Electricity Usage Monitoring and Alerting System

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***Abstract*— Electricity is one of the inevitable sources of energy in our day to day life. Almost every single device we use from the moment we wake up until going to bed is electrically powered. Meanwhile, there is always a problem of power scarcity in our country. It mainly depends on hydraulic power, and we don't have much rainfall nowadays due to climate change issues. Our government is trying to overcome it and also to ensure power supply to all the consumers of the country without interruption. Reduced power consumption will lead to overcome electricity scarcity. Many pieces of research to monitor and reduce electricity usage is done in the past. However, most of them help to reduce electricity by displaying the total electricity consumption for a month. The best solution for this problem is to find the total electricity units consumed by each device for a given period of time rather than calculated as a whole. We have developed a gadget that will sense the electricity units consumed by a particular device being plugged in and will wirelessly transmit the units consumed in real-time and stored on a database. The total units consumed by the particular device per month will be calculated and displayed. Two prototypes are designed for this research and were tested over a two-week period of time. These gadgets can be plugged into any sockets and will help to detect the amount of power consumption, used through the gadget.**

Keywords – Electricity, NodeMCU, Alerting, Monitoring, IoT

I. INTRODUCTION

Due to the increased usage of electricity, there is a need for monitoring the electric devices and alert the consumer at the correct time. As a result of the rapid development of technology, many devices that need electric power to work are being invented every day. The devices might consume only a small amount of power for one-time use, but the fact is when we use it several times and have many such small devices, the power consumption will be increased eventually without our knowledge. This research will help them to know the power they consumed, and they will also get to know that their device is used more than they expected. This paper proposes an idea that allocates electricity units for each device in the house (per month); when the allocated amount reaches its limit, it will alert the user that a particular machine is running out of allocated units. Hence, the user can reduce the electricity usage of the device which is spent unwantedly and also be able to maintain their monthly electricity bill as planned. This idea does not only help to warn the user about the excess usage of electricity, but also the user gets to know how much electricity that they are using with each device and appliance in their house per month [1]. This monitoring system helps them to analyze the electricity misuse, and also to reduce the power wages. Precisely, this idea helps to maintain our electricity expenses in control. If each house in our country uses this idea, then the whole country can do electricity savings in the long run [2].

The implementation of this idea needs the latest technology and methods for an effective output. We believe that the updated technological knowledge of the current trends in technology will help to come up with a smart solution. When the question raised that how to implement the idea, it was decided that the Internet of Things (IoT) perfectly suits this idea [3]. Because the NodeMCU is the most common device used in the IoT based projects so far, and it is easy to use NodeMCU for our project. Therefore, we decided to move with this technology for implementation [4].

The electric devices use an electric current, which should be measured. Therefore, a current sensor must be used here to measure the electric current consumed by the devices. A microcontroller is needed to process the data collected from the sensor. The sensed data will be analyzed and will be displayed on a webpage where the users can access their accounts and view their subscribed details.

The objective of this research is to produce a useful gadget that helps people to monitor the electricity of their house to control the extra electricity usage as well as the wages. Therefore, the product should be cost-effective to buy and used by almost every house in the country. For that, we did a feasibility study to find different ways in which the plan can be implemented, and we selected the best possible solution, which is durable, as well as cost-effective [5].

This system will allow the user to view the details of the electric units consumed and also facilitate to prepare a pre-planned schedule of electricity usage. This will help to reduce the total energy consumption of a community and also reduce the regional and national electricity demand as a whole. If everyone knows their usage in more detail through our system, the general public can understand and will practice efficient mechanisms in electric power consumption in the future in the long run.

II. RELATED WORKS

There are similar researches that were done in the past for measurement and monitoring of electricity. In the research named "The electrical energy monitoring systems," they have designed it based on non-intrusive sensors, Factorial Hidden Markov Model algorithm (FHMM) and Bluetooth Low Energy (BLE) techniques. Sensors have been placed under one-point observation for the purpose of measuring the electricity consumption of the entire load [6].

Elamvazuthi and his co-researchers made an "Electrical power consumption monitoring using a real-time system," The research is to develop and implement a portable electronic power meter based on a micro-controller that can calculate three-phase power supply for a single device to maximize power use in a plant.[7].

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Nama et al. have done another work, which was titled as "Real-time monitoring system of electrical quantities on ICT Centre building of the University of Lampung based on Embedded Single Board Computer BCM2835". The voltage monitoring was performed using a step-down transformer to sense voltage and a Current Transformer SCT- 013 100A to sense the current. Power, Power Factor value and Energy were derived with the help of some scientific calculations. The application was developed using Python programming language, precisely for the purpose of collecting data and perform calculations that run on BCM2835 Embedded Single Board Computer[8].

However, we have used the low-cost components to build the gadget. Moreover, the gadget designing can be done quickly by assembling the parts. The hardware implementation is done with the components of IoT based secure protocol. Also, the whole gadget designed to be a low cost one for the users.

III. Methodology

The process of developing the system starts by getting readings from the household electric devices with the help of current sensors. The sensed values will be transmitted with the help of the microcontroller (NodeMCU) to the server for analysis and alerting service. The sensor needs to connect with the microcontroller to get the value of the electricity consumed. The microcontroller must be able to send the data received from the sensor to a server. The NodeMCU is selected for this purpose. The measured values will be sent to the server using MQTT (Message Queuing Telemetry Transport) protocol with the help of the inbuilt Wi-Fi module of the NodeMCU [9].

Then the MQTT server will serve the user with a webpage by representing the electricity consumption of each device separately. Also, the allocated electricity units and the electricity units consumed can be changed by the user anytime. It has been set to push notifications when the allocated electricity units are about to exceed.

The system is developed using IoT components and it is divided into two parts. One part senses and calculates the units; the other part will display the details of electric units and alerts the user when it is overused. This system uses a web application for displaying the current consumption of each device. Further, the system is installed in a household environment to measure the energy consumption of electrical devices [10]. It can be used in a smart home project to provide the user to monitor the electricity utilization.

A. Hardware Development

The hardware is designed as a gadget that looks like a multi-plug and can be plugged into the electric socket installed in houses. The electric device will be plugged on top of the gadget. The components, sensor module, NodeMCU and power convertor are fixed inside the gadget box with the aid of jumper cables. ACS712 current sensors of 20A are selected and it operates on 3V power, given by the microcontroller and outputs an analog voltage that is proportional to the current flow on the sensing terminals [11]. Microcontroller (NodeMCU) includes hardware which is based on the ESP-12 modules and firmware, which runs on the in-built ESP8266 Wi-Fi module [11] .The power supply must be given separately to the NodeMCU ESP-12E because it only needs 5V power for operation. A power converter is collected from the old mobile chargers and it is connected to the NodeMCU through USB cable. The way we connected the hardware components is shown in Figure 1 and the inner part of gadget we made is shown in Figure 2.

The data received from the NodeMCU will be transferred to the database server using the MQTT protocol. The MQTT protocol and database server will connect to the Wi-Fi network, allowing users to monitor their electricity consumption for each device separately and displayed via a dedicated front end.

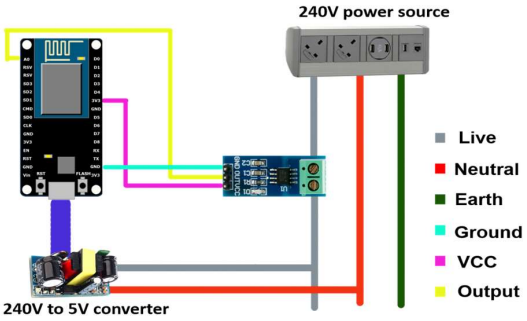

Figure 1: Illustration of Hardware Component Connection

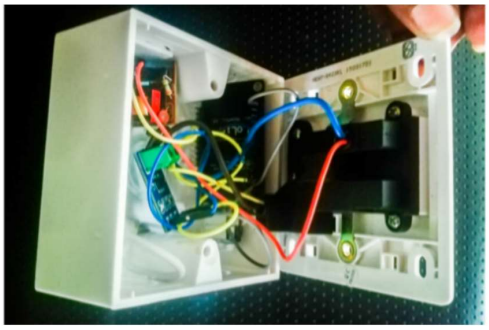

Figure 2: Inside the gadget

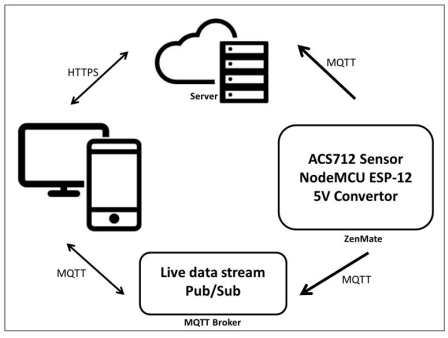

Figure 3: Data Transmission Diagram of the Gadget

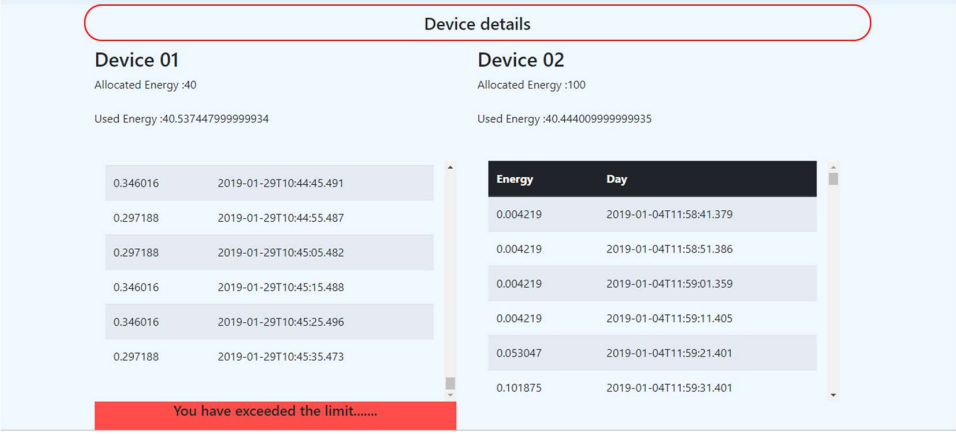

Figure 4: Device Details and Alerting Page

B. Software Development

The software design of the NodeMCU can receive signals from the current sensor and convert the analog value into Amperes and send it to the server [12]. The conversion equation is given below:

$$float\ I = \frac{\left(\left(\frac{sensorValue}{1024}\right) \times 5000\right) - 2607}{100}$$

Here, the power consumed by the microcontroller is negligible even though it's powered with the electricity passed through the gadget itself. The values will be sent to the server for real-time processing. The transmission requires a low bandwidth network protocol with low latency. Therefore the MQTT protocol is used for this gadget [9]. The way of data transmission of the gadget is shown in Figure 3. The message queue protocol enables the application to have low power usage, send minimum data packets, and efficiently distribute information to one or more receivers. The software design of the server plays a significant role, like receiving data from NodeMCU, processing the values, presenting the data to the user, and pushing alert notifications. The server stores the measured values that were coming from different devices and stores them with time stamps. The units are calculated for a month and compared with the allocated units. Users will receive alert notifications whenever a specific device is about to exceed its allocated electricity units for the monthly plan updated by the user. The webpage containing the device details is shown in Figure 4.

IV. Result and Discussion

The system is tested at various stages in the process. The testing process includes the hardware development stage of the gadget, software development for sending data, storing data, viewing data, analyzing data, and alerting the user. Each unit of the gadget was tested to verify the performance of the system. After the implementation of the whole system, we carried out a performance test to ensure that the system is working properly. To do so, we have tested our gadget with few devices for a certain duration of time by allocating them a limit.

The testing process is performed to check the alerting functionality when the electricity usage of an electric device exceed the allocated limit.

A. Current Sensor Testing

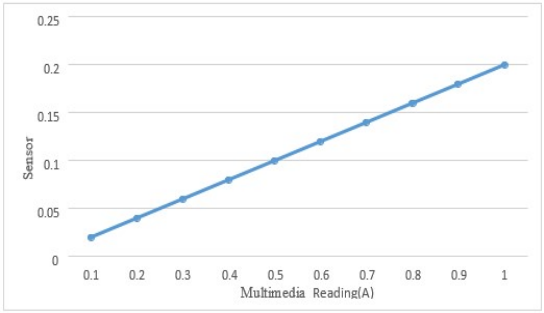

Figure 5: Current Sensor Testing Graph

In the initial stage of implementation, the first step was to connect the current sensor with NodeMCU and to check whether it measures the electric current accurately. The current sensor is tested by supplying it with different values of current through a variable digital power supply to ensure the accuracy of the sensor. The sensed values with the values displayed in the Integrated Development Environment (IDE) has been checked with the help of the serial monitor. In the beginning, it has been found some deviation in the values and it must be solved to make it more accurate. Hence, we started to note down those values and plotted a graph, which is shown in Figure 5. Some alterations were made based on the graph and the datasheet of the current sensor, and the equation applied was programmed accordingly to the NodeMCU [11]. After a few attempts, we got the correct output in the serial monitor, which matched the variable current supplied to the sensor. Finally, the accuracy of the sensor was ensured.

B. Using Indicators

As the gadget is made up of electronic components and deals with electricity, it can be damaged or get burnt for heavy use. We can use the LED bulbs inside the gadgets as the

indicators to make it easier for the users to identify whether the gadget is still in a working condition or damaged. There is a red LED and a blue LED inside our gadget, and the way they blink when switching on the gadget can indicate the state of the gadget.

C. Security Controls

The sensed data and the user data should be passed through a system that doesn't allow any unauthorized access. The user data and their device data will be only known to the user. The measured data send by MQTT protocol secured with encryption mechanism and the user accounts are protected with a password authentication as well.

D. Performance Analysis

The testing details of how we tested each part of the proposed system has been clearly explained in Table 1.

TABLE 1: TESTING RESULTS

Name	Unit Testing	Scenario
Gadget	Checking the sensor and Microcontroller for reading the analog value.	Check the sensor reading is set to zero when the gadget is not used.
		Measure the sensor with different load values to confirm sensor compatibility for different devices.
	Checking the Node MCU program to send the sensed data	Writing MQTT pub/sub-codes to receive the sensed data. Sending the data to the dedicated server.
Message Queue Protocol	Sending data to Message queue	Choosing a broker for the topic current sensor.
		Create a topic for the test and connect with the server.
		Receive data in real time
		Able to differentiate different topics' data in the message queue simultaneously.
Front End	Analyzing the data in the server	Able to retrieve and store the message coming from a broker.
		Able to differentiate devices data receiving at the same time
		Able to view the data in real-time
	Checking the front end with user entries	Log in to the application with username and password
		Create an account in the application
		Able to add/delete devices
		Able to allocate units
		Graphical data statistics
	Alerting the user	Alerting the user with a notification

When the design and implementation of the gadget are completed, we decided to test some most common devices used in average houses to ensure our gadget is working properly. We divided the devices into two categories, as follows, in order to make the testing more efficient.

A. Commonly used devices

The first category includes the devices which almost everyone has in their home. This category is chosen to ensure that our system is compatible and adopts all types of devices. The resulting values are given in Table 2. According to Table 2, the electric geyser consumes 0.39 units of electricity for an average of 10 minutes' usage. Hence, for a month, it will consume about 11.7 units of current flow.

TABLE 2: TEST VALUES OF COMMONLY USED DEVICES

Device	Reading (Average 10 min) (A)	Reading (kWh)
Electric Geyser	10.07	0.3860
Table Fan	0.19	0.0073
Fridge	0.79	0.0303
Laptop	0.09	0.0034

B. Devices frequently forgot to switch off

The second category includes the devices which are forgotten to be switched off by most of us commonly. This category is chosen to satisfy the main objective of this system. The resulting values are displayed in Table 3.

TABLE 3:TESTING VALUES OF DEVICES FREQUENTLY FORGOT TO SWITCH OFF

Device	Reading (Average 10 min) (A)	Reading (kWh)
CFL Bulb	0.14	0.0053
Wi-Fi Router	0.14	0.0053
LED Television	0.24	0.0092
Mobile Phone Charger	0.14	0.0053

According to Table 3, even though LED Television consumes 0.01 units for 10 minutes of usage, it might influence in doubling electricity wages because LED televisions are used at least 1 hour per day and it will consume 1.8 units per month.

The following equation is used to calculate the electricity units from the above readings.

$$1\ Unit(kWh) = \frac{PF \times I \times V}{1000 \times 3600}$$

Here, PF denotes the power factor, I is the current flow, and V denotes voltage.

In the current era, the general public having an awareness of some devices like rice cooker, iron, immersion heater, geyser and etc. which consumes more power than the other devices like mobile charger, Wi-Fi router, etc. But when we calculate the total power consumption of a month, it's important to consider the total amount of time we used that particular device because there is a chance that simple devices may consume more power as they have used invariably as little drops make the mighty ocean. For example, if we consider one-hour usage of a Wi-Fi router, it consumes only a few units, but the geyser consumes more. But at the end of the total power usage of the Wi-Fi router per month, it will go higher than the geyser.

Also, due to the rapid growth of Information Technology, the invention of auxiliary devices to enhance the functionality of an already existing device. (i.e: for apple iPhone, iPod, iWatch,AirPod) is taking place. Since we are unknowingly adding extra electric appliances into our houses, it may result in increasing in bills because, at the end, everything needs

power. Table 4 shows the connection between the power consumed and the duration of the device is used.

TABLE 4:MONTHLY POWER CONSUMPTION DETAILS OF DEVICES

Devices in a Sample House	Usage Hours Per Day	Watts	Watthours Consumed in a Day	KWh	Monthly Units
Rice cooker	1	700	700	0.7	**21**
Cloth Iron	0.5	1100	550	0.55	**16.5**
Motor 1000L Tank	0.5	1000	500	0.5	**15**
Television	3	133	399	0.399	**11.97**
Mobile phone charger 3 times avg charhing	2	25	50	0.05	**1.5**
Fan (usage while sleeping inclusive)	10	110	1100	1.1	**33**
Laptop	8	50	400	0.4	**12**
Total Units					**110.97**

As shown in Table 4, it's now clear that we still don't know which device consumes more power, so that some devices need continuous observation throughout the month, and it's sure that in the end, we will have many unexpected devices in that list.

V. CONCLUSION

In this paper, we present a much better monitoring and alerting system for the users to keep track of their electric usage of appliances. The proposed system allows the user to create a monthly electricity usage plan in the webpage, and it alerts the user whenever the usage exceeds the monthly plan. The gadget which senses and monitors the electricity units consumed by each device. This can be used with any device and can get the electricity unit usage details without replacing the existing power meter.

Furthermore, it is a very cost-effective product, unlike several other similar products which cost a lot. [5] Here, we compromise the users with the minimum cost, which they can afford. We believe that this will be an extraordinary product to analyze the usage pattern of each user regarding their electricity consumption. This electricity usage data will greatly helpful for the plan of big data analysis to find out specific user's electricity devices and usage patterns to automatically allocate them the required electricity units. The users can realize that the amount of money they paid as electricity bills by wasting through our gadgets. This project helps power providers to control the electricity wastage and to reduce the electricity wages of householders caused by excess use of electric devices.

As there is an awareness about some electric devices (cooker, motor) which consumes more electricity bill, people have become more concerned about minimizing the usage of such devices, still, we couldn't find the exact reason of the increased electricity bill. Because of our laziness, we need devices even to do a simple task. This results in health problems, again, people start buying things to maintain their health. This cycle continues without an end. But when we visualize the power usage of such unwanted extra devices, people may think before buying those devices if they don't need it. Therefore, through the proposed gadget, people can estimate their monthly electricity usage estimate, do optimize charging, can increase the lifetime of devices, can reduce the usage of the device and also can be able to find their own usage pattern. The number of members in the family, the number of juvenile members, the number of retired members and the number of mobile phones will affect the electricity bill when we consider a middle-class family. As a whole, these types of patterns can also be identified through this research

Users can discover the devices that consume more electricity based on allocated usage limits through the proposed gadget and also can identify the devices that the users forgot to switch off and contribute to increased electricity payment. This gadget is useful in minimizing the electricity bills and also helps in expanding the lifetime of a device and preplanning the electricity usage of houses. Therefore, if we can give an early alert to consumers on their electricity usage by each and every equipment, then the consumers can identify the high electricity consuming devices and take necessary actions to reduce it. This system not only gives an economical benefit to the consumer but also will help to save energy as a whole. Finally, this project is a simple contribution to the smart home project.

VI. REFERENCES

[1] CEB, "Ceb.lk," [Online]. Available: https://www.ceb.lk/bill-calculation-commercial/en.

[2] CEB, "Ceb.lk," [Online]. Available: https://www.ceb.lk/power-plants-list/en.

[3] ELECTRICAL TECHNOLOGY, "Internet of Things (IoT) and Its Applications in Electrical Power Industry," [Online].Available:https://www.electricaltechnology.org/2016/07/internet-of-things-iot-and-its-applications-in-electrical-power-industry.html.

[4] A. Ahir, "AHIRLABS" [Online]. Available: Https://www.ahirlabs.com/2017/10/21/what-is-nodemcu-esp8266/.

[5] Sense.com, "Sense.com," [Online]. Available: https://sense.com.

[6] T. Juhana and A. I. Irawan, "Smart non-intrusive power consumption monitoring system," in 10th International Conference on Telecommunication Systems Services and Applications (TSSA), Denpasar, Indonesia, 2016.

[7] I. Elamvazuthi, M. K. A. A. Khan, S. B. B. Shaari, R. Sinnadurai, and M. Amudha, "Electrical power consumption monitoring using a real-time system," IEEE Conference on Sustainable Utilization and Development in Engineering and Technology (STUDENT), Kuala Lumpur, Malaysia, 2012. pdf/view/168326/ALLEGRO/ACS712.html.

[8] G. F. Nama, D. Despa and Mardiana, "Real-time monitoring system of electrical quantities on ICT Centre building University of Lampung based on Embedded Single Board Computer BCM2835," in 2016 International Conference on Informatics and Computing (ICIC), Mataram, Indonesia, 2016.

[9] R. K. Kodali and S. Soratkal, "MQTT based home automation system using ESP8266," in 2016 IEEE Region 10 Humanitarian Technology Conference (R10-HTC), 2016.

[10] M. J. Mnati, A. V. d. Bossche and R. F. Chisab, "A Smart Voltage and Current Monitoring System for Three-Phase Inverters Using an Android Smartphone Application," PMC, 2017.

[11] ALLDATASHEET.COM, "Electronic Components Datasheet Search," [Online]. Available: https://pdf1.alldatasheet.com/datasheet-pdf/view/168326/ALLEGRO/ACS712.html.

[12] Henry's Bench, "ACS712 Arduino AC Current Tutorial," [Online]. Available: http://henrysbench.capnfatz.com/henrys-bench/arduino-current-measurements/acs712-arduino-ac-current-tutorial/.