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Internet of Things based Energy Supervision and Control for Household Appliances

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***Abstract:** This paper proposes an efficient method to manage energy consumption. In usual practice; a major focus is given to the total cost generated in an electricity bill. The amount of power consumed by individual appliances remains a question. This study demonstrates the usage of sensors to determine the power consumed by individual appliances and a microcontroller to perform computations and put on the internet for future analysis. This power management mechanism helps us control appliances thereby preventing wastage of power, thus making the world a better and a smarter place to live in.*

***Keywords:** sensors; home automation; internet of things; monitoring of power & current; smart power management system*

I. INTRODUCTION

ith a drastic increase in the world's urban population, arises a major challenge in the distribution of sustainable power to these places. The advancement of technologies has resulted in the omnipresence of sensors which tend to increase the power consumption. However, it is possible to control consumption by taking advantage of networking, cloud and data analytics.

All the appliances at our homes and in commercial spaces belong to the physical world, which can be made smarter by making it sense the environment and communicate the information over the internet, which is the crux of IoT. The information thus communicated can be therefore analyzed from any corner in the world to extract the precise particulars. An efficient way to manage power is identified to involve the usage of internet protocol-enabled services. This system requires sensors to be integrated into the energy consuming appliances which are capable of establishing wireless communication with the mobile phone of the user. The power consumption is analyzed and sent over the internet for controlling the devices.

Around 40% of the generated electricity in the country is consumed by plug load devices in building sectors [1]. Energy conservation is one of the crucial needs for the development of the nation which is the why smarter systems are being developed for consuming power efficiently.

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II. PRELIMINARIES AND MOTIVATION

Some of the techniques which measure energy consumption by appliances and transmit information over the internet for analysis are non-intrusive load monitoring system, device-level load monitoring system. The paper on Smart design of IoT[3,4] suggests the use of a smart grid with a two way communication.

A technique called CPS (Communicating Power Supply) uses an electricity metering system which measures the power consumption of appliances and enables the interaction between electroniic devices[5].Another technique called Non invasive current sensing [6] is used to measure current in plug load devices without breaking the circuit of devices.

Android phones also play a major role in power management by making use of applications to automate required devices.The android phone can be used to switch on/off, control,measure and monitor the devices by analyzing their statuses linked over to the local intenet as demonstrated in the paper on Android phone enabled Home automation[7]. The paper on Renewable Energy Based Home Automation System using ZigBeedemonstrates the usage of ZigBee technology is used for home automation [8].

Internet of Things is the preeminent approach which brings life to the whole concept of Power management thereby improving the efficiency,speed and accuracy of the system,by enabling the communication between the technological devices.Further advancements of IoT [9,10,11,12] can be made by innovation in fields like wireless sensors and nanotechnology.

III. MATERIALS AND METHODS

The work proposed here demonstrates a Smart power management system using IoT. Using the information obtained from a current sensor, an Arduino Controller computes and sends the data over the internet. Considering the voltage as a constant, the energy consumption is analyzed and the cost generated by each device (Bulb, fan AC) is then displayed via a user interface application. Figure 1 shows the proposed block diagram for the Smart power management system.

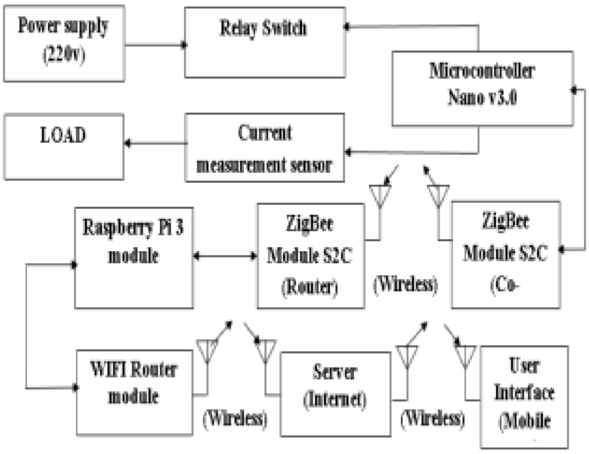

Fig1. Smart Power management system

a) Current Measurement Method

This system involves the measurement of current in the appliances using a current sensor ACS712 [14], which works on the principle of Hall-effect. The principle states that whenever a current carrying conductor is placed in a magnetic field, the voltage is created across its edges perpendicular to the direction of both the current and magnetic field. The sensor is located between the source and the load. A voltage called Hall Voltage in microvolt is generated. The measured values are read by the microcontroller through its ADC channel.

b) Switing Appliances

A relay switch, connected to the microcontroller is used to turn the appliances on/off which permits the user to control the appliances through his smart phone.

c) Arduino Nano Control Unit

Arduino Nano microcontroller, programmed by Arduino software (IDE) is used in this system, to which the current sensor (ACS712) and the relay switch are connected. It receives the data from the sensors and sends it to Raspberry Pi prior computations. The instantaneous current output is determined by the direction of current flowing through the terminals of the sensor. If the current is flowing in a positive direction, then ACS712 output voltage increases above Vsource/2 and sensitivity measured is positive. If, in the negative direction, then ACS 712 output voltage decreases below Vsource/2 and the sensitivity is negative. It was found that, 1024 counts were produced for an ADC microcontroller of 10bit.

Equation 2 gives the RMS Current value using RMS value of the voltage calculated by the Microcontroller from the hall voltage.

$$\mathbf{Vrms=(Vsource/2)*0.707} \quad \mathbf{(1)}$$

The sensitivity of ACS712 (100mv/A) is considered to calculate the RMS current value using eq(2)

$$\mathbf{I = Vrms*1000/mV\ per\ Amps} \quad \mathbf{(2)}$$

Power is then calculated using the following equation,

$$\mathbf{Power= I*V} \quad \mathbf{(3)}$$

(Assuming V=220V)

d) Communication Module

A high level communication protocol named ZigBee (IEEE 802.15.4) is used to create the personal area network by acting as an intermediate device connecting the various controllers with the RaspberryPi.

Fig.2 ZigBee Communication Module

e) Raspberry Pi Control Unit

Raspberry Pi, programmed using Python, is connected between the controller and the database server and acts as the central hub for the system. It transmits the energy consumption information to a database server for monitoring and calculating the cost generated. For storing real-time energy data, cloud storage and web hosting are used. It also serves as an intermediate between the user and the devices by turning them on/off when user raises the request.

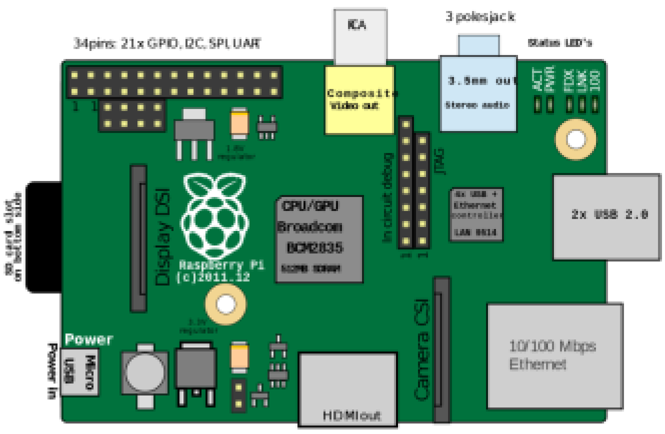

Fig.3 Raspberry PI Programming Module

f) Real World Data Storage

The online database (php My Admin) is used to store the incoming data from Raspberry Pi using the WiFi at home, which can be analyzed later. The database uses php language to calculate the power units and the cost generated for these power units for each appliance. Prior to computations, the data is sent to the user interface android application for the user's benefit.

Power units are calculated using the following equation,

$$\mathbf{PU = (PM * UT)/1000\ (kwhr)} \quad \mathbf{(4)}$$

Where, PU – Power Units

PM – Power Measured

UT – Utilization Time

The time used is the difference between the device switched on and switched off.

Utilization time =Device on time – Device of time (5)

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g) Graphical User Interface - App

User interface is a module which enables the user to control the appliances from his smart phone. It also serves as a display unit which displays the power consumed and cost generated by each appliance, thereby allowing the user to smartly manage power. It is developed using node js language.

h) Overall Flow of Energy Supervision and Control

Step 1: The current and power in each appliance are measured by the current sensor and Raspberry Pi respectively.
Step 2: The Current value is calculated by the microcontroller, **I = Vrms*1000/mV per Amps**
Power= I*V
Step 3: The controller transmits data to the Raspberry PI in the format ‘CUR1# PW1# CUR1# PW2#*
Step 4: The communication protocol ZigBee, enables the communication between Arduino and Raspberry Pi.
Step 5: Raspberry Pi then uploads the power consumption information to the database server through the Wi-Fi connection present in the house.
Step 6: On the Internet, an online database is maintained (phpMyadmin).
Step 7: The power units and the cost generated by these units are calculated by the database server.
Step 8: The data is then stored in the database for future observation.
Step 9: The values of power, power units and cost are then displayed over a user interface app for the user’s inference.
Step 10: The user has the luxury of Home automation which enables him to switch on/off the device by the tap of his/her smartphone.
Step 11: The user interface triggers the Raspberry Pi through the database server, which in turn triggers the relay switch connected with the controller.

IV. RESULTS AND DISCUSSION

The Paper was implemented into a real working model and the findings comprise of two parts:
1) Experimental Model Readings
2) Comparison of Readings with Real life scenario.

1) Experimental Model Measurement

The following findings were extracted from the working model. Snap shot of the working model is shown below in figure 4.

Fig.4 Experimental Setup

Arduino Control Unit Measurement

The current sensor (ACS712) provides an accurate measurement and can measure currents upto 20 Amps.It then sends the readings to Arduino interfaced to it.The microcontroller then performs the power consumption calculation.It also controls the relay switch to turn the appliances on/off.The readings are then sent to raspberry pi through zigbee module.

Raspberry Pi and online Dbase Readings

Raspberry pi acts as a central hub which allows several microcontrollers to be connected to it, thereby receiving information from several devices for further processing. The Pi transfers the data to an online database (phpMyAdmin) through a WiFi connection. It also receives inputs from the user to turn the devices on/off using a relay switch.
The database serves as a storage unit which holds the data for further analysis.The number of power units consumed by an appliance is determined from the average power and the time period for which the user uses the appliance. The systems performs these computations when the device is turned off and adds the computed value to the previous readings such that the user receives the data once the device is turned off. Using the government provided unit rate chart the calculation is carried out and is displayed to the end user through the interface. The values of current, power, power units, time used and cost of units used by a single appliance. Similarly the values of different appliances could be stored in the database for further processing.

Model of Android Application with GUI

Fig.5 Model Mobile App and its Graphical User Interface

An android application helps the user to remotely control his appliances and monitor the power consumption. Fig 5 shows the GUI of android application [2].

2) Comparison of Readings with Real Life Scenario

This system helped us measure the current and power units of 40 W CFL and LED light bulbs and 45w table fan. By comparing these results we were able to come to a certain conclusion that the Smart Power Management System could be used in different scenarios of daily usage. We have determined the values of power and current for 30 minutes, but the tabulated column is of 10 minute samples. The graph is based on the full table value.

Comparing LED and CFL 40W bulbs

Table 1. Current and Power reading of 40W LED light

TIME	Power (W)	Current (A)
9	42.19	0.19
9.02	42.19	0.19
9.04	40.08	0.18
9.06	40.08	0.18
9.08	37.97	0.17
9.1	40.08	0.18
9.12	42.19	0.19
9.14	37.97	0.17
9.16	40.08	0.18
9.18	37.97	0.17
9.2	37.97	0.17
9.22	40.08	0.18
9.24	37.97	0.17
9.26	37.97	0.17
9.28	40.08	0.18
9.3	40.08	0.18

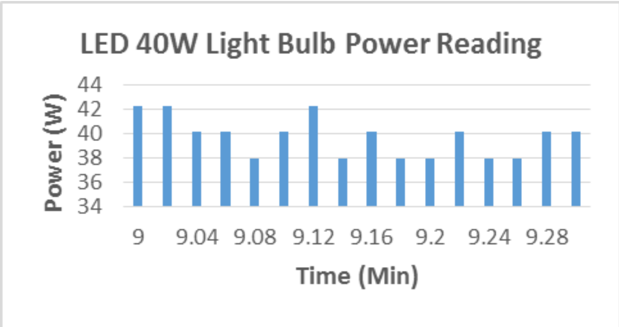

Fig. 6 Graphs for Power reading of 40 W LED light

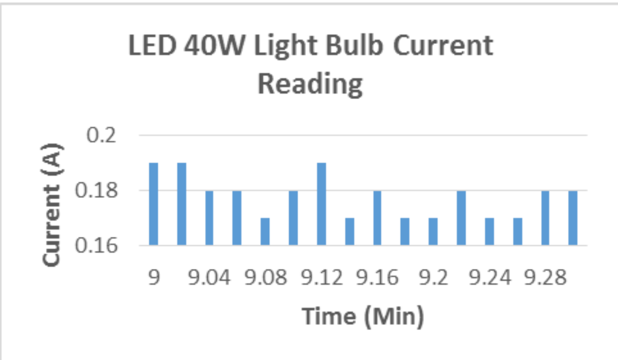

Fig. 7 Graphs for Current reading of 40 W LED light

Table 2. Current and Power reading of 40W CFL light

TIME	Power (W)	Current (A)
11	42.19	0.19
11.02	42.19	0.19
11.04	42.19	0.19
11.06	40.08	0.18
11.08	44.3	0.2
11.1	42.19	0.19
11.12	42.19	0.19
11.14	40.08	0.18
11.16	42.19	0.19
11.18	42.19	0.19
11.2	44.3	0.2
11.22	42.19	0.19
11.24	40.08	0.18
11.26	40.08	0.18
11.28	40.08	0.18
11.3	46.41	0.21

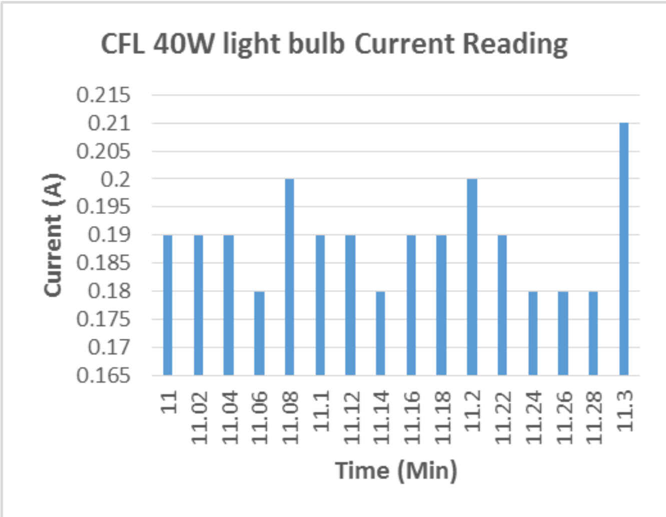

Fig. 8a Graph for Current reading of 40 W CFL light

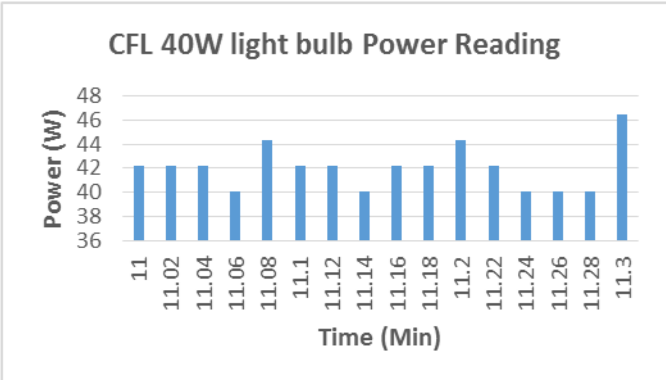

Fig. 8b Graph for Power reading of 40 W CFL light

From the readings taken for an LED light bulb and a CFL light bulb we can clearly infer that the LED bulb consumes less power when compared to a CFL bulb. A clear indication is obtained when the readings are plotted with respect to time in a graph.There was less fluctuation in the graph of LED light when we compared with the graph of CFL light.The current consumption was very high in the case of CFL which will proportionally increase the power consumed by the appliance.

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Furthermore, the conducted experiment shows that the power consumed by older appliances is very much high and it could increase the units consumed which in turn reflects in the electricity bills. All these are shown in table 1,2 and figure 6,7 and 8.

1.1.1. Comparing 75W Ceiling Fan and 45W Ceiling Fan

Table 3. Current and Power reading for 75W Ceiling Fan

TIME	POWER (W)	CURRENT (A)
17	73.26	0.33
17.08	73.26	0.33
17.1	73.26	0.33
17.14	77.7	0.35
17.2	75.48	0.34
17.24	75.48	0.34
17.28	75.48	0.34
17.3	73.26	0.33

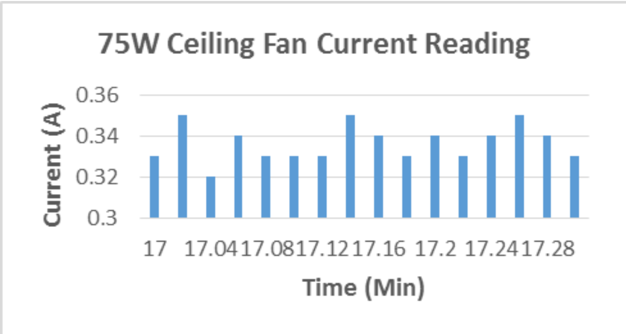

Fig. 9a. Graph for Current reading of 75W Ceiling Fan

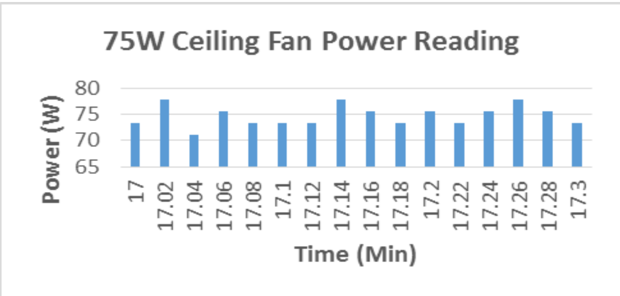

Fig. 9b. Graph for Power reading of 75W Ceiling Fan

Table 4. Current and Power reading of 45W Ceiling Fan

TIME	Power (W)	Current (A)
15	40.08	0.18
15.02	44.3	0.2
15.04	42.19	0.19
15.06	46.41	0.21
15.08	40.08	0.18
15.1	44.3	0.2
15.12	40.08	0.18
15.14	42.19	0.19
15.16	44.3	0.2
15.18	42.19	0.19
15.2	42.19	0.19
15.22	40.08	0.18
15.24	42.19	0.19
15.26	44.3	0.2
15.28	42.19	0.19

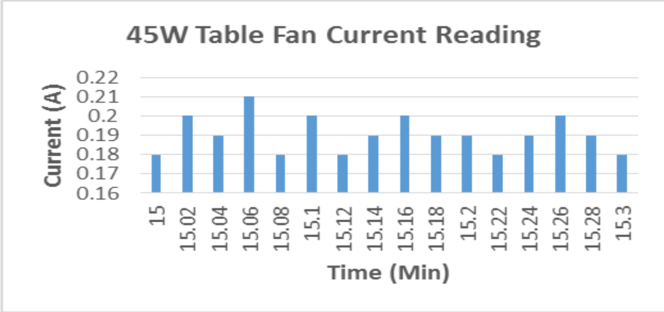

Fig10a. Graph showing Current reading of 45W Ceiling Fan

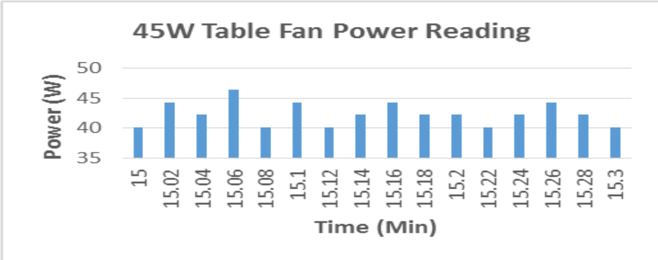

Fig10b. Graphs showing Power reading of 45W Ceiling Fan

The system is now used to measure the current and power readings of a 45W and a 75W old ceiling fan. From the observations we could infer that the older fan consumes more power than the newer one. Therefore this system also helps us to inspect the efficiency of appliances as shown in Table 3, 4 and figure 9, 10.

Power Consumption Analysis and Suggestion to Consumers

The system is then used to measure the power and current consumption of various other appliances in the household and the readings are recorded in the tabular column below, Table 5.Thus, this system highly benefits the user by providing him information about the efficiency of the system. Efficiency plays a key role in power management and the user can therefore control power consumption, using the analyzed information by deciding whether to keep the appliance or upgrade it.

Table 5. Current and Power reading for different Appliances

Current (A)	Power (W)	Power Rating (W)	Comments
0.18	40.08	40 W	Working to its efficiency
0.19	42.19	40 W	Not efficient
0.19	42.19	45W	Working to its efficiency
0.32	70.4	75 W	Working to its efficiency
0.13	28.60	32 W	Working to its efficiency

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V. UTILIES AND APPLICATIONS OF THE PROPOSED ENERGY SUPERVISION AND CONTROL METHOD

- Provides the user with the power consumption Information of individual appliances, thereby enabling him to judge the efficiency of the appliance.
- This system can be used in industries having heavy machinery, to measure the instrument's power consumption and helps them to take power management decisions.
- In industries performing high-speed work, these systems can be used to reduce the power wastage in appliances.
- In smart cities this system can be used to manage power, as these cities use a lot of sensors and appliances.
- This system can help reduce the cost of living in community places by managing power in a smarter way
- In larger cities, where power is stored and distributed to other places, this system helps in reducing power wastage.

VI. CONCLUSION

Thus the presented work involving an internet connected energy controlling and monitoring system, benefits the user by providing them with the information about the power consumption which accounts for efficiency of the appliances, and enables them to take better power management decisions. The user can be benefitted by spending less amount on power and electricity bills. It is also accurate and could suggest the user for replacement of devices. Thus Spigot makes the world better place to live in by promoting energy management and conservation.

FUTURE SCOPE

The System can be made more efficient by incorporating a voltage sensor across the appliances which provides a more accurate measurement of power. Furthermore, the system can be compared with government installed power meter which in general generates the electricity bill for the whole house, so that the user can clearly analyze his expenditure on electricity bills smartly.

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