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IOT BASED HOUSEHOLD ELECTRICITY ENERGY MONITORING AND CONTROL

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ABSTRACT

Internet of Things (loT) has opened up a myriad of applications in many areas, including medical and healthcare networks, smart home control, and environmental surveillance. IoT is supposed to bring about a large amount of progress in the ubiquitous computing sector. IoT-based energy management programs may allow a significant contribution to energy conservation. Therefore, this paper focuses on the design and implementation of an IoT based household electricity energy monitoring and electric bulb remote control for the reduction of electrical wastage using ESP 32-bit microcontroller. The ESP 32 microcontroller was used as the brain of the entire system which processes the energy consumption, temperature reading. Temperature monitoring can assist tremendously in the explosion and burning incidence avoidance, thereby saving lives and properties. The ESP32 microcontroller also handles the internet connectivity via its inbuilt WIFI module in order to transmit the real-time energy consumption, temperature reading, and electric bulb remote control over the internet. A MATLAB app was designed to serve as user interface for monitoring the household electricity energy consumption, temperature reading and electric bulb remote control via Thingspeak cloud server from MathWorks (makers of MATLAB) and also monitors the temperature and electricity consumed by the pressing iron and the hair dryer. Whenever, the electricity consumption or temperature reading exceeds the set threshold on the MATLAB app, a notification is sent to the user's Email. The system could be used for reducing the wastage of electrical energy in the house by proper scheduling and monitoring of the appliances.

Keywords: ESP 32 microcontroller, IoT, MATLAB, Thingspeak, MathWorks, WIFI module.

INTRODUCTION

Energy monitoring and management are one of the most critical needs for industries and households. In various fields like lighting, air conditioning etc. the concept of energy-efficient devices has emerged. Energy control is an essential method for the energy output assessment of various instruments. This document implements an energy monitoring system that shows the power consumed by each or several devices. This will help a customer spot power bill error. The internal energy bill frequently displays disproportionate sums, contributing to frustration and concerns by customers (S. Thakare, *et al*., 2016).

A smart energy monitoring and management program can help a consumer evaluate and handle the data on energy usage at unit level, rather than thinking it is a fixed monthly cost. This also lets a customer remove the normal, energy-efficient appliances. Importantly, the control device will alert the customer to excessive over usage arising from equipment malfunctions, lack of adequate maintenance and the like. Furthermore, careful use of resources will allow for better budgeting (S. Thakare, *et al*., 2016).

Several research works have been done on home automation technology. A ZigBee-based home automation device was developed. The interoperability of different systems in the home environment is a key part of the development process (K. Gill *et al,* 2009). Smartphone and Wi-Fi as a networking protocol and raspberry pi as a home computer monitoring and control system are seen in (Pavithra & Ranjith, 2015). Implementation of IPv6 and 6LoWPAN, which is a single network controller for both classic and modern forms of home automation, but the deployment cost of this home automation, is high (M. Kovatsch *et al.,* 2010). Wireless solutions such as ZigBee and 6LoWPAN are deployed as no cables need to be installed.

Real-time evidence on the control of household energy use through the Internet of Things (IoT) can be included in (R. Bhilare & S. Mali, 2015). The architecture of home automation focused on the stand-alone Arduino BT Panel, the home automation system built on a mobile phone (R. Piyare & M. Tazil, 2011). Introduction of a remote-control feature utilizing mobile and Bluetooth technologies can helps physically impaired people (R. A. Ramlee *et al.,* 2013).

The design of an energy meter that is focused on non-invasive current sensing was introduced (AH Shajahan & A Anand, 2013). The benefit of non-invasive current sensing is that it can be located at any level where the power is to be measure. The specifics of the energy used in this situation are seen on the smartphone. ENC28J60 the Ethernet module has been used to transfer data over the Network. An automated meter reading system (AMR) focused on power line contact (PLCC) was developed. PLCC includes the transmission of data through electrical wiring cables. This probability involves sufficient alteration of the domestic wiring of the building (SH Ju et al., 2015). Furthermore, an intrusive procedure is used to track the current from the mains. The downside of this kind of system is that the operator cannot calculate the power used by a particular unit.

Considering the contributions from various literatures, this paper proposes an electricity energy monitoring, temperature monitoring and electric load control. Electricity energy measurement will be handled by a non-invasive current sensing technique using a split core current transformer. Internet access is achieved through the ESP 32 microcontroller built in ESP8266 WiFi module. Temperature measurement is achieved through the use of a DHT 11 sensor and a MATLAB app is designed to serve as a dashboard for real time energy monitoring and control of electric load via thingspeak cloud server. This concept allows user to determine the smartest way to usage of electricity to avoid energy wastage.

SYSTEM DESCRIPTION

A. Overview

This paper proposes an IoT based household appliances energy monitoring and control system. The system computes the instantaneous power consumption, temperature measurement and uploads the values to the MATLAB app via thingspeak cloud using the Wi-Fi module. The block diagram of this system is as shown in **Figure 1**.

The system has ESP 32 microcontroller, DHT 11 temperature sensor and current sensor SCT-013-000 as its input devices. The current sensor is the main part of the circuit. The current values are sensed by SCT-013-030 on real time basis and are transmitted wirelessly to the server through the in-built Wi-Fi module of ESP 32 microcontroller. The user display is implemented through an OLED display module. **Figure 1** shows the configuration of IoT based household energy monitoring and control system. This is the interaction between system to system and system to the person. The multiple methods of monitoring and controlling of the appliances are used in this proposed system.

The temperature and current sensors were used as input to the ES32 microcontroller while the OLED display, LED and a pressing iron were used as output devices to the ESP 32 microcontroller. The ESP 32 microcontroller sends the sensed information to the internet via the thingspeak cloud server and the information are monitored via a MATLAB app.

The MATLAB app provides an additional option for switching the appliances (ON/OFF) of the home. Notification for excessive power consumption or over temperature notification was achieved through Email.

B. ESP 32 microcontroller

The ESP32 microcontroller, as seen in Figure 1, is dual core, which implies it has 2 processors. It's built-in for Wi-Fi and Bluetooth. It operates 32-bit programs and has a clock frequency that can reach up to 240MHz and has a RAM of 512 kB. This particular board has 30 or 36 pins, 15 in each row. It also has wide variety of peripherals available, like: capacitive touch, ADCs, DACs, UART, SPI, I2C and much more. It comes with a built-in hall effect sensor and built-in temperature sensor (R. Santos, 2020).

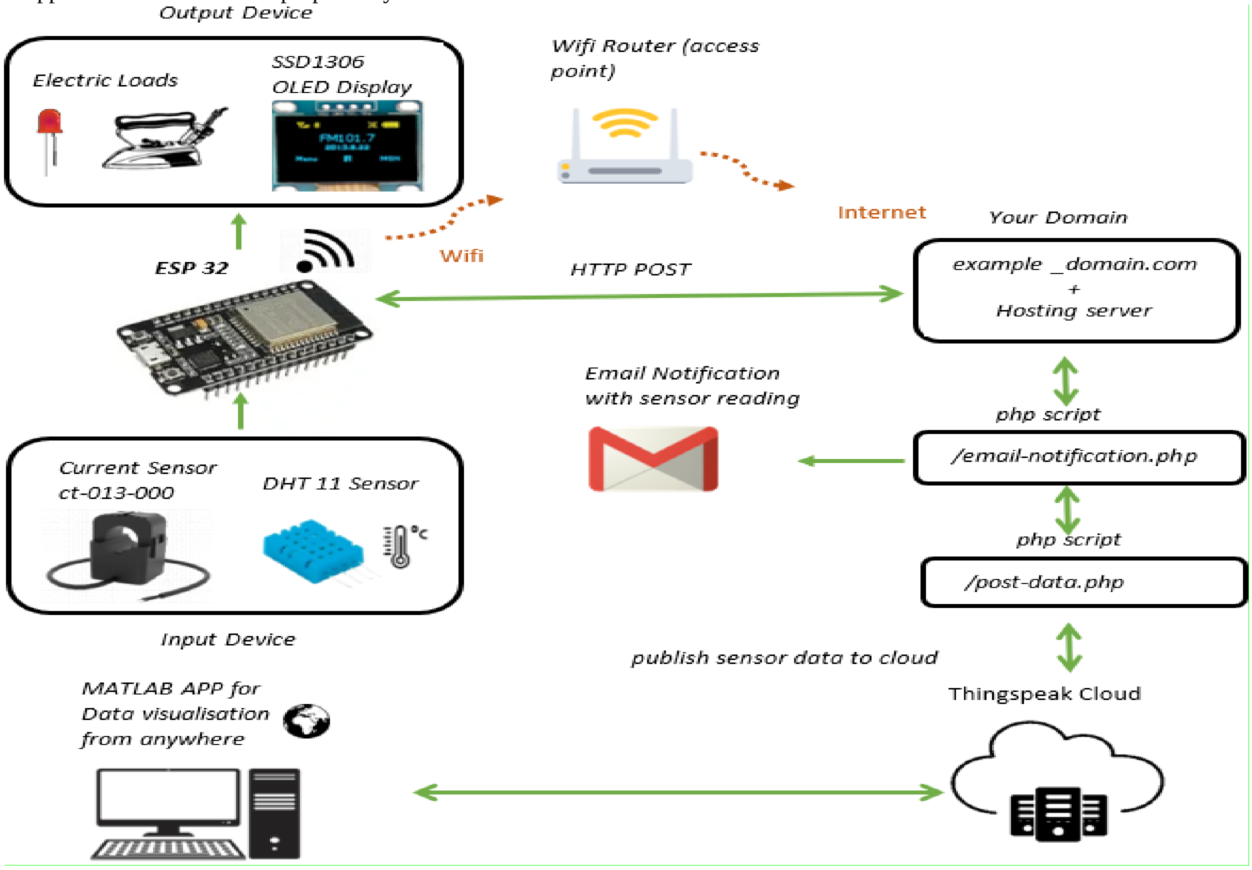

Figure 1: Configuration of IOT based Household Energy Monitoring and Control System.

C. Split Core Current Transformer sensor SCT-013-030

The SCT-013-030 series are AC (AC) sensors. These are particularly useful for measuring electricity consumption or generation in buildings. The sensor SCT-013-000 contains a sensing power of a nominal current of 100 A and provides a nominal output voltage of LV (Donald & Wayne, 1978). The resulting output voltage is then supplied by an analogue to digital converter (ADC) input of the ESP 32 microcontroller. With the support of the circuit shown in **Figure 2**, this voltage waveform is moved upwards by 1.65V dc. The output signal's rms value is decided within the system and its power is measured.

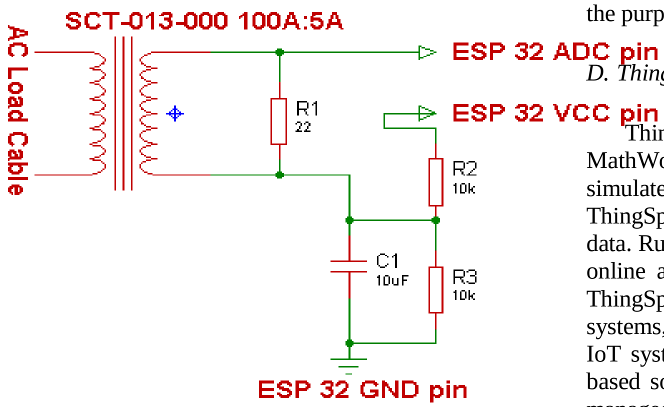

Figure 2: SCT-013-03 Sensing Circuit

The AC flowing within the primary produces a magnetic force field within the core, which induces a current within the secondary coil circuit [11]. This within the secondary coil is proportional to the present flowing within the primary winding:

$$I_{secondary} = CT_{turnsRatio} \times I_{primary}$$

$$CT_{turnsRatio} = Turns_{primary} / Turns_{secondary}$$

The number of secondary turns within the SCT-013-000 is 2000, therefore the current within the secondary is one 2000th of the present within the primary. This ratio is written in terms of currents in Amps e.g. 100:5 (for a 5A meter, scaled 0 - 100A).

1. Calculating a Suitable Burden Resistor Size

SCT-013-000 needs to be used with a burden resistor (see R1 in **Figure 2**) for its current output. The burden resistor completes or closes the CT secondary circuit. The burden value is chosen to provide a voltage proportional to the secondary current. The burden value needs to be low enough to prevent CT core saturation.

$$PPC = RMS\ current \times \sqrt{2} = 100\ A \times 1.414 = 141.4$$

$$SPC = \frac{(PPC)}{no.of turns} = \frac{141.4\ A}{2000} = 0.0707A \qquad (2)$$

Where PPC: Primary peak current
SPC: Secondary peak current

Since the ESP 32 is running at 3.3 V: AREF / 2 will be 1.65 Volts. So, the ideal burden resistance will be:

$$IDR = \frac{\left(\frac{AREF}{2}\right)}{SPC} = \frac{1.65\ V}{0.0707\ A} = 23\ \Omega \qquad (3)$$

Where IDR: Ideal burden resistance

23 Ω is not a common value, therefore 22 Ω was chosen for the purpose of this project as shown in **Figure 2** (R1)

D. ThingSpeak server for IoT

ThingSpeak is an IoT analytics software application from MathWorks (MATLAB). ThingSpeak helps to compile, simulate and evaluate live data sources in the cloud. ThingSpeak provides instant visualization of device or device data. Run the MATLAB code in ThingSpeak and perform the online analysis and processing of the data as it comes in. ThingSpeak accelerates the creation of IoT proof-of-concept systems, particularly those involving analytics. You can build IoT systems without setting up servers or developing web-based software as shown in **Figure 3**. ThingSpeak offers a managed solution for small to medium-sized IoT systems that can be used in manufacturing (mathworks, 2020).

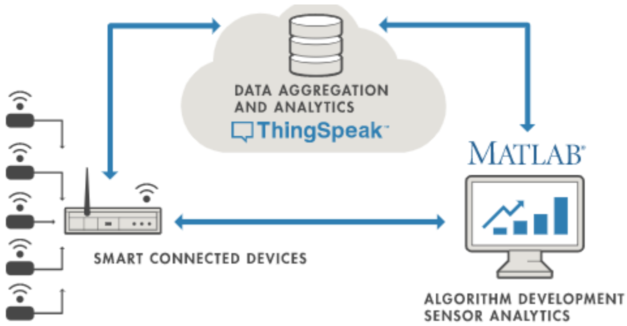

Figure 3: Layout of ThingSpeak server for IoT

E. MATLAB GUI App Designer

Without having to be a professional software developer, the App Designer lets you create professional apps. Drag and drop visual components to design the GUI, and to quickly program your behaviour using the integrated editor. The App can be shared using MATLAB Drive™, or by creating standalone desktop or web apps with MATLAB Compiler™ and Simulink Compiler [14]. **Figure 4** shows the designed MATLAB GUI app designed for this design.

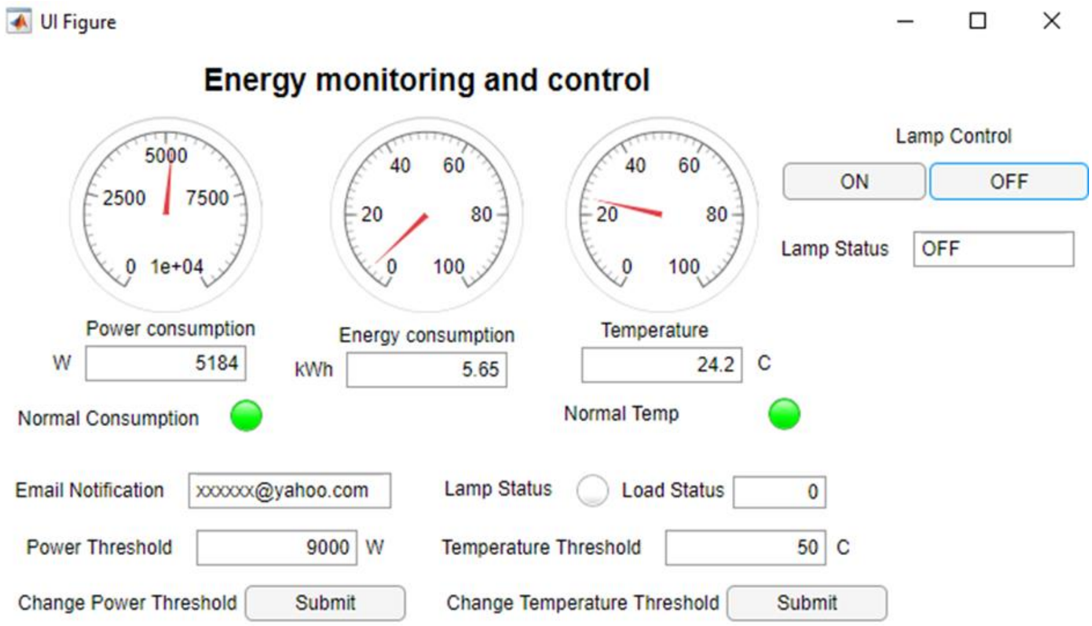

Figure 4: Designed MATLAB GUI App Designed for This Research

SYSTEM IMPLEMENTATION

Figure 5 shows the system block diagram where hairdryer and pressing iron life wire were passed through the current sensor. The current sensor and temperature sensor are connected as input devices to the ESP 32 via its Analog to Digital Converter (ADC). The relay, LED and OLED display are connected as output devices. The inbuilt WI FI module of the ESP 32 was used to connect to the home internet router for accessing the thingspeak cloud.

Figure 6 shows the hardware experimental setup used for testing and observing the performance of the household energy monitoring and control system.

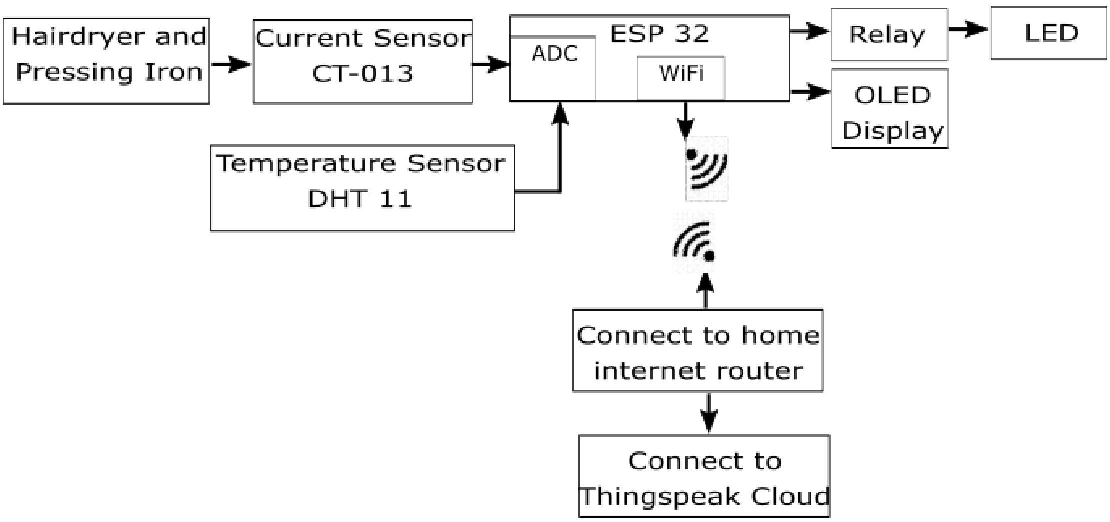

Figure 5: System Block Diagram

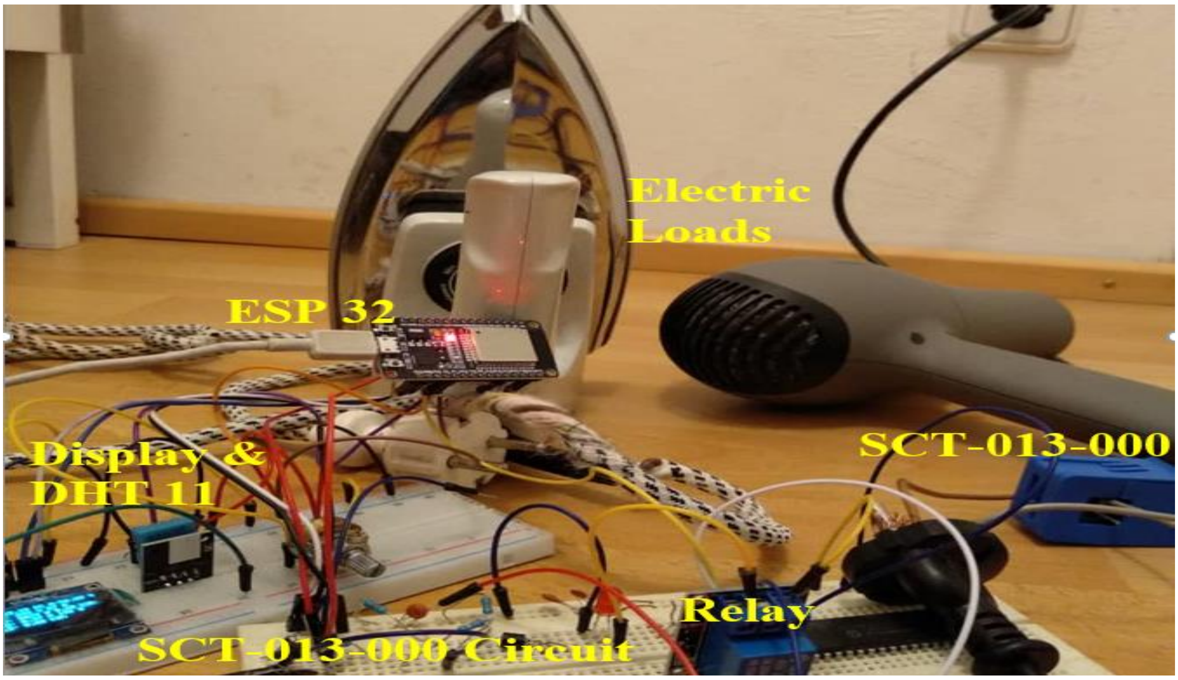

Figure 6: Hardware Experimental Setup

RESULTS AND DISCUSSION

Figure 7-9 show the testing of the system at different case scenarios. The STC 013-000 current sensor, DHT11 temperature sensor, relay board for LED control are connected to the ESP 32 microcontroller. A 2000 W and 1500W hair dryer and pressing iron were respectively considered as major electric consumers in this design. Arduino IDE software was used to program the ESP 32 microcontroller. The MATLAB app monitors the temperature and electricity consumed by the pressing iron and the hair dryer. Whenever, the electricity consumption or temperature reading exceeds the set threshold on the MATLAB app, a notification is sent to the user's Email.

For power consumption calculation of the major electric consumers, an assumed household RMS voltage of 240 VAC was multiplied in C program with the current sensed by the ESP

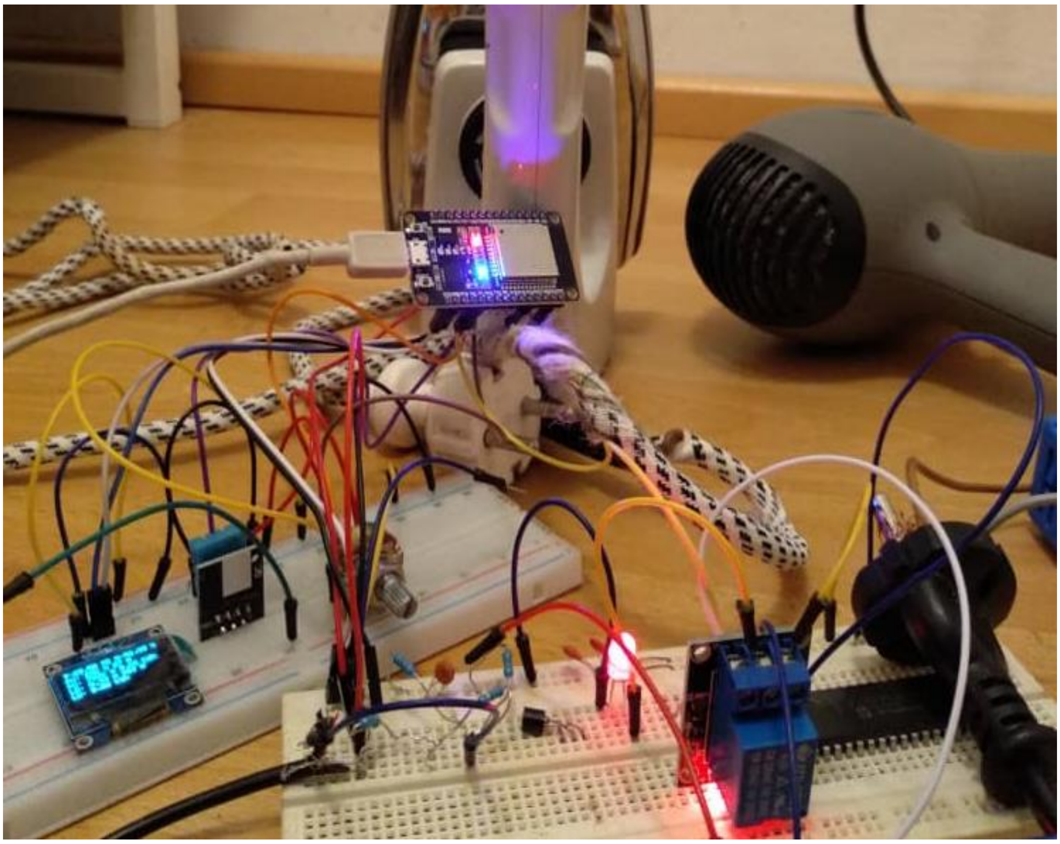

Figure 7: LED Control Via Relay and MATLAB App

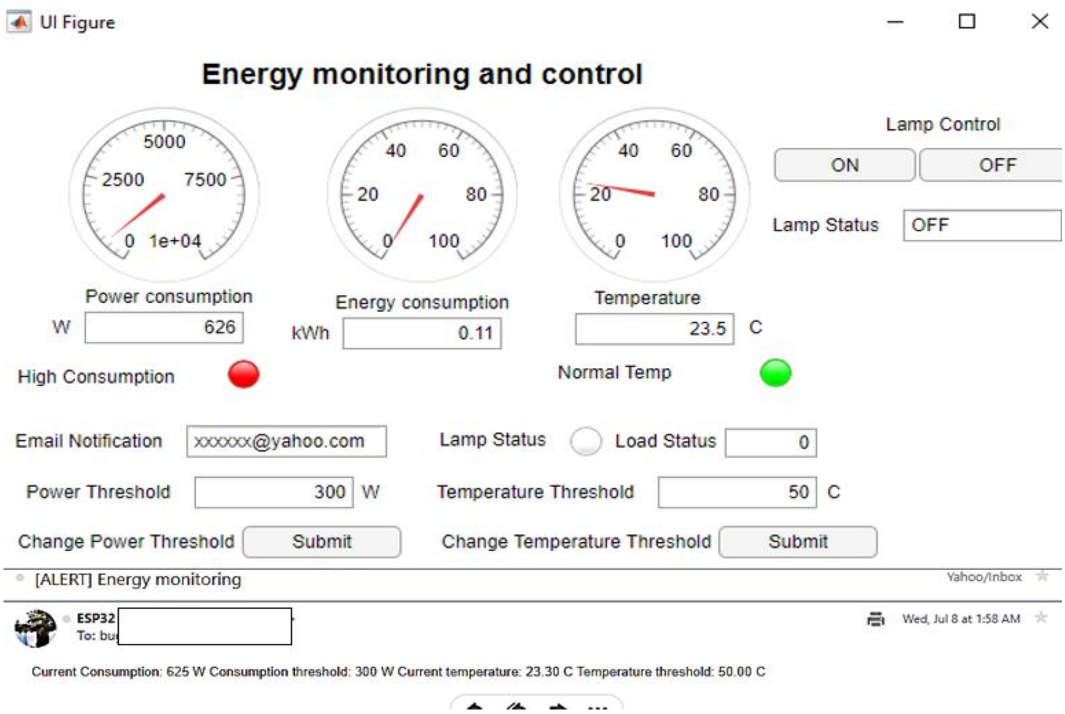

Figure 8: Email Notification for Over Consumption

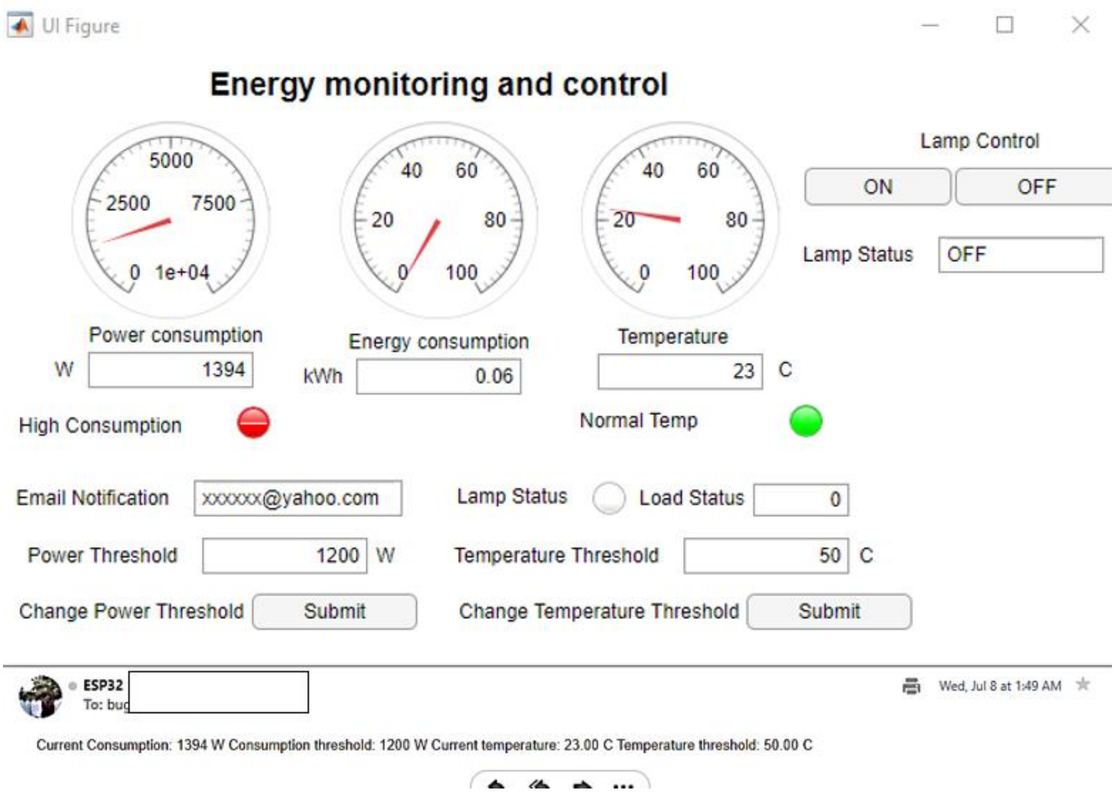

Fig. 9: Email Notification for Over Consumption

CONCLUSION

This paper presents the implementation of a household energy monitoring and control device which monitors the power consumption and temperature reading (see **Figures 7, 8 and 9**). The energy monitoring device assumes the voltage to be 230Vrms and subsequently computes the power consumed by means of current sensing only.

An LED is assumed to be a light bulb in the home and it was controlled (ON & OFF) using the MATLAB app via the thingspeak cloud server remotely.

Pressing iron and a hairdryer were used as major loads and the hairdryer was operated at different fan speed for validation of the implemented system. The power and energy consumption of the aforementioned major loads were transmitted via the thingspeak cloud server to the MATLAB app for monitoring from anywhere. Email notification was sent whenever temperature or power consumption exceeds the set threshold. This system could be used for reducing the wastage of electrical energy in the house by proper scheduling and monitoring of the appliances. Including voltage sensing into the hardware as well as processing it to calculate power can improve the accuracy of this device.

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