). RPS is made up of four modules: a step-down transformer, a full-bridge rectifier, a smoothing capacitor, and a voltage regulator. The step-down transformer transforms a 230V, 50Hz, single-phase alternating current source to a 12V alternating current supply. A bridge rectifier transforms the 12V AC voltage to 12V DC voltage using the 12V output voltage. The voltage waveform's output contains ripple voltages. To maximize the DC output and to reduce voltage ripples a 1000 microfarad capacitor is used. The output waveform of the smoothing capacitor will give a smooth waveform and reduces the ripples present in the waveform. A voltage regulator is used to convert the voltage to constant 5V DC. LM7805 voltage regulator is used which is a 3-terminal regulator in which input pin accepts DC voltage upto 35V and ground pin for establishing ground for the regulator and output pin gives +5V regulated DC voltage output.

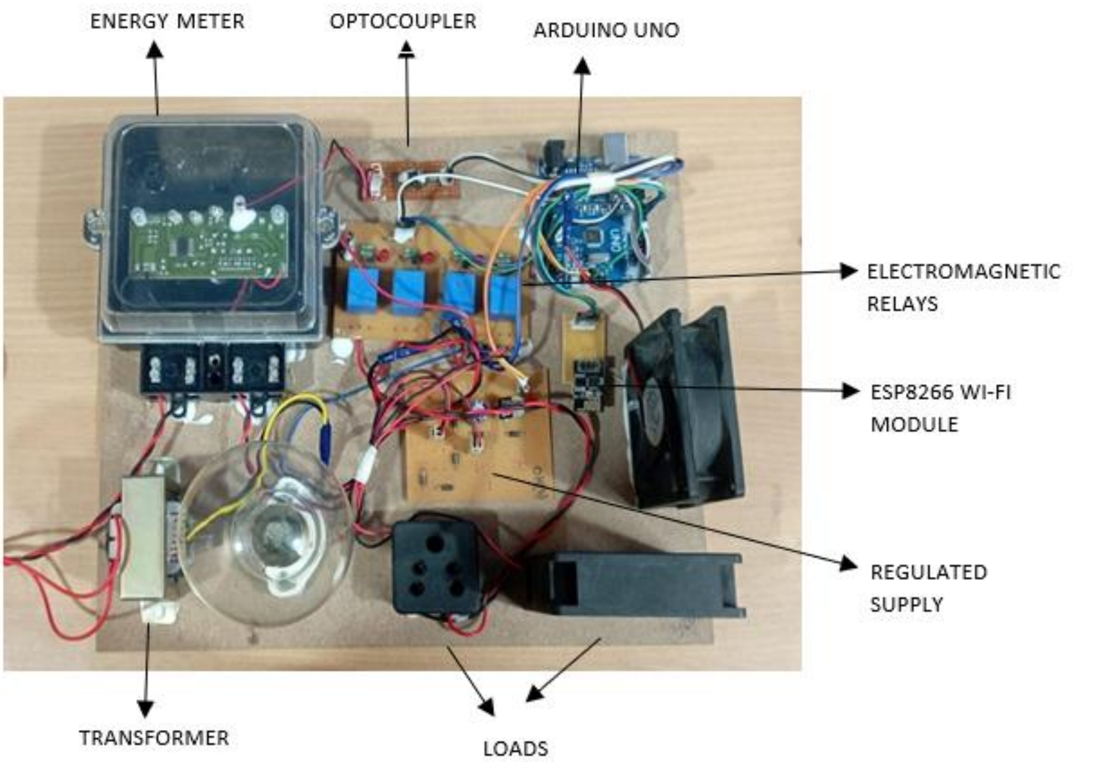
The 12V DC supply is given to the electromagnetic relay and 5V DC supply is given to the Arduino UNO. The electromagnetic relays are used to control the different loads by switching ON/OFF of the loads based on the consumer’s preference. Here, four electromagnetic relays are used which are connected to each one of the four loads. The four electromagnetic relays are connected to Arduino UNO by digital ports 10,11,12,13 so that the loads can be operated from a remote place through Blynk application. Arduino UNO is used as a microcontroller with Atmega328 as a controller in it. Arduino takes 5V DC voltage as input source. Arduino is connected to optocoupler, Wi-Fi module ESP8266 and relays. Blynk app interfaces with Wi-Fi module ESP8266 which the scale of energy consumption and also buttons to turn ON/OFF electromagnetic relays.

When the energy consumption exceeds the set peak value (here 0.3 KWH), an email is sent to the receiver's email address from the author's email address (these emails are used in code of Wi-Fi module ESP8266) using SMTP protocol. All input and output modules are interfacing to the Arduino. Arduino process this data to the Blynk app and user will control the devices and disconnect the load from the Blynk application by using a smart phone.

IX. SOFTWARE DESCRIPTION

This project is built using an Arduino UNO and an ESP8266 Wi-Fi module. As a result, the code is written in the Arduino IDE software. The Arduino Integrated Development Environment (IDE) includes a code editor, a message area, a text console, a toolbar with common function buttons, and a series of menus. It communicates with and uploads programs to the Arduino UNO and Wi-Fi module ESP8266 hardware. The project's code is written with appropriate header files and particular Arduino & Embedded C commands. The code is compiled and run in the Arduino IDE.

X. HARDWARE DESCRIPTION

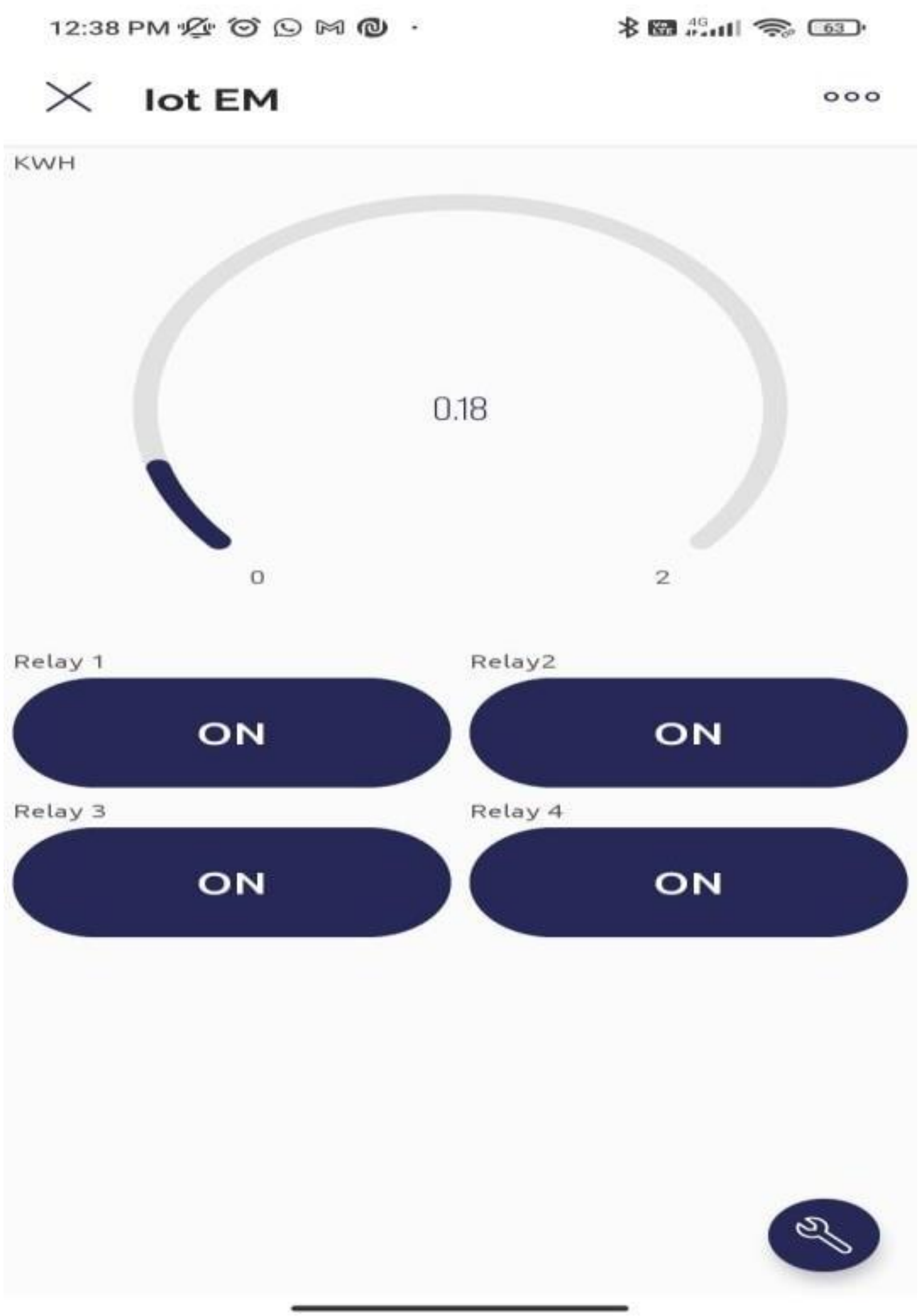


XI. ENERGY CONSUMPTION CALCULATIONS

We are using an energy meter with a pulse rate of 3200 imp/kWh.

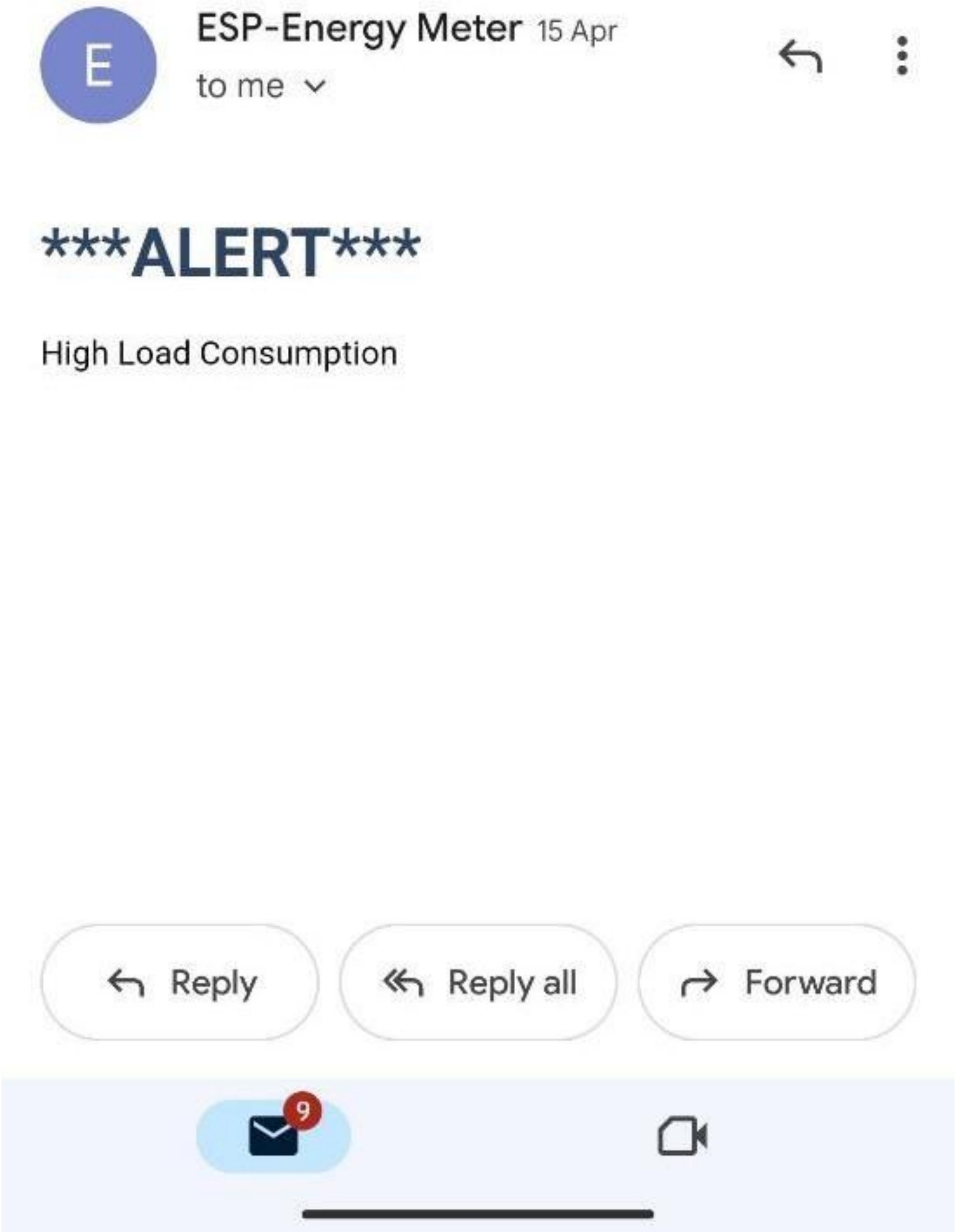
- Pulse= (Pulse rate*watt*time)/ (1000*3600)
- Pulse= (Pulse rate*watt*time)/ (1000*3600)
- Units= PF*Total pulse/1000

XII. RESULTS



Below peak load consumption

Above peak load consumption



Email notification at peak load consumption

XIII. CONCLUSION

Energy usage is increasing on a daily basis. Energy crises can have serious economic, social, and environmental consequences, such as rising energy prices, slower economic growth, more unemployment, and harmful environmental consequences. In this project "Load Demand Response Controller" the system will measure the energy consumption of the consumer using an energy meter which is coupled to Arduino UNO using optocoupler. A peak load demand value is set and the system notifies the user by sending an email when peak load consumption takes place using Wi-Fi module ESP8266. The consumer can use Blynk app to check the consumption rate and control the unwanted loads when the energy consumption exceeds peak value. This provides users with greater control over their energy consumption, load demand response controllers can help reduce peak demand, improve grid stability, and lower greenhouse gas emissions.

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