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IoT Based Smart Energy Management System

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Abstract

Energy is a very important aspect for any household, industries, agriculture and so. Managing the energy efficiently and conserving it intelligently for appliances is very much important. The energy usage is directly affected with Coal, oil and so towards power generation.

Towards this, there has been lot of research work carried out in developing some smart lighting system pertaining to classroom for conserving the energy. In one another research, researchers have developed Android based Smart home system for monitoring the usage of power to avoid any kind of anomaly.

In none of the research, researchers have worked towards automating the appliance control towards conserving the energy. Most of them concentrate on controlling the appliances using android devices.

So with the upcoming of machine to machine communication where devices can be connected wirelessly leading to IoT, we here have developed an IoT based Smart Energy Management system where appliances like Fan and Bulb to start with are controlled wirelessly based on humidity and light intensity information. These inputs are used towards controlling the appliances intelligently rather than just switching on or off. In addition the system also keeps computing throughput the day power consumption of the appliances which gives the user knowledge on power being consumed over a period of time. These details are updated in Cloud server. This prototype system developed have achieved energy conservation at every household

Keywords: Android, IoT, M2M

INTRODUCTION

Increasing economic growth and consumption patterns are leading to ever growing demand for energy. Since most of the energy supply is from fossil fuels, the resource is depleting thus increasing cost of energy. Burning fossil fuels has also increased concentration of carbon-di-oxide in the environment leading to extreme weather patterns. Hence it is imperative that Industries and commercial enterprises take steps to reduce energy wastage, become energy efficient and reduce costs.

Industry in India consumes 45% of the 900 billion Units of power produced. 35% of electric power produced is lost, and the losses are due to Transmission & Distribution (16%), theft (10%), Inefficiencies among users (10%). The 10% inefficiencies are largely among the industrial and commercial users who have high KVA HT connections. Inefficiency can also arise due to harmonic problems, faulty wiring, feedback from sub systems, and neighboring electrical systems. This leads to a drop in power factor and higher utilization of energy leading to higher rate slabs and penalties. Some organizations like Data centres measure Power Usage effectiveness where units consumed per annum is much higher than that required to power their total equipment. All these are applicable to industries like SMEs, cement, steel, auto, heat treatment/cooling, food processing, chemicals, plastics, textiles, commercial spaces using HVAC equipment, hospitals, hotels etc.

Research [1][2] has been carried out employing Raspberry Pi3 for monitoring the Temperature and humidity data and controlling the same resulting in an Automated temperature and humidity control using IoT

Research also been carried out in developing smart home monitor and control system using Zigbee, Bluetooth etc. Also research been done on Smart Home monitoring using Android and wireless sensor where usage characteristics of electrical power from each socket outlet is monitored in real time towards minimizing the hazards by electrical faults[3]

In addition to the above, research carried out employing IoT Technology for automatic lighting and control in Classroom using Arduino. The system can also be controlled using mobile app via bluetooth too.[4]

Also research been carried out towards developing an Energy

Management system for smart Home [5] towards managing energy consumption and generation simultaneously.

In none of the research, system been developed towards controlling the electrical appliance usage based on environmental condition which could ultimately reduce the energy consumption of home.

So with the upcoming of Machine to Machine communication where all appliances can be wirelessly enabled using Zigbee or Bluetooth, we here have developed a small IoT Prototype system employing Hall and Light intensity sensor to give the Temperature, humidity and light intensity of the environment. The readings are fed to Arduino microcontroller which in turn is communicated to Edge level processors called Raspberry Pi3 wirelessly. The proposed system is a smart Energy Management system consisting of a raspberry pi3, Arduino microcontroller, Wi-Fi shield and modules like Hall sensor, light intensity Sensor and ambient temperature sensor. The Arduino microcontroller will vary the appliance usage i.e. fan speed and light intensity based on humidity, temperature and lighting condition of the environment resulting in energy usage reduction. These amounts of current consumed by the appliances are captured and same sent to Raspberry Pi3 using Wi-Fi which ultimately calculate perdiocially the power and plots a graph on the power consumption and same uploaded in cloud server. This way the system have achieved consumption in energy usage of appliances i.e. fan and bulb based on environmental conditions. This gives the user's knowledge on power consumption of the appliances in real time. The rest of the paper is organized as follows. Section II talks on literature survey pertaining to the research work. Section III talks on our proposed IoT Based system along with Data Flow diagram and Flowchart of the entire system functioning. Section IV talks n hardware and software design pertaining to prototype. Section V talks on implementation results and analysis towards validating our system. Section VI is the Conclusion and Future work.

LITERATURE SURVEY

In this section, we would be discussing briefly on various literatures available pertaining to Energy Management and Smart Home System

In one of the research reported, IoT Based Automated Temperature and Humidity Monitoring and Control system developed [1] using raspberry pi. Pi receives the temperature as well as humidity values sensed and the same sent to the internet. This project however has resulted in prototype development of automated temperature and humidity control with good feasibility.

Research also been carried out towards Smart Home Control and Monitor System using IoT [2] where an User Friendly GUI been developed which can be accessed globally from any device that has internet connectivity.

In addition to the above mentioned research, Smart Home Monitoring prototype developed by employing Android mobile handset and Wireless Sensor systems [3]. This system monitors the usage characteristics of electrical power at the socket outlet in real time. This system measures the Voltage Current and temperature of socket outlet periodically from each room and monitored data sent to the system towards computing the threshold violation for action by the user before circuit breaker gets tripped or fire breakout happens.

Also research work carried out in developing an Automatic Lighting and Control System for Classroom [4] for the efficient use of energy. They have also provided mobility and remote command execution to system using Android mobile App via Bluetooth to control lighting based on voice command

Energy Management System for Smart Home [5][6] has been developed to manage energy at the level of appliances. So towards this a Smart Home Energy Management System Architecture been developed. In this system, Sensors control the energy consumption of home appliances. In addition Solar Energy is used as an alternate source where according to change in the weather conditions, resources can be switched. Energy data from numerous home servers are aggregated by the PC server and accordingly compare them for producing statistical analysis information.

IoT based Home Energy Management system for Rural Area in Myanmar [7] has also been developed. In this research, demand of electricity been forecasted and accordingly mechanisms been implemented towards meeting the energy demand. Energy demand could be met using non conventional energy sources like solar, thermal etc.

IOT BASED SMART ENERGY MANAGEMENT SYSTEM

The existing Smart Home and Energy Management system have looked more into controlling the appliances and also managing the hazards for electrical faults. In none of the research, system has been developed towards energy conservation by monitoring the environmental conditions and accordingly controlling the appliance usage accordingly.

So with the upcoming of Machine to Machine communication called IoT, we here have developed an IoT Based Energy Management System where environmental sensors like Temperature and light intensity sensor employed and reading sensed are sent to Arduino Microcontroller. Based on sensed reading, the Arduino microcontroller is programmed to control the appliance usage accordingly. In addition to controlling the appliance usage, the amount of current drawn by each appliance is computed using Hall Sensor which are sent wirelessly using Wifi module to Raspberry Pi3 where

total power consumption of each appliance is computer periodically and same plotted as graph. The graphical information on power consumption versus time for all appliances with varying environmental conditions is uploaded in cloud server. The system design of IoT based Energy Management system is shown in Fig. 1. Figs 2 and 3 shows the Data Flow Diagram and Use Case diagram of our system

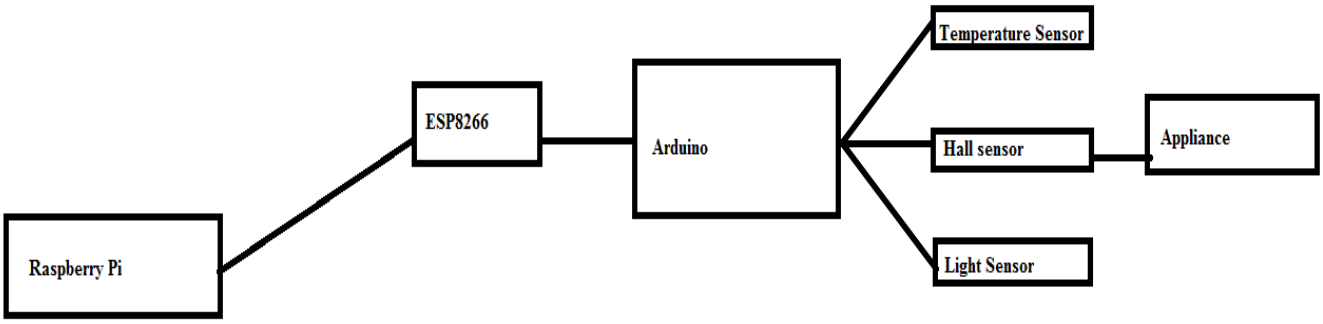

Figure 1: IoT Based Smart Energy Management System

The BH1750- light intensity sensor will be used to measure the light intensity in the form of lux and send it to the Arduino. The Arduino runs a code that obtains the temperature and humidity from the DHT11 sensor. The Arduino then controls fan and light based on the temperature, Humidity and light intensity. Based on the data captured the Arduino will also control the voltage required to be sent to the appliance with the help of transistor. The Hall sensor will measure the amount of current sent to the appliance and send it to the Arduino. The Arduino will then send the current consumed to the raspberry pi. The pi will receive the current consumed and calculate the power consumed and then upload it to a webpage and also will plot a graph based on the amount of current consumed.

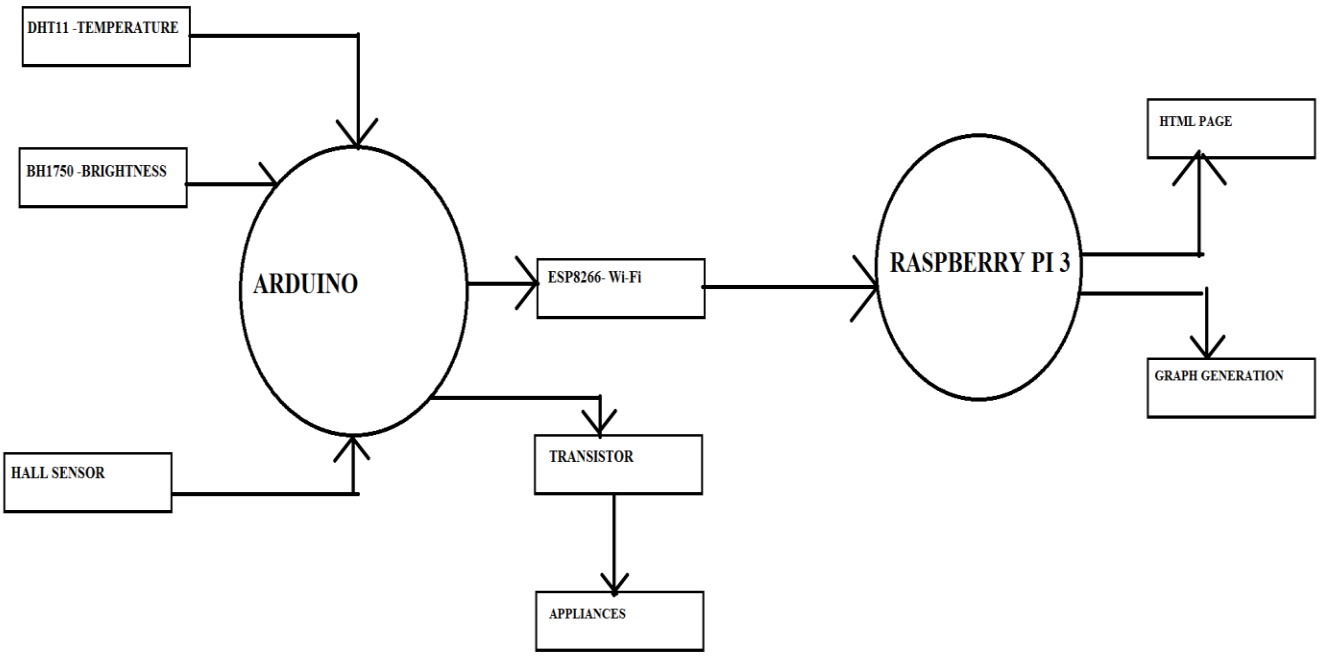

Figure 2: Data Flow Diagram

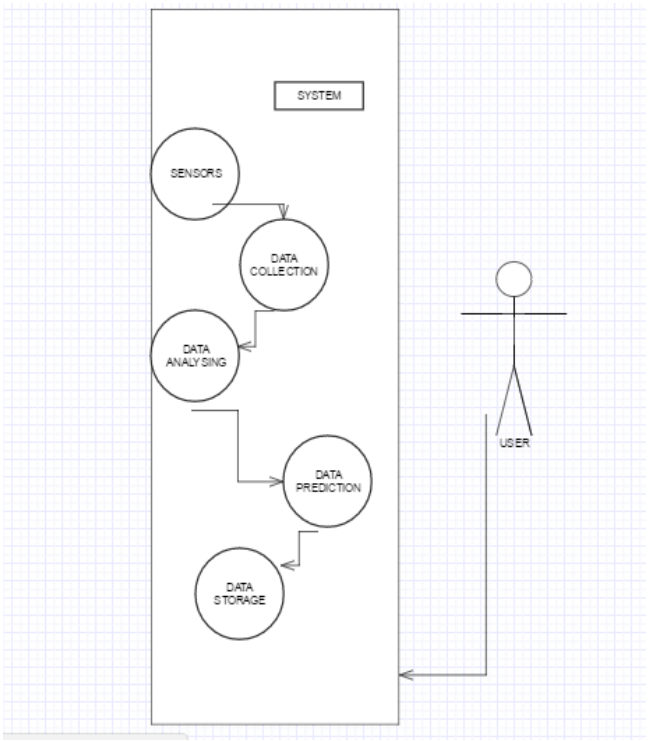

Figure 3: Use Case Diagram

A. Algorithm

The power consumption of the appliances is measured every 30 seconds and sent to the Raspberry pi. The Arduino calculates the current consumed in amperes and sends it to the pi. The pi then calculates the power with the help of voltage. The Maximum power consumed by the appliance at highest usage is 60 watts but with the help of this system the maximum goes only up to 45 watts. The power consumed is stored in a list and from the list we can calculate the average total power consumed in the day.

- The temperature and brightness is obtained from the real time environment
- The Arduino controls the transistor based on the value obtained from the sensor.
- The Current consumed by the appliance is obtained from the Hall sensor
- The Current value is sent to the Pi.
- The Pi calculates the power and uploads it to the HTML page and plots the graph.

HARDWARE AND SOFTWARE DESIGN

The hardware components used in this system are connected with the help of jumper wires. The temperature sensor and the light intensity sensor are deployed into the environment to collect real time data. Since we have only developed a prototype we have not used appliances like fan and light that run on 220 volts of power instead we have used a computer coolant fan that runs on a 12volt battery and a led light instead of an electric bulb. The connections that have been made to each of the hardware components are given in the description following each component

A. Humidity and Temperature Sensor

DHT11 Sensor is a temperature and humidity sensor which has been calibrated with digital signal output. This Sensor ensures high reliability and excellent long term stability. Resistivity type humidity measurement and NTC temperature measurement component is included in this type of sensor which is connected to a 8 bit microcontroller which ultimately offers an excellent quality, fast response, anti-interference and cost effectiveness.

Figure 4: DHT11 sensor

B. Light Intensity Sensor

BH1750FVI is a Digital Light sensor which is most suitable for obtaining the ambient light towards adjusting LCD and Keypad backlight power of Mobile phone . Unit of light quantity is called lumen where light flows from a source in one second. In here, reading are taken as Lux which is equal to one lumen per square meter:

Lux=1Lm/m2**.**

Figure 5: Light intensity sensor

C. Darlington Resistor

The transistor is used to vary the amount of current going into the appliance. This resistor called Darlington pair consists of

compound structure containing two bipolar transistors. These two transistors are connected in such a way that current amplified by the first transistor is amplified by the second one.

Figure 6: Darlington transistor

The transistor consists of three pins the base pin, the emitter pin and the collector pin. The collector pin is connected to the Arduino, the base pin is connected to the wire that carries power supply to the device and the emitter pin is connected to the ground pin. The amount of current passing can be controlled by giving different values in between 0-255. The collector pin is connected to the analog output pin number 9 for the power supply to fan and the collector pin is connected to the analog output pin number 10 for the power supply to the light. In this prototype since we need to measure the amount of power consumed, the wire from base pin is connected to one end of the current sensor.

D. Hall Sensor

The Allegro™ ACS712 is a Hall sensor providing economical and precise solution in industries, commercial and communication systems. The hall sensor is used to measure current flowing in the wire. The hall sensor can measure the current by placing a fixed resistance for the wire. A part of the wire that is going to the appliance from the transistor is cut and made to go through the hall sensor. The hall sensor has 3 pins- voltage pin, the ground pin and the output pin. The voltage pin is connected to the 5 volt supply from Arduino and the ground pin is connected to the ground and the output pin is connected to the analog pin in the Arduino. The output pin from the hall sensor measuring current in fan is connected to the analog pin A2 and that measuring the current into light is connected to Arduino pin A1.

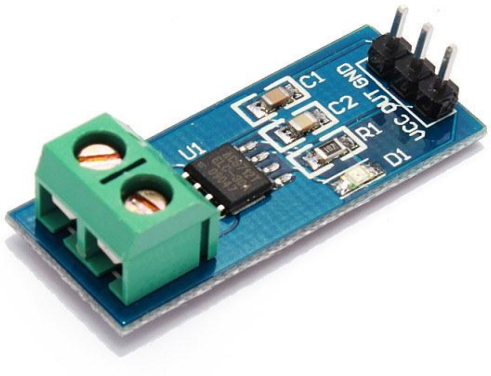

Figure 7: Hall sensor

E. ESP8266 Wi-Fi Module

ESP8266 is a Wi-Fi networking module or solution allowing Wifi networking function from one host to another. The ESP8266 requires 3.3 v to 5V. ESP8266 need to communicate via serial 3.3 V and does not have 5V tolerant inputs, so you need level conversion to communicate with a 5V microcontroller like most Arduino use.

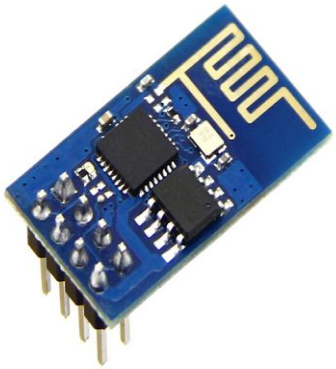

Figure 8: ESP8266 Wi-Fi module

F. Appliances

In this research, we have tried to depict 2 appliances light and fan. The PC cooling fan is used instead of a real fan and a Led is used instead of a light. We have used a 12 volt battery as a power supply to both the appliances. To operate with real appliances, we will use a relay to switch off and on the power and a 220 volts electricity voltage line. The cooling fan runs at top speed at maximum of 12 volt and the light too glows brightest at full 12 volt, the speed of the fan and dimness of light can be controlled by the transistor.

Figure 8: Appliances

The Arduino UNO is responsible for getting temperature and intensity of light from the sensors and based on that it varies the current provided to the appliances and it also then measures the current consumed by each appliance and then sends this data to the raspberry pi. To accomplish this task in Arduino, we use the Arduino IDE version 1.6.12. The Raspberry pi is installed with the Noobs Operating System and has been provided with a 8 GB memory card. Both the Pi and the Arduino have to be connected to the same network. The raspberry pi runs a python code that receives data continuously from the Arduino and then computes power computed and plots a graph and also uploads the data into a html page. The IoT based Energy Management System is also tested with the possible real time sensor values that will generate different output based on specific threshold. The test cases used to verify the correctness of application logic is given in Appendix A. The actual output of the system verified with the expected output and found it is perfect

IMPLEMENTATION RESULTS AND ANALYSIS

The complete hardware prototype of IoT based Energy Management system developed employing Arduino and Raspberry Pi3 as microcontroller and processing unit. In addition Temperature and Light Sensors deployed and same connected to Arduino microcontroller. Also the Arduino unit connected using Wi-Fi Module to Pi3 for communication of current drawn from each appliance for computing total power consumed and same plotted as graph. The results been updated as HTML Webpage in Cloud server. Fig.9 shows the complete IoT based Energy Management System Prototype wit all sensors and connection

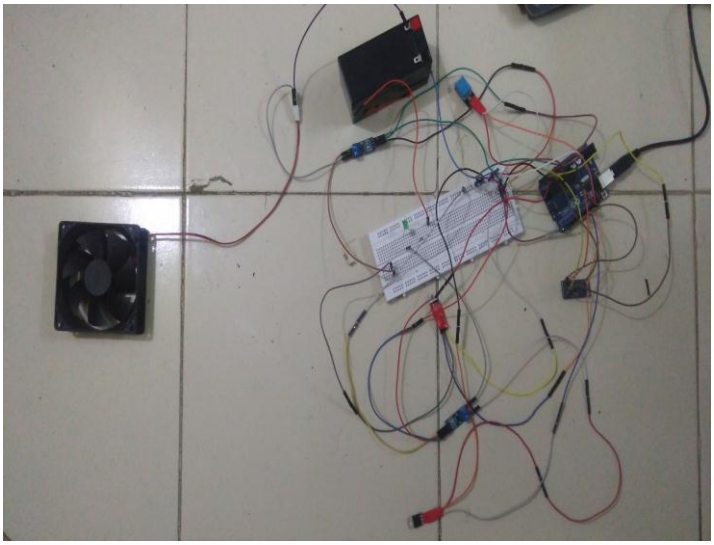

Figure 9: Hardware Prototype

Fig.9 shows the Arduino IDE Environment of controlling the appliances.Fig.13 shows the Raspberry Pi3 environment where Python code written for receiving the current consumed for calculation total power consumed for each appliance. Fig.14 shows the total power consumption of the appliances based on current drawn from the appliances against time. The same plotted as a graph. Fig.15 and 16 shows the HTML Webpage of total power consumption

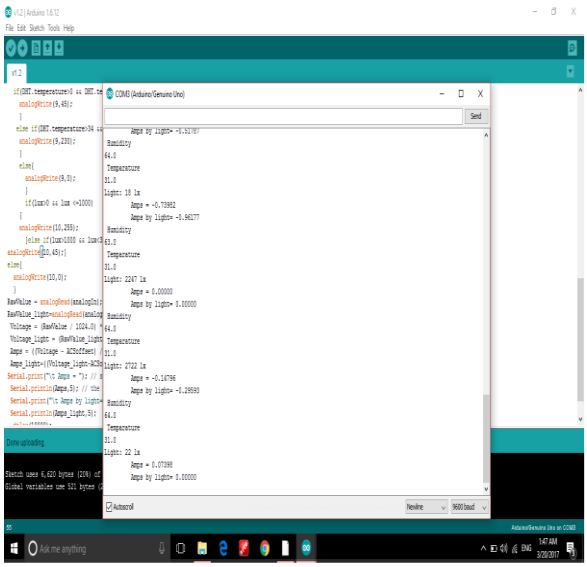

Figure 10: Arduino IDE Serial Window

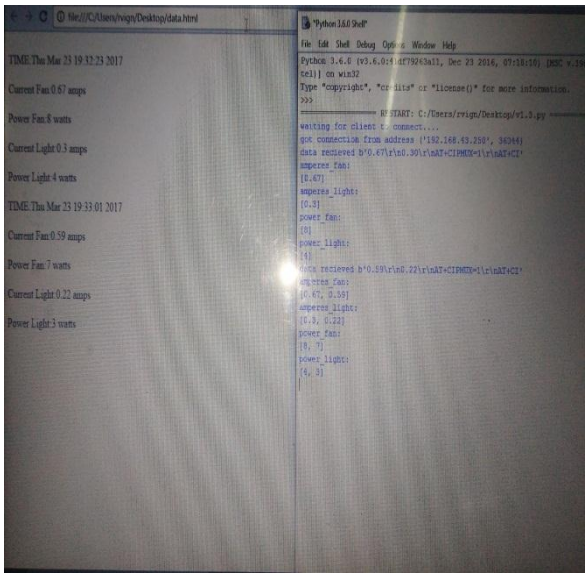

Figure 11: Python Receiving side

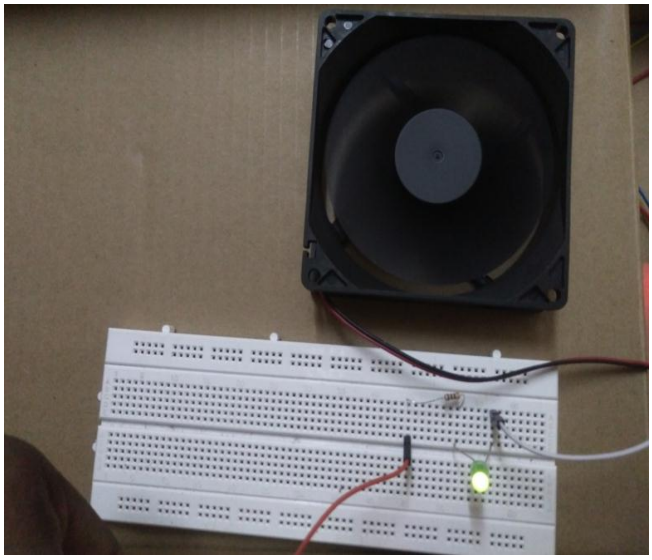

Figure 12: Appliances Operating at Full Power

Fig.12 fan operating at full speed and light in full brightness based on Temperature and Light intensity.Fig.13 shows the fan operating at half speed and light in dim condition based on temperature and light intensity. The two screenshots show as how appliances controlled based on environmental condition for energy consumption by Arduino Microcontroller

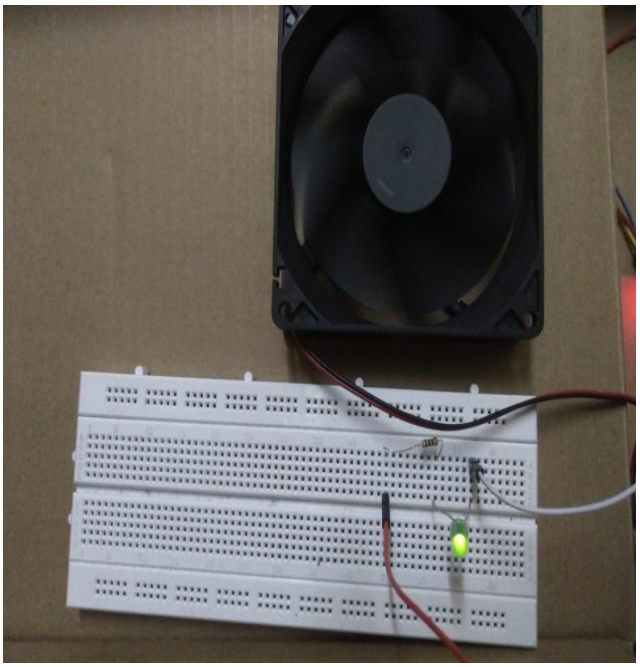

Figure 13: Appliances Operating at Half Power

Fig.14 shows the total power consumption of the appliances based on current drawn from the appliances against time. The same plotted as a graph. Fig.15 and 16 shows the HTML Webpage of total power consumption

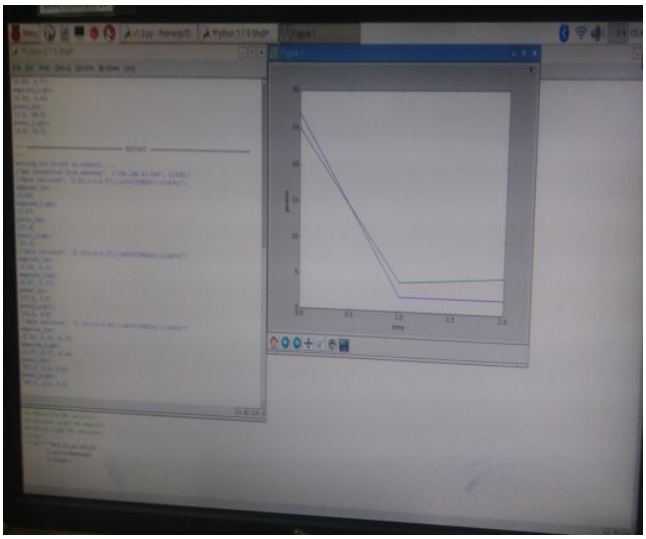

Figure 14: Power Consumption of Appliances

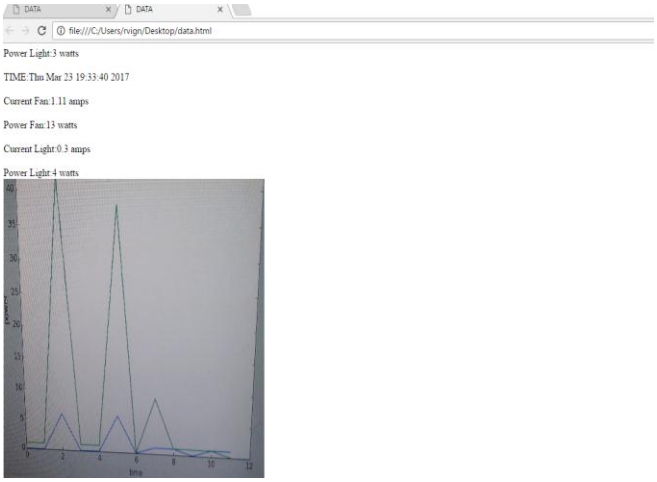

Figure 15: HTML page

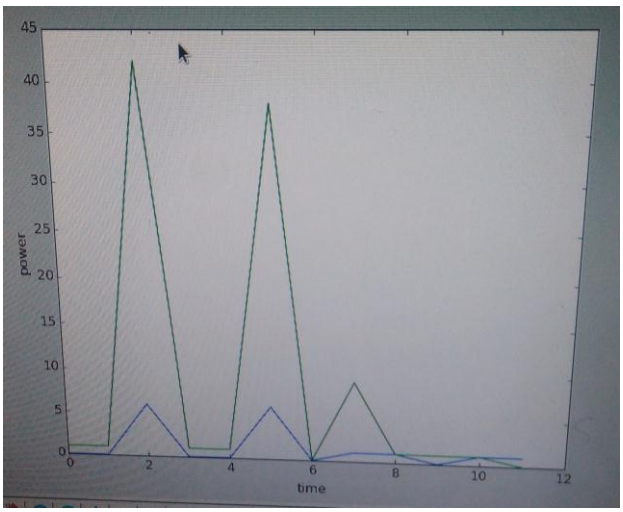

Figure 16: Total Power Consumption

CONCLUSION AND FUTURE WORK

Smart Home and Energy Management is current trend with the development of IoT. Lot of work been reported in regards to controlling the appliances of home and also on monitoring the electrical parameters towards hazard. Also work reporting in controlling the appliance for energy consumption.

So with all these work reported, we here have developed an better IoT system for Energy Management which takes the Humidity, Temperature and light intensity into consideration and accordingly interfaced with Arduino Microcontrollers for controlling the usage of appliance like speed of fan, light intensity rather than just switch on or off. Also the prototype system computes the current drawn from each appliance based on appliance usage and send to Raspberry Pi3 where total power consumed of appliances computed against time. This information is computed all through the day and same uploaded in cloud server too. This ultimately achieves in energy consumption of every household resulting in Energy Management using IoT. The system so developed is not fully complete as we have developed a prototype only for controlling two appliances i.e. fan and light. In future, we propose to extend the system for controlling appliances like Refrigerator, Air cooler, Television etc. The presence of human only will switch on the appliances. More amount of power can be saved based on the lesser usage of the appliances. There can be also a manual control over the appliances. We can implement algorithm that learns the change in the weather based on season and detect changes in season based on the temperature, humidity and brightness.

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