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Internet of Things (IoT) based Energy Tracking and Bill Estimation System

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ABSTRACT

Electrical energy is an important form of energy in the present times. For better or worse electricity is indispensable to life as we know it. Although we may not yet be able to produce enough clean energy to power the world, we can reduce environmental damage by learning how to save electricity is becoming a priority for more and more people. The purpose of this project is to design a system which can track and estimate the bill using IOT from anywhere [1] in world. The project design comprises of NodeMCU, four channel relay, OLED display and MIT app Inventor 2 [2] as cloud Interface. Here NodeMCU fetches average consumption detail of loads from and logs estimated bill to the cloud-hosted database, monitors the duration for which each relay in a 4-channel relay module was switched-on, performs calculations, and transmits real-time results to an IoT cloud interface. 4-channel relay module executes switching instructions on loads sent over the internet via the control unit. This paper provides highlights on cloud-hosted database details, hardware design, IoT cloud interface application design, and working principle with mathematical modeling of the proposed system and tested results of this system are discussed, with the cloud-hosted database and IoT cloud interface.

Keywords-- Internet of Things (IOT), Bill Estimation, NodeMCU, Google Firebase, MIT App Inventor 2, 4 Channel Relay Module

I. INTRODUCTION

Internet of Things (IoT) is a network of physical objects or it is a combination which consists of software, electronics, network, and sensors that allows these objects to collect and exchange data. In the early days of energy tracking, the only options available to owners and operators of real estate were expensive devices or "smart meters" that collected electricity data for the whole building. More recently, companies have developed Internet of Things (IoT) devices capable of affordably capturing data at the equipment level. With this data, the same technology companies could begin building "insights libraries" or different algorithms used to identify inefficiencies and recommend specific actions.

As capabilities advanced, energy tracking allowed these algorithms to detect more than energy inefficiencies. Now, this energy tracking is being used to predict equipment failures and help with other maintenance requirements. Electric meter or conventional energy meters [3,4], measure the total power consumed over a time interval. Electric utilities use electric meters installed at customers' premises for billing and monitoring purposes.

The goal of the project is to accurately predict the monthly electricity bill of the household appliances or industrial appliances. The consumers [5] will get the information regarding how much electricity is used by each appliances. By which consumer can understand how much money they are spending to use them. Using the information consumer can estimate how much electricity an appliance is using and how much the electricity cost so they can use according to their needs.

This project comprises of components such as 4 Channel relay module, NodeMCU, OLED display, Cloud firebase, IOT cloud interface. The IOT cloud interface used in this project MIT app inventor 2, which displays real time power consumption [6] along with the electricity bill and the information can be accessed from anywhere in the world with proper internet connection. If there is no proper availability of internet connection then it can be controlled by external switches which are employed on the board. Earlier, energy meter consists of measurement chips, current and voltage sensors [7], and smart plugs [8] which increases the cost. Inspite of using all these components we have employed NodeMCU which perform all functions and makes the system simplified.

II. PROPOSED WORK

This section contains system architecture, hardware design, IOT Cloud interface application design, working principle and system implementation.

2.1 System Architecture

The block diagram represents the Architecture of the proposed system implemented. It comprises of seven blocks which are four channel relay module, NodeMCU, Cloud firebase, IOT cloud interface, Display, control unit.

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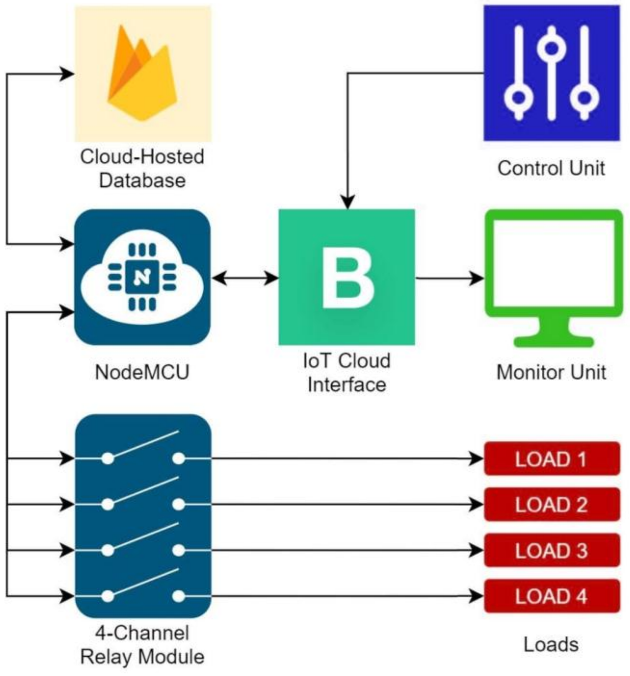

Figure 1: System Architecture

2.1.1 NodeMCU

NodeMCU is a open source IoT platform, which runs on the ESP8266 Wi-Fi SoC . Since NodeMCU is an open-source platform, its hardware design is open for edit/modify/build. NodeMCU board consist of ESP8266 WIFI enabled chip. The ESP8266 is a low-cost Wi-Fi chip developed and it is available in reasonable price.*it collects* information of real time power consumption of loads and calculates the estimated bill to the cloud firebase by recording the period in which each relay was turned on.

2.1.2 Four Channel Relay Module

Four channel relay module is a combination of 4 relays on a single board. It is a 5V relay module and each channel needs a 15-20mA driver current. It is used to perform switching operations. Each relay is connected to the respective load. Each relay can handle a load running on AC current having an optimal voltage of 220v.

2.1.3 Cloud Firebase

Google Firebase is a Google-backed application development software that enables developers to develop iOS, Android and Web applications. It simplifies the system design. Through this we can fetch the average energy consumption of each load. Even without the use of current and voltage sensor, Measurement chips [9] we can track and estimate the bill.

2.1.4 Loads

The proposed system can have a maximum of four loads as the relay module used in this system is of 4-channel. A load can be any circuit, appliance, or device that runs on alternating current and has a maximum voltage of 220, but average consumption in Watts of that load is required as an input to this system.

Table 1: Sample Entries Made In Database

Type of Electrical Load	Name of Electrical Load	Average Consumption in Watts
	Blender	625
	CFL Bulb-450 Lumens	10
	CFL Bulb-900 Lumens	18
	LED Bulb-450 Lumens	4.5
	LED Bulb-900 Lumens	8
	Ceiling Fan-36 Inches	55
	Ceiling Fan-48 Inches	75
	Induction Stove-07 Inches	1500
	Induction Stove-09 Inches	2750
	Iron	1500
	Microwave	900
	Toaster	1150
	Fluorescent Tube Light-04Foot	40
	Fluorescent Tube Light-08Foot	75
	LED Tube Light-1600 Lumens	20
	Broadband Router	12
	Charging stand-Laptop	50
	Charging Stand-Mobile	6
	Charging Stand-Tablet	10
	Laser Printer	20

2.1.5 IoT Cloud Interface

MIT app inventor 2 the android application is the IoT cloud interface with both control unit and monitor unit built-in. Through this application we can build our own system by which we can track and control the power consumption of loads.

2.1.6 Monitor Unit

The monitor unit implemented in the system is OLED display the OLED display module breaks out a small monochrome OLED display. It's 128 pixels wide and 64 pixels tall. The OLED display is very readable due to the high contrast. As the display makes its own light, no backlight is required. This significantly reduces the power required to run the OLED and it displays the real-time results of estimated electricity consumption by each load connected to the system and estimated bill of total consumption.

2.2 Hardware Design

The Four channel relay is connected to the ESP8266 NodeMCU and the 4-channel relay that We have used has four input pins i.e., IN1, IN2, IN3 and IN4.The GND of four channel relay is connected to the GND of NodeMCU (ESP8266). The VCC of the Relay is connected to the Vin pin of NodeMCU. The input or the signal triggering terminal (INX) of each relay is connected to a unique digital pin D1 D2 D3 D4 of NodeMCU, and each load is connected to each operating contact terminals of the 4-channel relay module, respectively as shown in fig.

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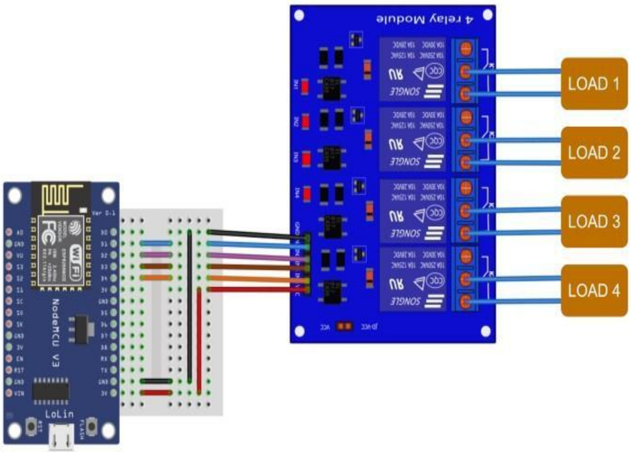

Figure 2: Hardware Connection Diagram

2.3 IOT Cloud Interface Application Design

MIT app inventor 2 the android application is the IoT cloud interface to the entire system with both control unit and monitor unit built-in.

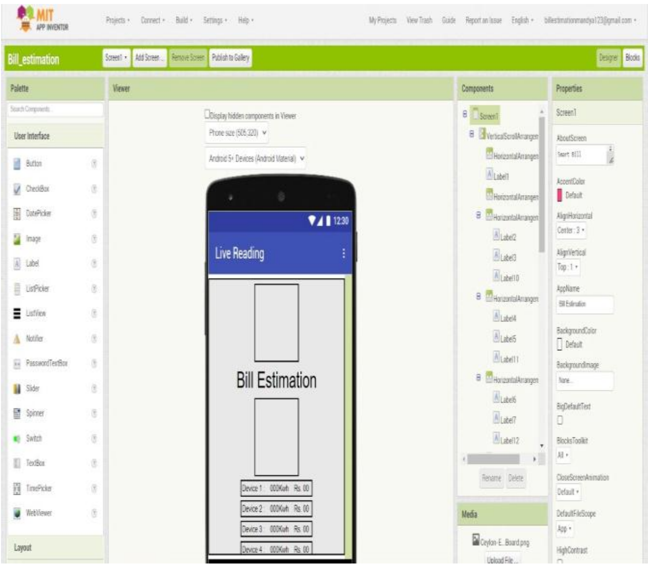

Figure 3: MIT AI2 Companion Interface

Through this application we can build our own system by which we can track and control the power consumption of loads, and it generates estimated bill of electricity consumption by each load, also through this application we can control the switching of four channel relay. The built app has been named as Bill Estimation.

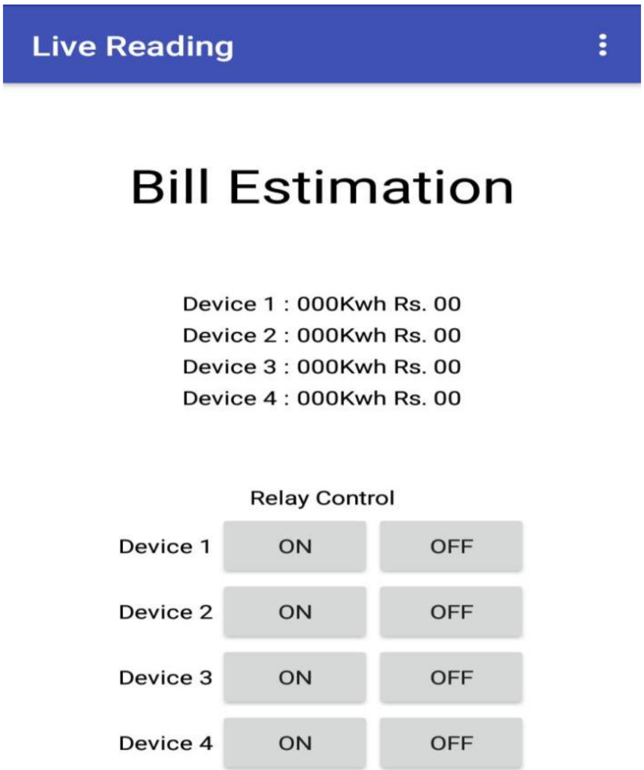

Figure 4: Control unit interface (Bill estimation)

2.4 Working

The algorithm for calculating estimated electricity consumption by each load and estimated bill of total consumption in the proposed system is shown using a flowchart in fig.5. At the start of the algorithm, libraries, SSID (network name) and password of Wi-Fi, credentials of the cloud-hosted database, the path of the variable to be fetched from the cloud-hosted database, credentials of the IoT cloud interface, some variables required for storing calculation, and connection of each relay in 4-channel relay module to unique digital pin of NodeMCU are initialized. Then NodeMCU checks for proper connectivity to Wi-Fi, and if the connection is successful, it fetches average consumption detail of loads connected to this system. If the last fetch of entries from the cloud-hosted database was successful, Arduino IDE's serial monitor prints the fetched data. NodeMCU then continuously monitors each relay in the 4-channel relay module as if loads are switched-on, then their respective relays are too.

Hours = (microseconds/(3.6e+9)) ………………. (1)
KWH = (watts*hours)/1000 …………………….(2)

Duration in microseconds for which any relay is switched on is converted into hours through equation (1),

These obtained hours are further used in the calculation of estimated electricity consumption in kWh by each load connected to this system through equation (2),

Total kWh consumption = Total consumed units…… (3)

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Estimated bill = Total consumed units*cost-per-unit ……………. (4)

The summation of individual consumption in kWh by each load gives total kWh consumption by all loads. This total kWh consumption is equal to the total consumed units, as shown in equation (3). These units are then multiplied by cost-per-unit [10, 11] of electricity of an area to get the estimated bill of total consumption, as shown in equation (4).

The results of these calculations are stored in separate variables and are transmitted over the internet using virtual pins, which are defined in each widget of the monitor unit built-in IoT cloud interface. Simultaneously, NodeMCU logs the final estimated bill to the cloud-hosted database and resets variables.

If there is no proper availability of internet connection then it can be controlled by external switches which are employed on the board.

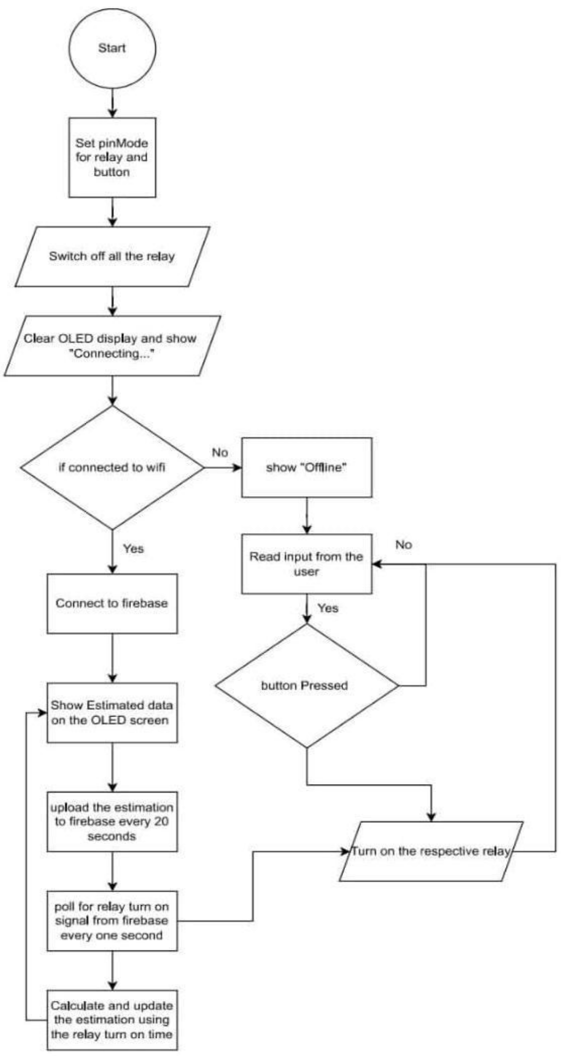

Figure 5: Bill Estimation Algorithm

2.5 System Implementation

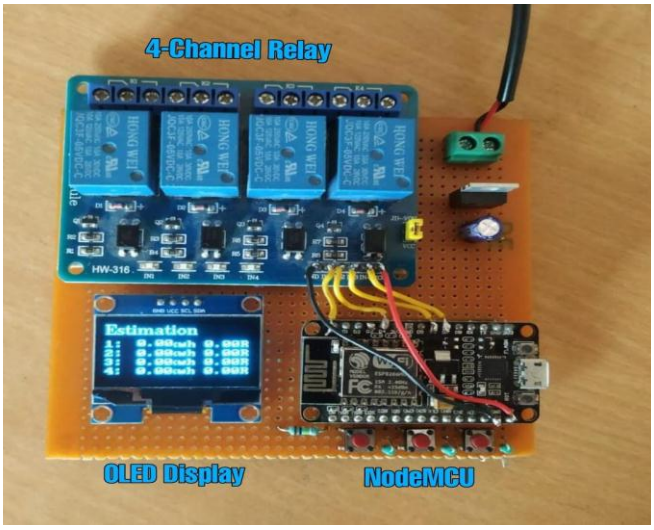

Figure 6: System Implementation

Fig. 6 shows the implementation of the proposed system in which the 4-channel relay module is connected to NodeMCU with support of jumper wires and is powered up using a 3V pin of NodeMCU while the mobile charger supplies 5V to NodeMCU using a USB cable. The unique digital pin of NodeMCU is connected, while the connection of one load is assumed to each relay of the 4-channel relay module. The implemented circuit consists of external Push buttons for the control operation, when there is no availability of Wi-Fi connection.

III. RESULTS AND DISCUSSION

This section consists of tested results of the intended system. Fig.6 shows the system implementation along with the output of switching of the respective relays from the instructions transmitted through the control unit built in IOT cloud interface Average consumption detail of each load connected to this system fetched from the cloud-hosted database and real-time results of kWh consumption by each load, total kWh consumption by all loads, total consumed units, and estimated bill of total consumption are displayed on the serial monitor.

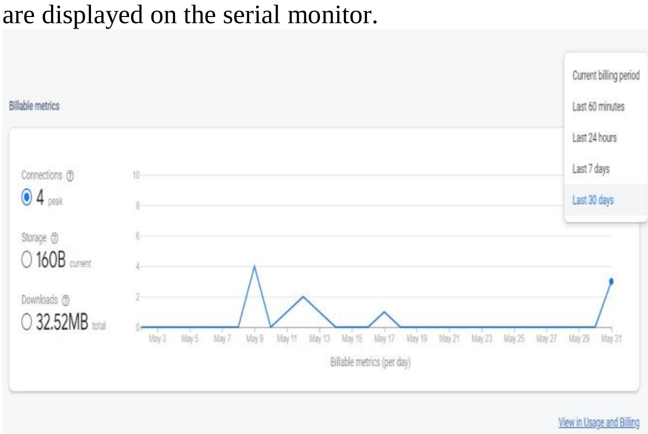

Figure 7.a

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The Fig.7.a shows the section consisting of tested results of the intended system, where 4 peak is the maximum number of relays connected to the load.

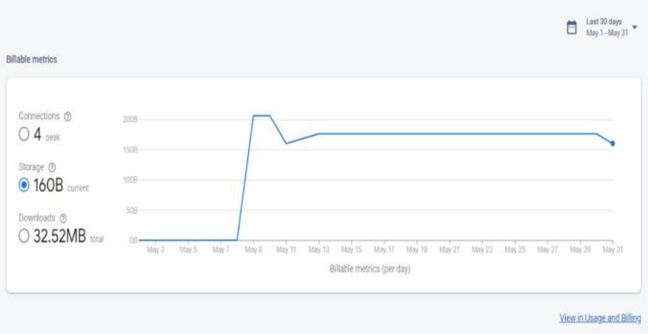

Figure 7.b

The Fig.7.b. shows, how much data is stored in database(s), not including Firebase hosting or data stored through other Firebase features. The no-cost limit per project is 1 GB.

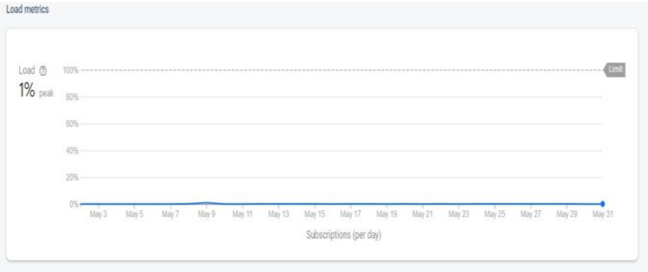

Figure 7.c

The Fig.7.c. shows, the percentage of database that's busy processing requests (either real-time or RESTful) over one-minute intervals.

IV. CONCLUSION

IoT based energy tracking and bill estimation system discussed in this paper with various sections is successful in building awareness about electricity usage by displaying real time estimated electricity consumption by each connected to it and real-time estimated bill of total consumption on monitor unit built-in IoT cloud interface. It has a simple design as it fetches the average consumption detail of loads from a cloud hosted database and not uses any chips or sensors to measure electricity, current, and voltage. It also has additional features of logging the final estimated bill of each month to a cloud hosted database and transmitting switching instructions for loads via a control unit built-in IoT cloud interface. Major advantage of this project is that usage of energy in terms of KWH and simultaneously the cost for the energy usage will be displayed. This project works under offline mode with the help of push buttons.The simplistic design and implementation of extra features were possible by utilizing the concept of the Internet of Things (IoT) in the proposed system.

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