Development of Web Based Laboratory Prototype for Remote Monitoring and Control of Electrical Appliances

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***Abstract*—The demand of electrical energy is increasing drastically and a significant amount of electrical energy is consumed in buildings particularly in small and medium sized building due to increased comfort level and use of modern electrical appliances. In this paper, a laboratory prototype is developed to enable the integration of commonly used electrical appliances such as lighting load controllers and plug load controllers in the Indian context, as well as any IoT devices that have open application programming interface. The overall objective of this research is to demonstrate energy savings potential achievable, while maintaining satisfactory occupant comfort and healthy working environment through intelligent algorithms. Using the developed prototype more than 52% energy is saved through load scheduling approach. Moreover, the cost associated with the development of the proposed solution is very less as compared to the existing solutions. It is a game changer in saving energy, improve occupant comfort and plays a transformational role in small/medium sized buildings.**

***Index Terms*—Internet of things, intelligent algorithms, smart energy systems, energy management, energy efficiency and conservation, sustainable development**

I. Introduction

The demand of electrical energy is increasing drastically around 8% annually. Of the order of 35% of the electrical energy is consumed in small (<5000 sq ft) and medium sized (5000-50000 sq ft) buildings in India and it is becoming a major challenge for the government. In India, most of the small and medium sized buildings are operating manually and there is a huge wastage of energy in such buildings due to lack of awareness about efficient use of energy, untrained manpower, or just negligence, as a result, lot of electrical energy is being wasted. By using information and communication technology-based approach, a significant amount of energy can be saved. By saving the energy, ultimately the natural resources are being saved, and our environment can be protected. Therefore, it is an urgent need of making technology not only available but affordable to save energy that will protect our environment and humanity. To adopt the energy efficient practices through building automation and energy management systems the citizens needs to be encouraged. These systems would play a critical role in the development of internet of things at grassroots level. The control and monitoring of building appliances become easier through building automation system. Building automation refers to control of home appliances using "The Internet of Things" that can automate most of office/house appliances through an easy manageable web interface by local networking or by remote control. With building automation systems, customer has an opportunity to experience convenience, comfort and be more efficient with energy usage to reduce daily energy costs apart from monitoring other important factors.

Limited Building Energy Management (BEM) solutions are available but they are costly for small and medium size buildings. Most existing solutions offered by companies such as Johnson Controls and Honeywell are expensive propositions structured around large new buildings. There is a need of cost-effective solutions for building energy management for such buildings. Virginia Tech-ARI has developed Building Energy Management Open Source Software (BEMOSS), a cost-effective solution for small/medium sized buildings for use in US context. Further, the developed BEM is limited to the appliances those have application programming interface (API).

There is lot of research is going on in this emerging area and the latest research are presented in this section.

Jongbae Kim *et al*. presented an internet of things-based energy management for domestic area along with solar photovoltaic plants which enables the developed model more scalable, reusable and interoperable. The future of this study is expected to contribute in providing the road map for internet of things-based energy management for domestic appliances [1].

Theoni Karlessi *et al*. presented a concept of smart and net zero energy building (NZEB) with an integrated design approach highlighting its principles and links the

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process with smart building technologies to minimize its carbon footprint [2].

Kelly E. Parmenter *et al*. presented an innovative approach to manage load at the demand side through a system comprising smart end-use devices and distributed energy resources. These devices are having a highly advanced controls and communications capabilities. In this work, potential for energy savings and reduction in demand is addressed [3].

Frederic Wurtz *et al*. have presented an optimization model for the design and supervising for valorizing a building energy property and contribute thus to the emergence of the concept of smart buildings (SBs) integrated in smart grids (SGs). This type of arrangements has the potential to be key pillars of the energy transition in terms of production, storage, load demand and load matching [4].

Larisa Dobriansky *et al*. described the types of policy, regulatory and institutional changes needed to support advanced microgrid investments that could serve as a "connecting building block" for the Government of India's smart grid, between the bulk power system and distributed assets, managing and optimizing distributed resources with smart technologies for the benefit of local facilities, customers, communities, the grid and the marketplace. India's "Smart Grid Vision and Roadmap" is intended to transform the Indian power sector into a secure, adaptive, sustainable and digitally enabled ecosystem by 2027. It recommends that the consideration of electricity reforms and hence harmonize on-grid with off-grid rural electrification efforts along with attracting private capital to increase supply and demand capacity through market-based approaches [5].

Girish Ghatikar *et al*. presented a characterization and effectiveness of technologies for India's electric grid reliability and energy security. In this work, smart meters and interoperable communications for data analytics and automated dispatch for load reduction during power deficiency are used. Using this a significant amount of load reduction is achieved. Further, the concept of auto demand response is provided which can improve the customer's representation and a utility's arbitrage for electrical energy shortfall and high cost of peak power [6].

Lalitha Suryanarayana *et al*. discussed about the Qualcomm Technologies Inc. (QTI) and its subsidiaries that are addressing the Intelligent connectivity as a fabric of smart cities by driving the evolution of intelligent connectivity standards globally (e.g. 3GPP LTE and Wi-Fi), designing robust M2M products for specific verticals, and building relationships for interoperable ecosystem enablement [7].

Xin Wang *et al*. [8] have presented an energy transaction mechanism to address the intrinsic variability of renewable energy sources for grid connected base stations that are also equipped with an energy storage unit aligned with the goal of using green wireless communications to reduce carbon emission, this deal with dynamic energy management for smart-grid powered coordinated multi point (CoMP) transmissions. An optimization problem is formulated to minimize energy transaction cost while guaranteeing quality of service. The merits of the proposed work were highlighted by the numerical tests using real time data. Real time energy management was carried out using a virtual-queue based algorithm.

Muhammad Naveed Naz *et al*. developed an effective model for energy management to ensure uninterrupted supply of energy generated from biogas, waste materials of animals and broilers. Multi objective optimization approach was applied to minimize the environmental impact and cost of electricity. In the proposed scheme, the problem of continuous, cost effective, and environment friendly supply of electricity has been formulated as binary integer linear programming (BILP) problem to jointly optimize the resource scheduling and demand side management. [9].

Aitor Arzuaga *et al*. described and analyzed LV network supervision solutions based on smart meters or advanced metering infrastructure plus other technologies focusing on the advantages and applications derived from the addition of intelligence into the LV into the Indian grid, based on some pilot experiences already in place in India and abroad [10].

Khamphanchai *et al*. have presented a Building Energy Management Open Source Software (BEMOSS) to improve sensing and controlling of equipment in small and medium sized commercial buildings. This software has been designed to target small and medium sized buildings and aims to optimize electricity usage to reduce energy consumption and implement Demand Response (DR) programs in buildings [11].

M. Kuzlu *et al*. discussed how BEMOSS is designed to work with three major types of loads in buildings i.e. HVAC, lightening (Dimmable ballasts and Wifi light switches) and plug (Smart plugs) loads. Besides this, BEMOSS can also supports the energy meter and different types of sensors. Moreover, the BEMOSS may allow communication between and associated load controllers having API using different technologies [12].

M. Pipattanasomporn *et al*. showed that initially the HEM (Home Energy Management) algorithm controls for the selected loads. These loads include, water heater, air conditioner (heating and cooling), dryer for clothes and electric vehicles charging station. The proposed solution will work during the demand response event with load prioritization, preference settings and without compromising the comfort level [13].

M. Erol-Kantarci and H. T. Mouftah presented an optimization based residential energy management where the objective function is formed that can manage the energy consumption by scheduling of home appliances for suitable time slots [14].

M. A. Pedrasa *et al*. have discussed the concept of DER where the coordination value has been calculated for both case that is when DER is scheduled independently and when DER cooperates with each other [15].

A. H. Mohsenian-Rad *et al*. have presented the optimization based residential load control scheme based on simple linear programming technique. The scheme is proposed for real time pricing that needs price indicator [16].

W. Khamphanchai *et al*. have described the BEMOSS platform and how an agent platform would facilitate the grid connected buildings operation with IoT Devices [17]. The limitation of the proposed work is the requirements of the API and the compatibility with the existing appliances.

Based on the literature review it is revealed that the existing solutions are expensive propositions structured around large new buildings and are not very suitable for the existing buildings. Further, the existing solutions are not compatible with the available appliances. The proposed product is a robust open-architecture software solution operating on a low-cost single-board computer, like Raspberry Pi. It is also different from existing solutions in terms of its features such as open-architecture solution, interoperability, automatic device discovery, scalability and ease of deployment. With the proposed product, it is possible to have deployment in one part of a building at a time and thereafter scaling it up based on actual experience of value derived. With its interoperability feature, it enables hardware devices integration across large range of products to work with existing gadgets and emerging IoT devices.

Unlike many existing, well established automation systems based on wired communication (which needs to be installed during construction of building) it uses wireless technologies such as Wi-Fi (IEEE 802.11) between controller and connected load through MCU, cloud networks, web server using JSON script (user side) and PHP script (server side) for achieving full control of lighting loads which are being used everywhere, and can be used for cheap and simple implementation even for already existing buildings. The leverage obtained by using the proposed system over other similar existing systems is that the status sent by WiFi connected microcontroller managed system can be received by the user on his mobile phone from any distance. Further, it provides a live monitoring panel for reading purpose open to all and a load scheduling panel for timed control in the lab itself.

II. Process Flow and Load Description

The process involved in the working of the system and the flow of information is provided in Fig. 1. The information flow takes place between server, client and the MCU with server acting as the hub for storing and sharing the information which means that client will store the information about the changes it want MCU to make on its side on the server and the MCU will check for this information at a fixed interval of time which can range from millisecond to minute depending upon how fast response from the system is desired. However, it is optimum to use 1 second as the request interval so as not to overload the server from too many requests. On the other hand, MCU stores the information about changes it have made and sensor data on the server and whenever the website is loaded or refreshed the JavaScript retrieves the data from the server and make changes to the DOM elements of the webpage accordingly and if there is any change in the data the DOM elements values will also change accordingly. Scripts on the server side are called by Node MCU which helps in monitoring changes in the system. These scripts are used for the automation processes. The major concern in this method is not to exceed the requests limits to the server. Though it is not of that much concern if hosting is done using local server but if online hosting is being used than most of these services have a requests limit of 1500 requests per minute. Under Ideal condition the requests made by our system was under 500 requests per minute. Microcontroller is connected to the Wi-Fi, SSID and password of which is already coded in its code. But if that somehow that Wi-Fi stops working or some fault occurs the system will lose internet connectivity and to switch to another Wi-Fi will require to code the SSID and password again and load it in the microcontroller which is not convenient at all. That is why using a Wi-Fi manager [18] is advisable. Initially it set up the ESP in station mode and tries to connect to the access point, if this somehow fails, it starts the ESP in APN mode, spins up a DNS and a web-server which is already coded in the program. By connecting to the access point of the ESP from smartphone or other similar device the web page can be accessed from which new login details of the new network can be provided as input to the ESP by user. Once the details are saved, the ESP will try to connect to this new network and will follow the same procedure if it again fails. If everything works, these login detail will be saved in the EEPROM of the device, so when the ESP boots again, it will try to connect to the network, login details of which was stored in the memory.

Monitoring of energy consumption pattern is one of the key techniques to utilize the electrical energy efficiently. After studying the electrical energy consumption pattern, the user may be able to identify the area where the concept of energy efficiency, savings and conservation may be applied. The implementation of energy monitoring and control in educational institutions is utmost important as there is lot of energy wastage due to negligence and lack of automation. The sanctioned load of the university is 4256 kW. This load is consisting of laboratory load, lecture rooms, administrative offices, faculty offices, hostels and miscellaneous load etc. As this is technical institution, therefore more focused is given on experiments and applications therefore the laboratory load is playing a significate role. Hence, a laboratory case study is conducted and a part of laboratory load is taken into consideration. The total load of the laboratory considered in this work is 2.64 kW consisting of 16 fans (60W) and 16 double (52.5W × 2 = 105W) fitted tube lights. The air conditioner load is not considered in this work. There are number of load control strategy adopted by the researchers [23]. In this work, the schedule of the laboratory is provided in the algorithm and accordingly the load was monitored and controlled. Moreover, the load was controlled manually apart from the load scheduling in case of any holidays or other activities in the university.

Fig. 1. Process flow diagram of the proposed system.

III. Development of Web Platform

The web-based platform is developed to control the electrical appliances mentioned above through micro-controller automatically by providing the load scheduling. The load scheduling means the time table or scheduling of the laboratory. However, the load is also controlled manually in case of any emergency or any other purpose. The web application is flexible and may allowed the changes as per the requirements or schedule of the laboratory in the next academic session or semester. The details of the various components of the web application used in this work are provided.

Based on the above information flow diagram, the website is created using HTML, CSS and JavaScript where HTML and CSS is for visual purpose only, which is to provide an interface which user can used. JavaScript is used to read data from the server and to send it back after user submits the changes. The main purpose of the JavaScript is to read the data, to parse it since it will be in the JSON format and to make changes in the website like different time set for different days of the week. It also generates the data back in JSON format to send it back to the server whenever user make any changes and submits it.

JavaScript object notation (JSON) is a data interchange format [19], [20] which is used in place of Extensible Mark-up Language (XML) for data interchange format. By using the JSON data can be accessed and manipulated easily. Further, the data can be read manually without using any script. The data is preferably handled by object and array. Using the JSON, the status of GPIO of micro controller pins such as current time, time set etc. can be stored. To give the idea of how the data looks, few lines of it are written down here as due to its large size whole data cannot be provided here.

{“value”:[0,1,0,1,0,1,1,1],
“current time”:{“hr”:01, “min”:23, “sec”:10}, “switch”:{“s0”:{“Mon”:{“time0”:{“use”:“no”,
“from”:“22:58", “to”: “15:02”}, “time1” … and so on.}

The server-side programming is done on PHP script logic because it is ease of implementation [21]. The main task of these scripts is to get information from the client side and change the data accordingly in the JSON files. The other job for these scripts is to send data back to the client. Though the JavaScript can itself access the data from the text file but due to the fact that browser caches such files, JavaScript won’t be able to get the updated data until browser is hard refreshed which is not convenient in terms of user experience. Hence after getting this data and sending it back to the client-side scripts in order to make the client receive the latest data instantaneously or in other words data should be interchanged in real time. For user interface, receiving the data, updating of control panel and send a message to control panel back to PHP scripts for updating and stored data accordingly [22].

The purpose of the server-side scripts is to echo the data for client-side scripts and for the micro-controller and to update data received from client and to also count the working and idle hours of each GPIO. Data received from the client side is stored in the JSON file. The content of this file is analyzed by another script, which assign the states for each switch in the array of value of object as discussed earlier. A snippet of the code is provided below.

```
$sw = ["s0","s1","s2","s3","s4","s5","s6","s7"];
$timer = ["time0","time1","time2","time3","time4","time5","time6","time7","time8"," time9","time10","time11"];
$today = date("D"); foreach ($sw as$v1){
foreach ($timer as $v3) {
$use=$data["switch"][$v1][$ today][$v3]["use"]; if($use == "yes"){
$from = $data["switch"][$v1][$ today][$v3]["from"];
$to = $data["switch"][$v1][$ today][$v3]["to"]; if($from == $time){
$data["value"][$x] = 0;
$Newdata = json_encode($data); file_put_contents('data.txt', $Newdata);
}
If ($to == $time) {
$data["value"][$x] = 1;
$Newdata = json_encode($data); file_put_contents('data.txt', $Newdata);
}
}
$x++;
}
```

JavaScript is as mentioned is used for client-side programming for preparing the data from client side and send it to server and to receive the same from the server, parse it and display it to the user in a conceivable form.

The micro-controller being used for the system is a Node MCU-12E. It is programmed to make requests to the server to receive the data or payload which contains the status of each GPIO and send the data of each sensors back to the server so that website can display it for the user to see. It is also used to make regular call to PHP scripts to execute them at fixed interval of time. Once the payload is received, Node MCU parses the data and then loos through it changing the state of its GPIO according to the data. Due to limitation of pages every aspect of the code cannot be discussed here. The program for Node MCU is written in C language and the compiler being used for this is Arduino IDE. Libraries like “ESP8266WiFi”, “ESP8266HTTP Client” and “ArduinoJson” are being used for connecting to WiFi, making HTTP requests to the server and to parse the JSON data received from the server respectively. The code responsible for accessing the server, process it and set the GPIO’s accordingly is written.

The web application is designed to provide an interface to monitor and control the desired appliances which are connected to the micro-controller. The other main goal is that the functions provided should not interfere with each other that is to provide with enough functionality which can function without an interference to other functions. The user interface is mobile friendly which means that it can be easily used in a mobile device or a tablet thus eliminating the need of creating an android or IOS application for it.

Upon accessing the web application, website or the web-page the user will be welcomed with the home page as giving the two major options to choose from one being the “Control” and the other being the “Monitor” where the first option gives access to the control panel and the other option gives access to the monitoring panel. The monitoring and control panel displayed are provided in Fig. 2 and Fig. 3 respectively. There is one more option named “Help” which don’t have any role in achieving the control or automation but is to provide user guidelines on how to use the other options like the control panel and the live-monitoring panel.

The control panel can be accessed by choosing the control option from home page. Upon clicking on the option user will have to enter username and password in order to access the control panel as shown below. It is done to ensure that only some authorized person can use it and any misuse is prevented. Once the correct username and password is provided the user can finally have access to the control panel. The panel provides two options, one is for manual control and other is for automatic control by setting time. The user can switch between these two by using “Use Clock” slider. In disabled position the slider user can use that switch to control manually which means that user will have to himself check the check boxes to turn on or turn off the desired pins of the micro-controller. In active position of the slider user can set the turning on and off time. The time input format is user’s device operating system dependent which is usually 12-hour format for windows and 24 hours format for androids.

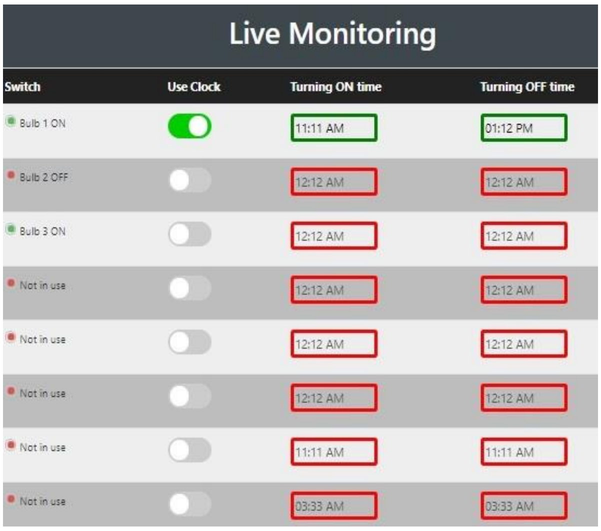

Fig. 2. Monitoring panel of the proposed platform.

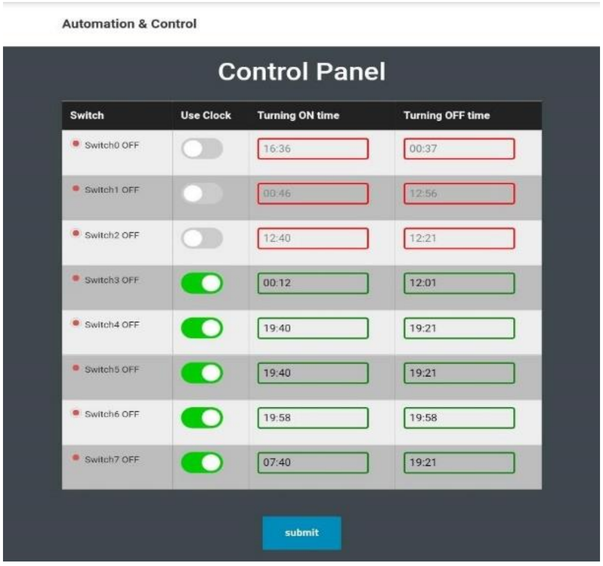

Fig. 3. Control panel for the proposed platform.

For having such automatic control, a clock is required and for this purpose server's clock is being utilized. There is one more option which gives more accurate time, which is Network Time Protocol (NTP) but this method is limited to number of requests being made at a given time which might reduce the accuracy of our system's clock. Hence using server's clock gives much better accuracy depending upon time interval within which requests are being made. One more thing to be noted that, if you check the checkboxes and then enable the slider to set time then the checkboxes will get unchecked at the turn off time but if the slider is enabled after unchecking then the checkbox will first get checked at turn on time and then unchecked at turn off time. User cannot check the switch checkboxes while slider is enabled. Also setting same turn on and turn off time will ultimately turn off the device at the set time as this is how the micro-controller is programmed. The inputs will only take effect until the submit button is pressed which enables to control multiple appliances at once and also prevent someone from spamming the switches which could cause mechanical problems in relays.

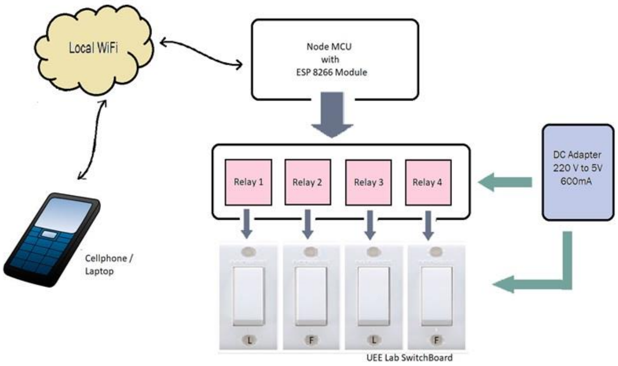

Fig. 4. Block diagram of the proposed system.

The user interface for the Monitoring Panel as shown in Fig. 2 is same as that of the control panel but the difference is that this panel does not take any form of input from users. It is only for visual purpose. It is not required to provide any form of authentication to access this panel like the one required in the control panel's case. The user can access it whether they be authorized or not. It gives the information about current settings of the system or any change that were made or being made. Any change made in control panel will get reflected in the live monitoring panel in real time. This panel uses same logic as the one implemented in the control panel for its dynamic behavior. Since this panel reflects any change made in control panel, hence it can be used to know which switches are turned ON and for what time they are switched.

IV. HARDWARE IMPLEMENTATION

The block diagram of the proposed system is provided in Fig. 4. The model developed for the demonstration purpose includes of 5V DC relays which can switch up to 10 A rated up to 250 V, A Node MCU as a choice for microcontroller because of its ease to use and low cost compared to other available counterparts. An adapter of 5V, 1A (max) with input of 100-240 V for powering up the relays as well as the micro-controller, SPST switches and SPDT switches. The microcontroller used in this system is NodeMCU which has an open source IoT platform. It includes firmware which runs on the ESP8266 Wi-Fi SoC from Espressif systems, and hardware which is based on the ESP-12 module. The term "NodeMCU" by default refers to the firmware rather than the DevKit. The firmware uses the Lua scripting language. It is based on the eLua project, and built on the Espressif Non-OS SDK for ESP8266. It uses many open source projects, such as lua-cjson, and spiffs. The micro-controller is programmed to use 8 of its GPIO pins but for testing and demonstration only 3 of them are used. Though the model is for testing purpose only but it can be easily used for real life applications also.

The relay used for the proposed system are having the specifications like 4-channel relay interface board operated at 5 V and each channel needs a driver current of 15-20 mA. It can be used to control various appliances and equipment with large current as it is equipped with high-current relays that work up to 10 A on AC as well as

DC. It can be controlled by microcontroller directly because it has a standard interface. The circuit diagram of the proposed laboratory prototype is shown in Fig. 5. The proposed prototype is developed in Utilization of Electrical Energy (UEE) laboratory of the university.

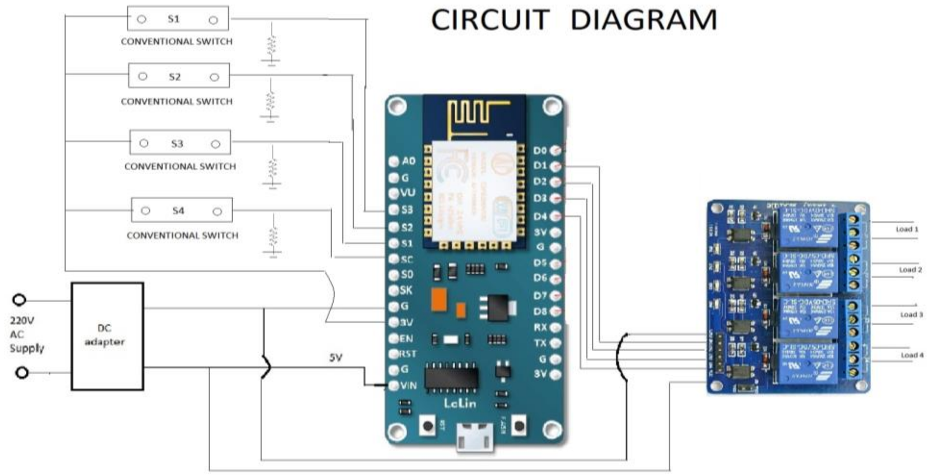

Fig. 5. Circuit diagram for hardware implementation.

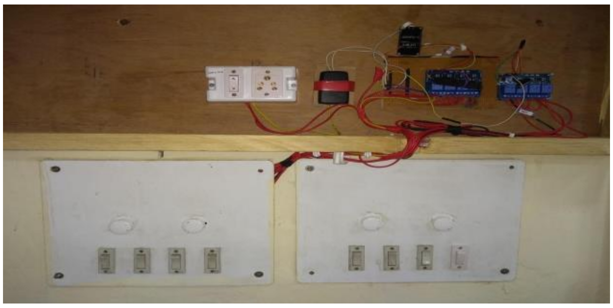
Fig. 6. Real time implementation of the proposed system in Laboratory.

Fig. 6 shows the hardware model which demonstrates the control of the considered load. A SPDT switch is being used to pass the single-phase supply between SPST switches and relays. When supply is passed to SPST switches the Node MCU and relays are turned off and hence can't be controlled via internet. This is convenient in scenarios of network problems. When supply is passed to relay, the SPST switches can no longer control the devices and devices can only be controlled via developed software platform.

V. Results and Discussion

The primary objective of the proposed work is to control appliances using a standard PC or smartphone with minimum modifications in the existing setup at low cost. There is high scope of extendibility, high scope of scalability and a user-friendly control interface. The proposed set up using internet of things has been experimentally proven to work satisfactorily by connecting simple electrical appliances to it and the appliances have been successfully controlled over WiFi using the web server. The user can use a computer/ tablet/smartphone within the defined network to access the web application created to control the lab appliances. The designed system monitors the operating status of load (on/off), turns the appliances on/off as per the requirement of the user by using web application buttons and implements an automatic time scheduled operation of connected loads with independent switch control from server and from conventional switches. Though the system currently controls lighting and fans of one section of the UEE lab, it is a frugal solution and can be easily extended to university level.

In the proposed work, the load consisting of tube light and fan is only controlled by the developed system. The same would be extended for the whole university which has a sanctioned load of 4256 kW. The monthly energy consumption in the university is provided in Fig. 7.

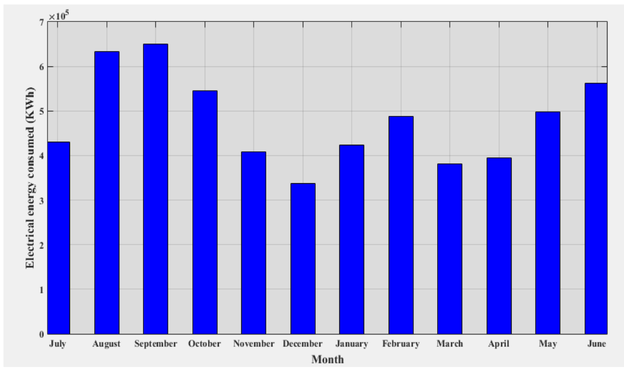

Fig. 7. Monthly energy consumption pattern of the University for a year.

A significant amount of energy can be saved through this solution. The results of a typical case study carried out in the laboratory using the developed system is shown in Table I. The total saving after applying the present solution is 52.12% which would save an amount of INR 112224. The electricity cost considered here is INR 8.4/kWh. If the same model is applied to other infrastructure like other laboratories, class rooms, faculty office and administrative block etc. then a significant amount of energy can be saved. The typical value for the energy saving is 5753400 kWh which would cost an amount of INR 25 million approximately.

However, the schedule may not be same, therefore the electrical energy savings may be changed accordingly. The other important parameter of any solution is the cost associated with the system. The hardware used in the system is easily accessible and within reasonable cost and can give a long life with reliable operation. The total cost of the proposed hardware setup is only INR 1000 which is very cheap as compared to the existing solutions. Moreover, the cost associated in the development of software platform is very nominal and depending upon the size of the system. Finally, it is noted that the annual energy savings are very high as compared to the cost of the system.

TABLE I: THE ENERGY CONSUMPTION AND SAVINGS CALCULATIONS

Description	Tube Light Load	Fan Load	Operational Hours	Annual Energy Consumption (kWh)
Description of Load	16×2@52.5 W each	16@60W each	---	
When operated for 10 hours	1680 W	960W	10 hours	26400 kWh
When operated for 4 hours	All Load	All Load	4 hours	12640 kWh
Load operated during non-operational of Lab	2×2@52.5W	2@60W	6 hours	
The annual energy savings	13760 kWh			

The proposed work may be extended for future research in the following ways:

- In this work, node MCU consisting of 4 switches have been used, however it can be extended to 8 switches as NodeMCU having 8 GPIO pins.
- The system can be connected with intelligent motion detectors such as 3D cameras to detect the presence of people inside the control area and the lights may be turn on/off accordingly.
- Moreover, the ambient light sensors can be connected to the system to detect illumination level of the considered area and dimming of the lights may be done accordingly.
- In addition, the proposed platform can be modified to control multiple appliances such as controlling air conditioners along with the lighting.
- Moreover, the integration of renewable energy-based technology may be integrated with the proposed building energy management system for sustainable development.
- Security feature like capturing the photo of a person moving around the house and storing it onto the cloud, smoke and heat detection, proximity sensing with alarm, etc. may be incorporated.

VI. CONCLUSION

In this paper, an elegant hardware-software co-design for real-time monitoring and control along with significant potential of energy savings is presented. WiFi network is used to enable communication between smart devices (controller) and common electrical appliances (to be controlled) connected with MCU. The hardware prototype is developed in UEE lab of Delhi Technological University, Delhi, India. Through the proposed IoT system, the users are able to monitor and control the electrical appliances using web and mobile devices and thus saving the energy. The system is fast and responsive, have very low complexity and all of its components can be easily acquired at a very low cost. Further, the energy efficiency concept which is an important and vital component for sustainable development is applied in the proposed laboratory prototype. Thus, it can be concluded that the interested individual can easily access this technology without requiring too much investment or time.

Further, the effectiveness of the proposed solution is validated through the real time experiments in the laboratory. It is envisioned that the proposed solution will not only save the energy but also provides the cost-effective solution to common people of the country which is a great contribution to the society and leads to the global sustainability.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

AUTHOR CONTRIBUTIONS

Mohammad Rizwan who conceptualized the topic, collected the data for the selected location, worked on this project, performed the case study and written/edited this manuscript. Ibrahim Alsaidan and Muhannad Alaraj have analyzed the data, validated the results and prepared the manuscript. All authors had approved the final version.

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