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IoT Based Smart Energy Management System

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Abstract- For each family, industry, or agricultural operation, energy is a crucial component. It is vital to carefully manage energy use and intelligently conserve it for appliances. Energy is a very crucial resource as it is the backbone of industries. Without proper management of energy there are multiple negative affects levied. These include rising temperatures, heat waves and drought, higher sea levels, abnormal weather patterns, increased intensity of natural disasters, smog and acid rain. Such outcomes are detrimental to all the species of the planet. Reducing energy usage lowers the quantity of electricity required by power plants, which in turn lowers the daily amount of fossil fuels burnt. Even a minor adjustment can have a big impact. Damage caused by water or high humidity which in turn leads to moisture in the energy meter is a common household issue, which is still undermined. Damaged wiring may arc or result in power surges that could break permanently plugged-in equipment. This may in turn lead to dangers to human life as well as property. Thus, it is also important to notify the user regarding high level of humidity so prevention methodologies can be utilized timely. Consequently, with the advent of machine-to-machine communication in which devices can be wirelessly connected, leading to IOT, we have developed an IOT-based Smart Energy Meter system in which appliances, such as light bulbs, can be remotely controlled based on humidity and light intensity data. These inputs are utilized to intelligently control the appliances, as opposed to just turning switch on or off. In addition, the system keeps track of the day-to-day power use of the appliances, thereby providing the user with information regarding power consumption over time. And a bill will be generated, along with a payment window for that bill. The Cloud server is updated with these particulars. High humidity is also detected in order to save the device from any damage that might be caused due to water, or rain. Every household can conserve energy with the help of this prototype device.

I. Introduction

Increasing economic growth and consumption patterns contribute to an ever-increasing energy demand. Since the majority of energy is derived from fossil fuels, this resource is dwindling and driving up energy prices. Additionally, the use of fossil fuels has raised the concentration of carbon dioxide in the atmosphere, contributing to extreme weather patterns. Therefore, it is vital that industries and businesses adopt measures to reduce energy waste, become more energy efficient, and cut expenses.

In India, 45 percent of the 900 billion Units of energy produced are consumed by industry. 35% of the electricity produced is lost due to transmission and distribution (16%), theft (10%), and consumer inefficiency (10%). The 10% inefficiency rate is concentrated among industrial and commercial users with high KVA HT connections. Inefficiency may also result from harmonic issues, bad wiring, subsystem feedback, and nearby electrical systems. This causes a decline in power factor and an increase in energy consumption, resulting in higher rate slabs and fines. Some enterprises, such as data centers, analyses the effectiveness of their Power Usage when the annual units consumed are significantly higher than those required to power their complete equipment. All of these are applicable to industries such as SMEs, cement, steel, automotive, heat treatment/cooling, food processing, chemicals, plastics, textiles, commercial spaces utilizing HVAC equipment, hospitals, and hotels, among others.

Utilizing Raspberry Pi3 for monitoring and controlling temperature and humidity data has resulted in automated temperature and humidity control via IoT. Research has also been conducted on the development of a smart home monitoring and control system.

In addition to the foregoing, research was conducted using raspberry pi and IOT technology for automatic room lighting and control.

No research has resulted in the development of a system for managing the electrical appliance usage based on ambient conditions, which could ultimately minimize residential energy consumption.

With the advent of Machine-to-Machine communication, where all appliances may be wirelessly enabled via Zigbee or Bluetooth, we have designed a small IoT Prototype system employing Hall and Light intensity sensors to measure the environment's temperature, humidity, and light intensity. The readings are sent to Raspberry Pi3 edge-level processor.

The suggested system is a Smart Energy Management system comprised of a Raspberry Pi 3 and modules such as a DHT11, a light intensity sensor, and an ambient temperature sensor. The Raspberry Pi microprocessor will adjust the appliance usage, such as light intensity, based on the environment's humidity, temperature, and lighting conditions, thereby reducing energy consumption. These amounts of current utilized by the appliances are captured and delivered to ThingSpeak, which calculates the power periodically and produces a graph of the power usage before uploading the data to a cloud server. In this manner, the system has optimised the energy consumption of equipment, such as light bulbs, based on ambient circumstances. This provides the user with real-time information regarding the energy consumption of the equipment.

The Raspberry Pi also utilizes the Python package Tkinter to create a graphical user interface for a prototype for the user to pay their energy bill, as well as alerting the user of high humidity conditions and sending an SMS reminder to pay the bill.

The remaining sections are organized as follows. Section II discusses the literature review pertinent to the research project. The third section discusses our suggested IoT-based system and includes a data flow diagram and flowchart of the full system's operation. The fourth section discusses hardware and software design in relation to the prototype. Section V discusses implementation findings and system validation analyses. Conclusion and Future Work comprise Section VI.

II. LITERATURE REVIEW

This section will provide a quick overview of the available literature on Energy Management and Smart Home Systems.
In one of the described research projects, a Raspberry Pi-based IoT-based automated temperature and humidity monitoring and control system was built. Pi gets the measured temperature and humidity measurements, which are then uploaded to the internet. This research has resulted in the construction of a feasible prototype for automated temperature and humidity management.
Research has also been conducted on IoT-based Smart Home Control and Monitoring Systems, for which a graphical user interface that can be accessed globally from any internet-connected device has been established.
In addition to the aforementioned studies, a prototype for Smart Home Monitoring was created using an Android mobile phone and Wireless Sensor systems. This technology checks the electrical power use characteristics at the socket outlet in real time. Periodically, this system checks the Voltage, Current, and Temperature of socket outlets in each room. The monitored data is then supplied to the system for the purpose of calculating threshold violations and alerting the user before the circuit breaker trips or a fire breaks out.
On addition, research is conducted in the development of an Automatic Classroom Lighting and Control System for energy conservation. In addition, mobility and remote command execution have been added to the system utilizing an Android mobile application and Bluetooth for voice-activated lighting control.
A Smart Home Energy Management System has been created to control energy at the appliance level. Consequently, an architecture for a smart home energy management system has been designed. Sensors regulate the energy usage of household appliances in this system. In addition, Solar Energy is employed as a backup source where resources may be swapped in response to weather conditions. The PC server aggregates energy data from several home servers and compares them to produce statistical analysis information.
In addition, an IoT-based Home Energy Management system for rural Myanmar has been created. In this study, the demand for electricity has been predicted, and methods have been established to supply that need. Non-conventional energy sources, such as solar, thermal, etc., might provide the energy need.

III. IOT BASED SMART ENERGY MANAGEMENT SYSTEM

Existing Smart Home and Energy Management systems have focused primarily on appliance control and the management of electrical fault hazards. No study has resulted in the development of a system to conserve energy by monitoring ambient conditions and adjusting appliance usage accordingly and providing user alerts for bills and humidity detection.

With the advent of Machine-to-Machine communication, also known as IoT, we've created an IoT-based energy management system that employs environmental sensors such as temperature and light intensity sensors and sends the readings to Raspberry Pi 3. The Raspberry Pi is configured to control the appliance usage based on the readings sensed. In addition to limiting appliance usage, the amount of current drawn by each appliance is computed using DHT11 and transmitted to Raspberry Pi3, where the total power consumption of each appliance is computed periodically and graphed. Graphical information on the relationship between power usage and time for all appliances operating under varied environmental conditions is posted on ThingSpeak. This data can then be further analyzed to understand user consumption patterns of energy.

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.

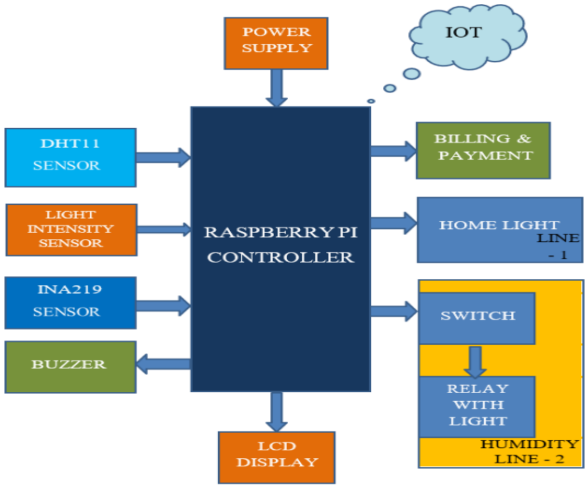

Figure 1: IoT Based Smart Energy Management System

This project starts by taking input from sensor readings from DHT-11 SENSOR (Take temperature and humidity readings) DHT11 sensor measures and provides humidity and temperature values serially over a single wire. It can measure relative humidity in percentage (20 to 90% RH) and temperature in degree Celsius in the range of 0 to 50°C.It has 4 pins; one of which is used for data communication in serial form.

Next, take light intensity readings from the LDR sensor.

The LDR Sensor Module is used to detect the presence of light / measuring the intensity of light. The output of the module goes high in the presence of light and it becomes low in the absence of light. The sensitivity of the signal detection can be adjusted using potentiometer.

Now, all these readings are then processed in the Raspberry pi.

The Raspberry Pi is a very cheap computer that runs Linux, but it also something provides a set of GPIO (general purpose input/output) pins, allowing you to control electronic components for physical computing and explore the Internet of Things (IoT).

Here, If LDR is less than or equal to threshold (i.e. LDR <=40000) the display screen displays "NIGHT TIME" and the LED is turned "ON". A light-emitting diode is a semiconductor device that emits light when current flows through it. Electrons in the semiconductor recombine with electron holes, releasing energy in the form of photoDHT11ns.

Once the LED glows, INA219 which is mainly the current sensor measures current and gives power and voltage.

The INA219 based Current sensor module CJMCU-219 is an I2C interface based zero drift and bi-directional current/power monitoring module. It can sense shunt voltage, current, and power at the same time and submit the data via I2C protocol. It has 0.1 Ohms, a 1% shunt resistor to fulfill the requirement

of current measurements. It has a powerful 12-bit ADC that converts the current sensed by a precision amplifier. The current sensing range is ±3.2A with a resolution of 0.8mA. Or else, if the LED doesn't glow, continue to record readings and send these readings to ThingSpeak. ThingSpeak is a IoT Cloud platform where you can send sensor data to the cloud. It includes a Web Service (REST API) that lets you collect and store sensor data in the cloud and develop Internet of Things applications. It works

with Arduino, Raspberry Pi and MATLAB (premade libraries and APIs 18 exists).But it should work with all kind of Programming Languages, since it uses a REST API and HTTP.

Henceforth, energy is calculated and further bill is generated. Tkinter module is used for generation of GUI for the user. Tkinter is the standard GUI library for Python. Python when combined with Tkinter provides a fast and easy way to create GUI applications. Tkinter provides a powerful object-oriented interface to the Tk GUI toolkit. Import the Tkinter module.

Hereafter, SMS is sent to the user to pay bill using Twillio API.

Twilio is a cloud communication company that enables users to use standard web languages to build voice, VoIP, and SMS apps via a web API. Hence, the Graphic User Interface is displayed to the user to pay bill. After successful payment completion the program execution stops.

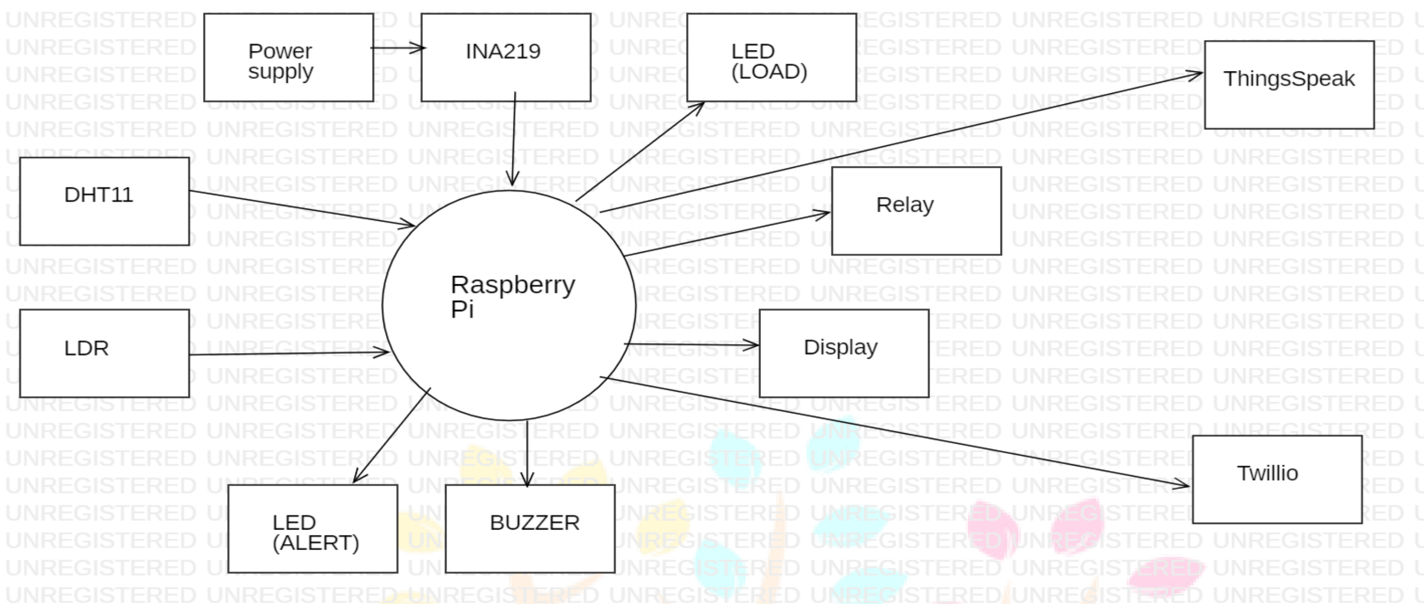

Figure 2: Data Flow Diagram

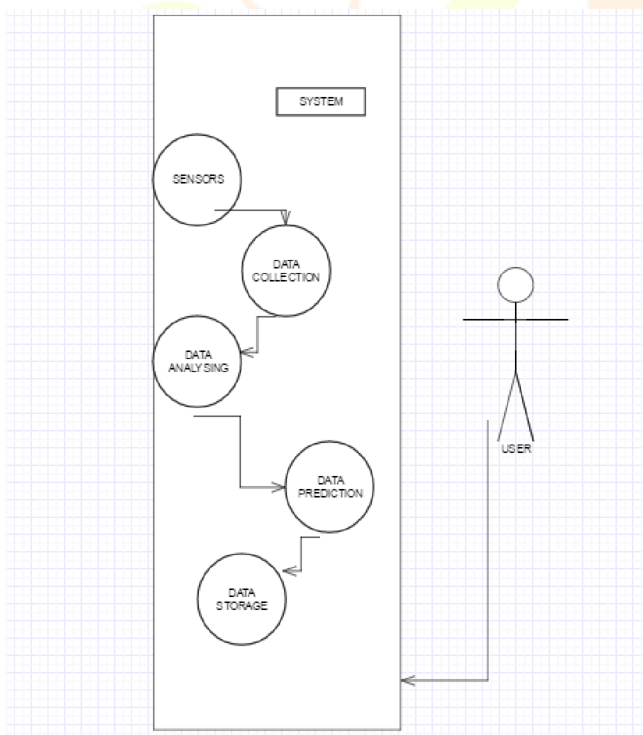

Figure 3: Use Case Diagram

A. ALGORITHM

Step 1: Initialize variable "TH" to record humidity and temperature readings from DHT11 sensor connected to pin 13 of raspberry pi.

Step 2: Initialize variable "ina" to record voltage, current and power recordings captured by INA219.

Step 3: Initialize variable "ldr" to record light intensity readings from LDR sensor connected to pin 21.

Step 4: Record humidity, temperature and light intensity readings.

Step 5: If (LDR <=40000) display "NIGHT TIME" and turn on LED, else continue to record readings and sent the reading to ThingSpeak.

Step 6: If humidity >80 turn on buzzer and display "IS IT RAINING? SAVE DEVICE FROM WATER", else continue.

Step 7: Calculate Energy from voltage, current and power readings recorded.

Step 8: Display total energy and bill amount.

Step 9: Send user SMS to pay bill using Twillio API.

Step 10: Display graphic user interface for user to pay bill.
Step 11: After successful payment completion STOP the program execution.

IV. 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

A calibrated temperature and humidity sensor, the DHT11 Sensor provides a digital signal output. High dependability and exceptional long-term stability are guaranteed by this sensor. This type of sensor, which connects to an 8-bit microcontroller, includes components for resistivity-type humidity measurement and NTC temperature measurement. As a result, it provides great quality, rapid response, interference-resistance, and cost effectiveness.

Figure 4: DHT11 sensor

B. Light Dependent Resistor

A photoresistor, also known as a light-dependent resistor, is a light-sensitive electrical component. The resistance alters as light strikes it. The resistance of the LDR can vary by orders of magnitude, with the resistance decreasing as the light intensity rises. An LDR or photoresistor's resistance values frequently range from several megaohms in complete darkness to a few hundred ohms under intense light. LDRs are still utilised in a number of applications where it is important to detect light levels, even though they were once used in photographic light meters. LDRs have been employed in a wide range of applications due to their inexpensive cost, ease of fabrication, and simplicity of usage.

Figure 5: Light Dependent Resistor

C. Raspberry pi

The Raspberry Pi is a credit card-sized minicomputer that can communicate with any input and output hardware, such as a monitor, a television, a mouse, or a keyboard, turning the setup into a fully functional PC at a reasonable price. The Raspberry Pi is a programmable gadget. Although it lacks ports and internal storage, it has all the essential components of a motherboard of a typical computer. An SD card inserted into the designated space is required to configure the Raspberry computer. The operating system should be placed on the SD card, which is needed for the computer to boot. Linux OS works on Raspberry Pi devices. This fosters diversity and reduces the volume of memory required.

After configuring the operating system, Raspberry Pi can be connected to output devices such computer monitors or High-Definition Multimedia Interface (HDMI) televisions. Keyboards and mice for input also need to be connected.

Figure 6: Raspberry pi

D. LED

When an electric current passes through a semiconductor device called a light-emitting diode (LED), the LED emits light. When current flows through the LED, the electrons and holes recombine and produce light. LEDs only let current flow in one direction—forward—and stop it from going the other way.

P-n junctions in light-emitting diodes are highly doped. When forward biassed, an LED will emit a colored light at a certain spectral wavelength depending on the semiconductor employed and the amount of doping. An LED is enclosed with a transparent cover, as seen in the image, to allow the light that is emitted to escape. Electrons from the semiconductor's conduction band recombine with holes from the valence band when the diode is forward biassed, releasing enough energy to produce photons that radiate monochromatic (single-color) light. Due to the thin layer, a sizable percentage of these photons are able to radiate from the junction and produce coloured light. Then, we may say that Light Emitting Diodes are semiconductor devices that transform electrical energy into light energy when operated in a forward biassed direction.

Figure 7: LED

E. INA219 Current Sensor

Texas Instruments released the INA219 shunt Current Sensor module. This module, which tracks shunt voltage, Bus voltage, current, and power, is zero-drift and bidirectional. The microcontrollers can receive data through an integrated 12C or SMBus-compatible interface. With a high resolution of 12-bits and 16 programmable addresses for flexible setup, the device contains an analog-to-digital converter. It includes an extra multiplier register that changes the power into watts. This compact, low-power current sensor gadget is useful for little embedded projects. The INA219 Current Sensor is a zero drift and bi-directional current/power monitoring module with an I2C compliant interface. The Arduino-compatible INA219 Current Sensor makes it simple to detect current, power, and shunt voltage. To meet the need for current measurements, this sensor module includes a 0.1 ohm, 1% shunt resistor. The DC voltage range of the INA219 Current Sensor is +26V.

Figure 8: INA219 Current Sensor

F. ThingSpeak

With the help of the IoT analytics tool ThingSpeak, you can gather, visualize, and examine real-time data streams online. Data sent by your devices to ThingSpeak is instantly visualized by ThingSpeak. You can perform online analysis and analyze data as it comes in with the option to run MATLAB® code in ThingSpeak. For IoT systems that need analytics, ThingSpeak is frequently used for prototyping and proof-of-concept systems.

Using a Rest API or MQTT, you may submit data directly to ThingSpeak from any internet-connected device. With ThingSpeak, you can construct sophisticated event-based email alerts that are triggered based on data from your connected devices, store and analyze data in the cloud without establishing web servers, and more.

ThingSpeak

Figure 9: ThingSpeak

G. Tkinter Module

The Python binding for the Tk GUI toolkit is called Tkinter. It is the de facto standard GUI for Python and the standard Python interface to the Tk GUI toolkit. Standard Python installations for Linux, Windows, and macOS come with Tkinter. Tk interface is where the name Tkinter originates. Steen Lumholt and Guido van Rossum wrote Tkinter, which Fredrik Lundh later updated.

Tkinter

Figure 10: Tkinter

H. Twillio Module

The Twilio Python Helper Library makes it simple for your Python programme to communicate with the Twilio API. On PyPi, you may find the library's most recent version. Applications created in Python 3.6 and later are supported by the Twilio Python Helper Library. Check out this guide if you're interested in upgrading from the older Twilio Python Helper Library 6.x to the more recent 7.x version. With the Twilio cloud communication service, the Twilio module offers stand-alone integration. It started out as a straightforward SMS integration solution for Drupal 7, but it has since grown to include the vast array of functions that are exclusive to the Twilio platform.

twilio

Figure 11: Twillio

V. IMPLEMENTATION RESULT AND ANALYSIS

Using Raspberry Pi3, a complete hardware prototype of an IoT-based Energy Management system was created. Temperature and light sensors are also installed and connected to the Raspberry Pi. In addition, the Pi3 transmits the value of the appliance's current draw for estimating overall power consumption and plotting the same as a graph on ThingSpeak. The entire IoT-based Energy Management System Prototype with all sensors and connections is depicted in Figure 12.

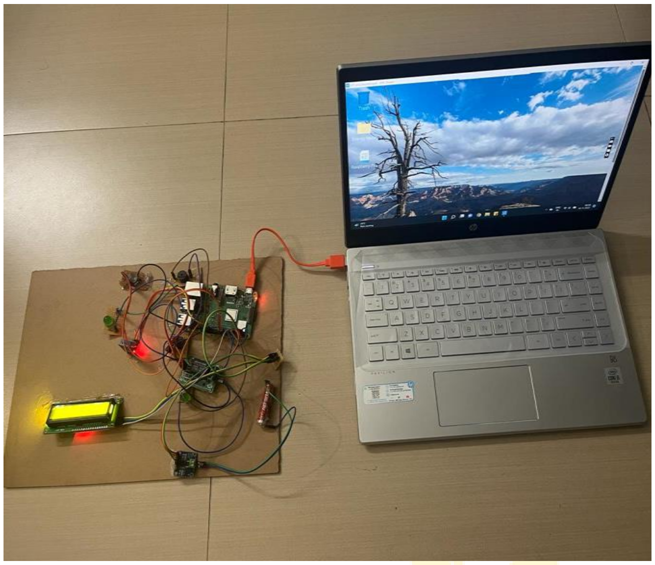

Figure 12: Hardware Prototype

Figure 13 depicts the Raspian IDE Environment used to control appliances. The Raspberry Pi3 environment in which Python code was created for receiving the used current and calculating the total power consumption by each device. The graphic user interface for payment is shown in Fig. 14. The overall Energy consumption of the appliances is depicted in Figure 15 by plotting the current obtained from the appliances versus time. The same as shown on a graph. The graphs of total power usage, temperature, and humidity are depicted in Figures 16 and 17.

Figure 13: Raspian IDE

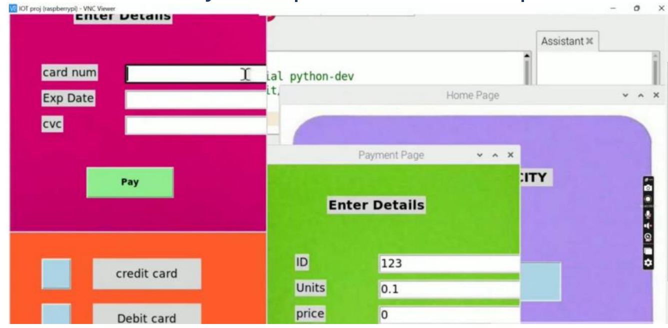

Figure 14: Payment GUI

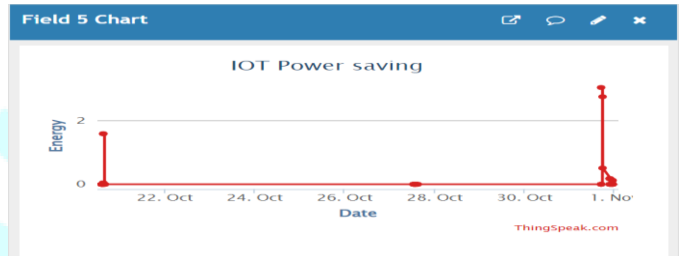

Figure 15: Energy Consumption graph

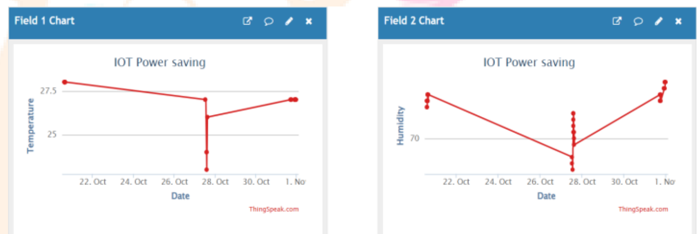

Figure 16: Temperature and Humidity graph

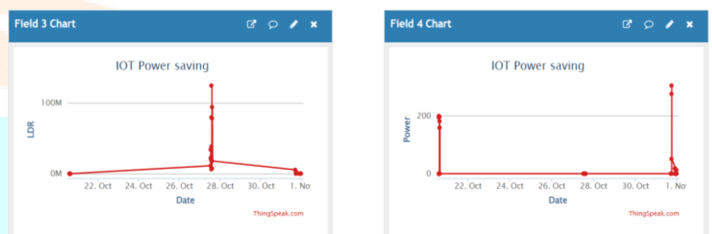

Figure 17: LDR and power graph

The aforementioned graphs demonstrate the visualization of the data captured by "ThingSpeak," an IoT analytics service that enables to gather, view, and analyze real-time data streams in the cloud. It can be observed that in times of high temperature, humidity and light intensity the power utilized is at the minimum while for vice-versa more power is utilized. This can be strengthened by the fact that the higher the light intensity the lower intensity of LED is required thus low power utilization.

VI. CONCLUSION AND FUTURE WORK

In this age of technological innovation, energy consumption monitoring and management are crucial. Utilizing a Raspberry Pi CPU, the suggested smart energy meter system for household management monitors energy usage. This project proposes a smart energy meter for monitoring and managing energy use, which would boost device and user awareness of energy consumption. Energy consciousness at the household level enables the user to adjust the power state of the devices according to their demands, hence reducing energy consumption. Therefore, the use of such intelligent energy meters in home management systems is vital. This project targets the following objectives:

• Increasing domestic energy consumption awareness.

• Monitoring and managing residential energy consumption with IoT.

• Water damage detection

This project can be further developed. The project collects sensor data, powers the LED, and uploads the data to the "ThingSpeak" cloud. To further improve this project, a machine learning model can be utilized to estimate power use based on this dynamically updated sensor data. Attaching a switch to Raspberry Pi, which, when activated, can detect electricity theft, is possible. The current model can only handle voltage up to 5V, although the average household voltage is 220V; consequently, this project can be modified to work with voltages greater than what is now accepted and configure this system in a "Smart-Home"

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