Smart Home Monitoring System for Reduced Power Usage

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Abstract

This project aims to create a smart home system using Internet of Things (IoT) technology to lower energy usage. Configure the microcontroller in a networked environment. The project acknowledges power consumption and the cost of household appliances to be inefficient. This project develops a fully operational application for a smart home monitoring system using Arduino IDE to program and manipulate a NodeMCU connected with a relay to be controlled by a smart device and control the power usage of home appliances. Along with incorporating an application that can remotely control the appliances' energy. This project is geared towards improving smart cities. The project will be capable of notifying homeowners when they leave their homes if any of their appliances, such as lights, fans, air conditioners, microwaves, or televisions, have been left on, and the electrical loads will be turned off by using an app on a smartphone.

Index Terms— Arduino IDE, Internet of Things (IoT), NodeMCU, relay, Microcontroller, Smart Home.

Introduction

A. Problem Statement

A problem homeowners face is the waste of energy on appliances that are not being utilized now. This causes higher energy consumption and higher energy costs per month. Also, the problem of continually operating appliances when not in use will make performance dwindle and lower their lifespan. Lastly, the problem of tracking all appliances and whether they are in operation.

B. Motivation

Power consumption is a rising cost in many households. A smart home monitoring system is both an efficient and effective way for homeowners to control the power and energy consumed. Thus, leading to conservation of energy and lower monthly electricity bills.

Background

Smart Home Monitoring has become a popular research topic. The academic journal "*Smart Home Monitoring System and Prediction of Power Consumption*" mentions using a smart meter to continuously monitor energy usage and notify the user if the energy being used has surpassed a set threshold. A mobile app and a hardware module are created to measure the energy used in each household item, a total monthly electricity bill, and predict the power usage for future months. [1] Similarly to this project, we will use a smart switch to control the appliances. However, instead of a voltage sensor, we will be using a NodeMCU. "Smart Household Socket with Power Monitoring & Control using Android Application "was another study to replace old commercial sockets with smart sockets which users can control remotely via an Android Application. [2] Before the introduction of smart household appliances, power and energy was being wasted daily and monthly. Using smart household appliances which one can control will enable efficient power consumption and management. Compared to this project, our project is an Internet of Things Smart Home Monitoring System and will be controlled using an application on a smartphone. Adding to previous studies and projects, we will incorporate the use of an Arduino IDE to program the NodeMCU and connect it to Wi-Fi and a 2-module relay. The relay will be connected to two loads representing the possible household appliance that may be connected. The Blynk Application will manipulate and control the loads by turning the switches ON and OFF via a smartphone or smart device. An important feature of the Blynk Application is its ability to allow users to enable notifications. The notification will notify users if a load has been left ON and may need to be turned OFF. This project's ability to monitor and remotely control household appliances will lower power usage and electrical bills and lead to a power-efficient environment.

Methods

A. **Components**

- NodeMCU- ESP8266

  A microcontroller can execute code entered from the Arduino IDE and connect to a home's network [3]. The microcontroller can also supply voltages through its various pins. This component connects to the Blynk software, executes the code from the Arduino IDE, and operates the relay.

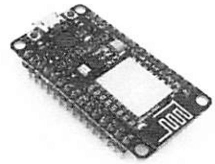

Figure 1: NodeMCU.

- Relay

  The relay is an electronic switch for circuits that requires an amount of voltage to operate. It differs from a regular switch because an input pin allows you to open and close the circuit hands-free [1]. We utilized the relay to create a switch that can open and close the circuit connected to the load. We used the voltage that the NodeMCU can generate to be the voltage supply for the relay and to send the input signal to open and close the circuit.

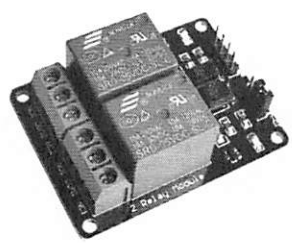

Figure 2: Relay.

- Blynk App.

  With Blynk, you can easily create smartphone applications that allow you to interact with microcontrollers [4]. The focus of the Blynk platform is to make it super-easy to develop the mobile phone application. We used the Blynk app to connect the two home appliances with the relay module.

Figure 3: Blynk App.

- Arduino IDE

  Arduino is an open-source electronics platform that uses simple hardware and software to make it easy. Arduino boards can take inputs - such as light from a sensor, a finger on a button, or a Twitter message - and convert them to outputs - such as turning on an LED, triggering a motor, or publishing anything online [5]. By providing a set of instructions to the board's microcontroller, you may tell it what to do. The Arduino programming language (based on Wiring) and the Arduino Software (IDE) (based on Processing) are used to doing this.

Figure 4: Arduino IDE.

B. ***Diagrams***

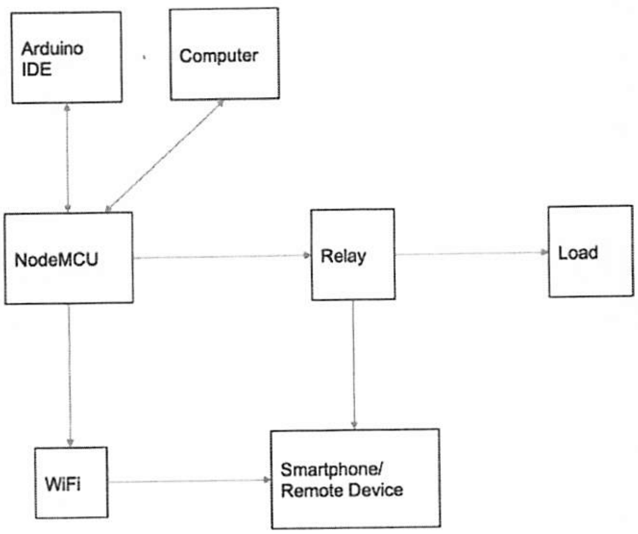

Figure 5: Block Diagram for system implementation.

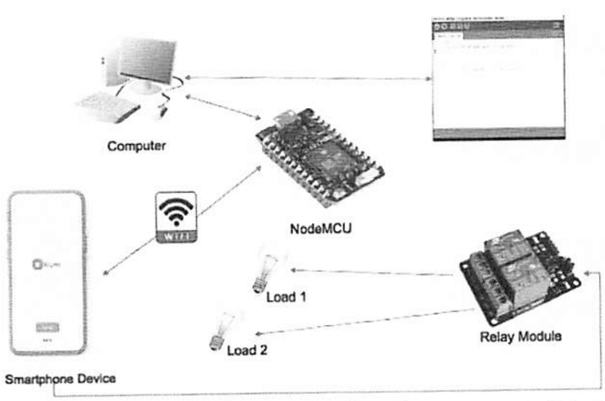

Figure 6: Implementation Diagram of loads connected to the circuit.

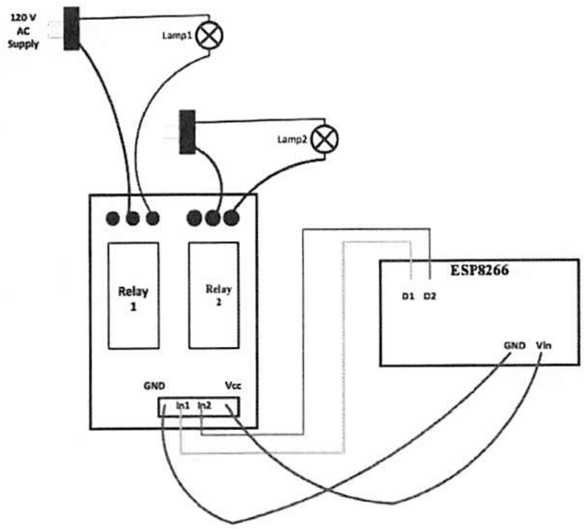

Figure 7: Load pin-out diagram from ESP8266 to the 2-channel relay.

System Analysis

The circuit begins with programming the NodeMCU using Arduino IDE to be connected to Wi-Fi. The NodeMCU connected to Wi-Fi can connect to a project on the Blynk Application website. The Blynk project must include virtual data stream pins, which will be used as virtual switches later in the project. Next is the implementation of the hardware. Two loads (household appliances) connect to a 120 V AC Power Supply and the 2-module relay. Ground, INPUT 1, INPUT 2, and VCC are then connected to the NodeMCU. Once hardware and software have been set up, the user must download the Blynk Application and open the project previously created on the Blynk Website. Users can turn virtual switches OFF and ON remotely from their smartphone and turn the loads connected to the relay OFF and ON. Along with controlling the switches at the press of the button, the Blynk Application also has the power to notify users if a load has unintentionally been left ON and may need to be turned OFF.

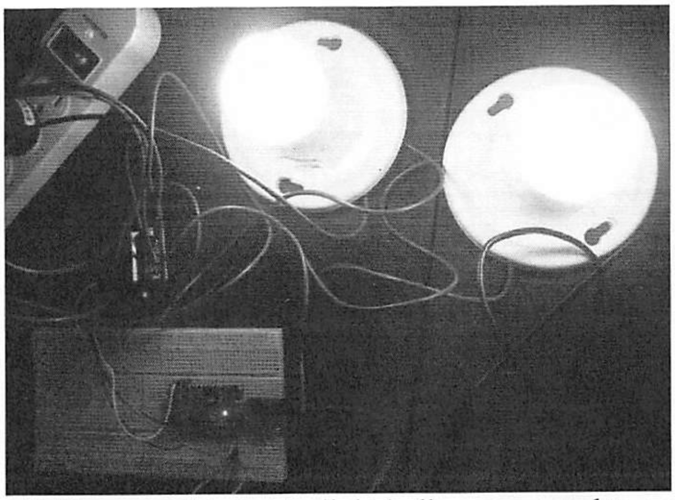

Figure 8: Two possible loads, light bulbs, connected to a power supply and the 2-module relay alongside the NodeMCU.

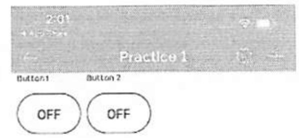

Figure 9: Home screen of the Blynk Mobile Application with buttons in place to manipulate load.

II. Results

A. *Internet of Things vs. Without Internet of Things*

Different home appliances use different power ratings. Figure 10 and Figure 11 display all the possible load component possibilities that may be used while using the Internet of Things System versus not using it. To create the table, several equations must be used. These equations include:

$$Energy\left(\frac{kW}{hr}\right) = Power \times time \quad (1)$$

$$Active\ Power\ (Watt) = VIcos\Theta \quad (2)$$

$$Power\ factor = cos\Theta \quad (3)$$

$$E_{Total} = \Sigma P \times time \quad (4)$$

Table 1: Data of the power, energy, voltage, and current household items are used per hour per day without using the Internet of Things.

Table 1 Daily Domestic Demand Profile (without IoT Systems)

[illegible]	Appliance	Qty	Power rating(Watt)	Actual power (Watt)	Energy (kW hr)	Voltage(V)	Current(A)	Hours used /day	Watts Hours /day
1	Refrigerator	1	200	115.6	0.287	122.9	1.094	24	9.288
2	Ceiling Fan	7	100	75	0.4	120	0.8	16	44.8
3	Lighting Point	15	60	11.4	0.301	121.4	0.163	12	66.36
4	Computer (Desktop)	2	100	71.4	0.45	121.7	0.529	12	10.37
5	Television (42 inches)	2	80	65	0.432	122.3	0.396	12	11.352
6	Cam screen and Monitor	1	100	79	0.15	122	0.456	24	12.72
7	Cam (VCR)	1	150	89	0.55	122.2	0.434	24	13.2
8	Computer (Laptop)	5	100	50.5	0.481	121.5	0.847	2	2.588
9	Ipad	1	50	9.5	0.382	122.5	0.149	2	0.764
10	Ice maker	1	100	45	0.3	121	0.61	24	7.2
11	Freezer	1	200	100	0.432	122.5	1.02	24	10.368
12	Dish washer	1	2400	1800	1.8	120	10	2	3.6
13	Machine washer and dryer	1	750	700	0.8	120	5	0.25	0.2
14	Air fryer	1	1500	1407	0.417	110.2	11.8	0.25	0.10425
15	AC	1	3000	2400	4	120	20	20	80
16	Stove	1	3400	3400	3	120	15	8	30
17	Heater	1	1500	1500	0.308	120.3	12.47	0.25	0.077
18	Miscellaneous	1	500	500	0.3	120	1	1	0.3
			14390	12377.4	17.5	121.0833333	84.308	Total Watts Hours	308.60425

Total Watts Hours/Day	308.60425	W.hr/day
Total kW hr/Day	[illegible]	
The average retail price of electricity is 13.8 cents/kWh	12.8	[illegible]
Total cost /day	3.0023024	$/day
Total cost /month	110.915972	$/month

Table 2: Data of the amount of power, energy, voltage, and current household items are used per hour per day using the Internet of Things.

#	Appliance	Qty	Power rating(Watt)	Actual power (Watt)	Energy (kW hr)	Voltage(V)	Current(A)	Hours used/day	Watts Hours/day
1	Refrigerator	1	300	115.6	0.387	122.9	1.604	24	9.288
2	Ceiling Fan	7	100	75	0.4	120	0.8	8	22.4
3	Lighting Point	15	60	11.4	0.381	121.4	0.183	6	34.29
4	Computer (Desktop)	2	[illegible]	21.4	0.43	121.7	0.329	4	3.44
5	Television (42 inches)	3	80	45	0.432	122.3	0.380	4	5.184
6	Cam screen and Monitor	1	100	70	0.53	122	0.456	24	12.72
7	Cam (VCR)	1	150	80	0.55	122.2	0.434	24	13.2
8	Computer (Laptop)	3	100	58.5	0.431	121.5	0.847	2	2.586
9	Ipad	1	30	9.5	0.382	122.3	0.149	2	0.764
10	Ice maker	1	100	45	0.3	121	0.61	24	7.2
11	Printer	1	250	100	0.432	122.5	1.82	24	10.368
12	Dish washer	1	2400	1800	1.8	120	10	2	3.6
13	Machine washer and dryer	1	750	700	0.8	120	5	0.25	0.2
14	Air fryer	1	1500	1407	0.437	119.2	21.8	0.25	0.10925
15	AC	1	3000	2400	4	120	20	14	56
16	Stove	1	3400	3400	5	120	13	4	20
17	Dryer	1	1500	1500	0.308	120.3	12.67	0.25	0.077
18	Miscellaneous	1	500	500	0.3	120	3	1	0.3
	Sum		14390	12377.4	17.3	121.0633333	84.146	Total Watts Hours	[illegible]

Total Watts Hours/Day [illegible]
Total kW hr/Day 9.2307625 [illegible]

The average retail price of electricity is 12.8 cents/kWh [illegible]

Total cost/day [illegible]
Total cost/month [illegible]

Energy Saving/day [illegible] kW hr/day
Energy Saving/month [illegible] kW hr/month

Saving per day [illegible]

Saving per month [illegible]

*B. **Load Curves***

Load curve: Is a graphic record showing the demand for power for every instant during the hour, the day, and the month of the year [6]. The load curve shows the relationship between Power (Watts) and Time (hours).

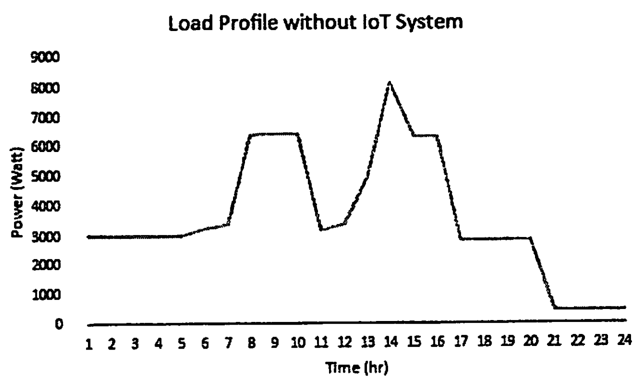

Figure 10: Power vs. Time relation of the entire load profile in an entire day without using the Internet of Things System.

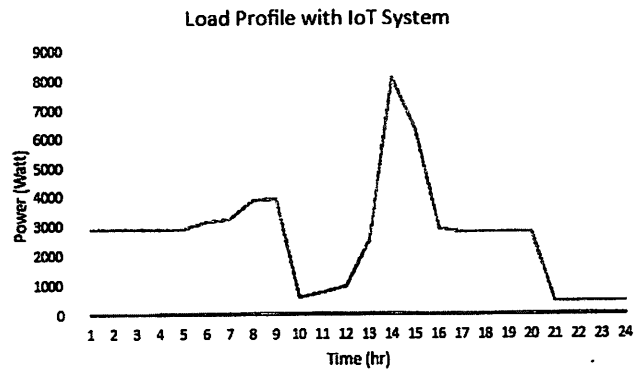

Figure 11: Power vs. Time relation of the entire load profile in an entire day using the Internet of Things System

Analysis

In Table 1, without using the IoT system, the amount of daily power was 309.7 Watts an hour per day. Knowing the average electricity price in Texas is 12.8 cents per kilowatts an hour [7], the total cost without the IoT system is $3.96 a day and $118.91 a month. In Table 2, using the IoT system, the amount of daily power was 225.7 Watts an hour per day. Applying It to the average price of electricity, the total cost per day is $2.88, and the total monthly cost is $86.67 a month. Comparing the two, this is about a $1.07 daily savings and a $32.23 monthly savings. Hence, the IoT smart home monitoring system is both an effective and efficient way for homeowners to control unnecessary energy consumption, thus leading homeowners to save big every month. Comparing Figure 10 and Figure 11, Figure 11 shows a significant drop in power between hours 9 through 14. This is due to controlling all appliances and not wasting any power throughout the day.

Conclusion

In conclusion, the circuit can give its user the ability to lower their energy cost per month by being able to monitor the load and manipulate the power connected to the load. The circuit could improve by adding more relays to handle various loads. The circuit could also be directed towards other home issues, such as water and gas. These are possible because of the Blynk App.'s ability to connect to devices and send signals through the home's internet connection, and the NodeMCU can utilize the Arduino IDE, which can be used in various situations. These three components, paired with a relay module, allow any form of electronic with a positive and ground to be manipulated remotely.

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