



## ORIGINAL RESEARCH ARTICLE

## DESIGN AND IMPLEMENTATION OF A COMPUTER-BASED POWER MANAGEMENT SYSTEM

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## ARTICLE INFORMATION

## ABSTRACT

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*Power supply is of great importance and interrupting it may impact negatively on our daily activities. With the application of power management systems, the vulnerability of energy is effectively managed, thereby ensuring a smooth flow of energy requirements for domestic and industrial operations. This also reconciles efficiency, safety, economic, health and environmental conditions. Therefore, this paper presents the design, construction and implementation of a computer-based power management system for household applications. It enables the user to transfer management of power supply to appliances in the house to a real time monitoring, switching and control system. This is achieved by programming an Atmega 328 microcontroller, which coordinates the overall activities of the system from a central control unit through an ESP8266 module. This wireless fidelity (Wi-Fi) module is where internally processed result is being sent to the central control unit. System design shows that the interoperability of the power management system is hinged upon a Wi-Fi as the signals are sent as packets in ASCII format from the point harnessed by the GUI software. The design was tested for performance and results show that when the power up icon is clicked on the personal computer, the bulb glows and when the power down button is clicked, the bulb goes off. Also, the measured and actual current of the transformer used in the design, justifies the efficiency of the power management system. The system design was seen to be more scalable and flexible when compared with existing home automation systems, and the hardware interface module can be handled by one server when there is Wi-Fi coverage. In conclusion, it is seen that power can be effectively managed from the personal computer, thereby reducing the overall power consumption in the facility.*

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**1.0 Introduction**

Our contemporary world is undergoing technological revolution which has prompted engineers to move with the recent trends in technology in order to meet with the current standards and specifications. Toward this end, efforts have been put in place to set up systems that enhance effective power supply management in order to minimize the up-scaling cost of generation,

transmission, distribution and supply. Power supply is indispensable in our daily activities, and its absence or inordinate interruption could result in a catastrophic process leading to systems collapse. The unstable energy costs, and the prevailing increase in environmental awareness and more severe legislations are some factors influencing the global drive for enhanced energy management. Therefore, power management system (PMS) is envisioned as the candidate technology to curb frequent fluctuations and prevalent disturbances in the operations of a typical power system, often resulting in total blackouts. The deployment of a suitable PMS could potentially enhance operational safety, regulate the cost of energy, and mitigates both health and environmental impacts. The objective of the proposed home automation system is to assist handicapped and aged people in controlling home appliances without any encumbrances, provide more safety control on the switches with low voltage methods of activation, user friendly interface and ease of operation.

### **1.1 Related work**

Home automation system was presented as multiple agent systems (MAS). Basically, home automation includes appliances and devices at home that are managed and maintained for home management (Conte et al., 2003). Similarly, a system in which task are performed by the appliances via the use of speech thereby establishing remote communication was presented (Potamitis et al., 2003). The method was targeted at the performance of real-life operations at home by physically challenged people where the speech is used as a medium for controlling appliances. In order to take suitable approach by speech recognition, the scheme of voice separation was adopted. The use of short message service (SMS) in automating devices and Global System for Mobile technologies was reported (Pan, 2003; Malik et al., 2009).

In another study, an automation system for homes in which a wireless internet-based connectivity was adopted for multifunctional devices was recommended (Alkar et al., 2005). It was observed that factors such as power failure and range pose a challenge despite the fact that flexible web-based solution at low cost were achieved. In addition, the design and implementation of an SMS based control monitoring systems (Stanescu et al., 2006), has three modules comprising of processing unit which is the microcontroller, sensing unit for monitoring the complex applications, and a communication module that uses cell phone via serial port RS-232 or GPRS modem. Consequently, problems arising from home automation system implementation ranges from lack of solidity, affinity issue, and acceptability among the aged and physically challenged people was investigated (Delgado et al., 2006), thereby devising possible solutions through various network technologies.

Furthermore, a general packet radio service (GPRS) was created, the status of alerts and home appliances are controlled and monitored by wireless sensor network which uses the medium of instant messaging to keep occupants abreast of possible dangers (She Jin et al., 2008). Monitoring remotely via mobile phone in which spoken commands are used was proposed (Malik, 2009). After generating the spoken words, it is sent in form of SMS to the microcontroller and control system which takes decision on a dedicated task. The remote control of appliances and supplying security when the end user is absent was reported (Jawarkar, 2008). The system is based on SMS and applies wireless technology to restructure the standard of living thereby leading to the flexibility and cost effectiveness of the system. More so, GSM technology is adopted by the system thus, providing global access to the system for security and automated

control of appliances. This in turn presents a better result to the challenges encountered daily by homeowners. More so, a real-time electricity consumption data is provided to residents via a virtual or physical in-home monitor (so called "energy dashboard"). The energy consumed at home is ardently managed using the data provided (Grunwald, 2009; Barnes et al., 2017).

Basically, research on energy monitoring till date has placed emphasis on the preoperative design and workflow in comparison with post-design monitoring. Key energy monitoring systems have been proposed which introduces a real time power monitoring tool for designing feasible buildings which perform adequately through optimization of the HVAC system (Brychta, 2017).

In another study, a comprehensive work describing how home appliance can be managed using mobile phone was designed (Ahmad et al., 2011). To manage the appliance, a command in form of SMS is sent by the user from his/her mobile phone to a computer connected to the appliance. Upon reception of the message, the command is sent by the computer to the microcontroller for controlling the appliance adequately. Here, distance is not a barrier as people can use this system to work in their homes from a very far distance.

Also, a prototype power management system was designed and developed for homes which will enhance energy behavior for achieving energy consumption efficiency. The home power management system developed under test produced outputs which exhibit good correlation with the input supply (Apeh, 2013).

Conclusively, this paper seeks to establish a suitable design principle, construct a functional Power Management System (PMS), develop a desktop app with communication capabilities for PMS and control.

## **2.0 Materials and Method**

### **2.1 Materials**

To achieve the design of this system, many components were assembled. Each component has a unique function different from the others and highly dependent on others. It is difficult to get a single component that can achieve the design on its own and no component function is trivial. Components used include: Atmega328 Microcontroller, Transistors: C1815, TIP 120, Resistors: 200Ω, 2.2kΩ, Relay: 30A Rated, Electrical Connectors, Copper clad, Etchant, Soldering lead, Drilling Machine, Correction ink, ESP8266, IC socket, Transformer and Capacitors.

#### **2.1.1 ESP8266:**

The ESP8266 Wi-Fi Module is a self-contained System on chip (SoC) with integrated Transmission Control Protocol/Internet Protocol (TCP/IP) stack that can give any microcontroller access to Wi-Fi network. The ESP8266 is capable of either hosting an application or offloading all Wi-Fi networking functions from another application processor (Imoize et al., 2019). Each ESP8266 module comes pre-programmed with an Attention (AT) command set firmware. It can simply be hooked up to Arduino device and get about as much Wi-Fi-ability as a Wi-Fi shield offers. The ESP8266 module is an extremely cost-effective board with a huge, and ever-growing open source community support. Block diagram description of the ESP8266 is as shown in Figure 1 (Adetona et al., 2018a).

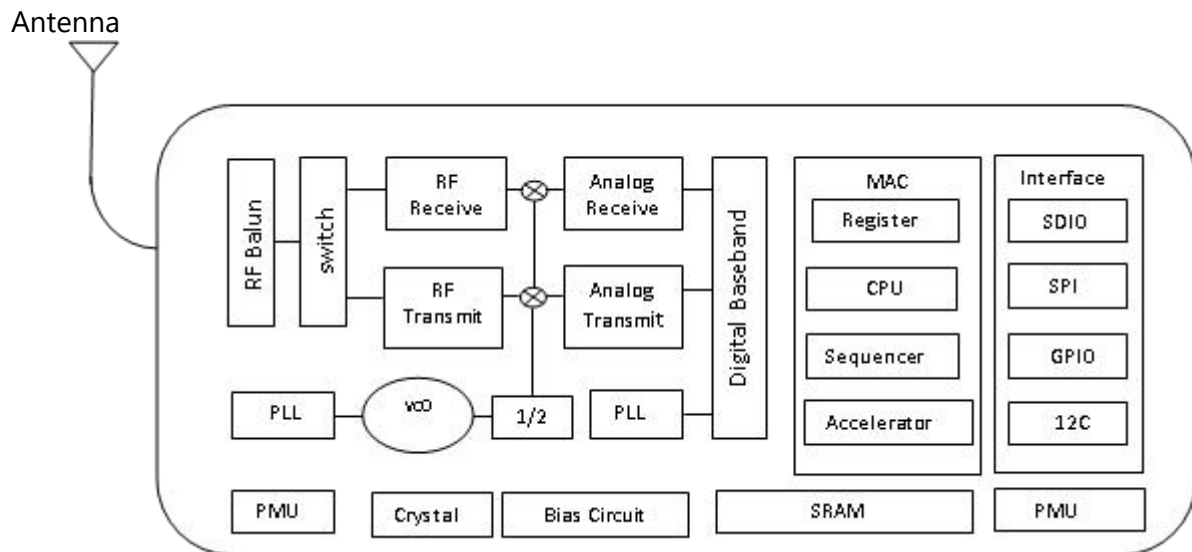


Figure 1: Description of the ESP8266 module

### 2.1.2 Microcontroller:

The Microcontroller is the central processing unit which coordinates every process that occurs in the system ranging from data processing to arithmetic and logical processes while being able to transmit and receive signals through its Universal Asynchronous Receiver/Transmitter (UART). A UART is the channel with which programming that controls a computer's interface to its attached serial devices. Atmega 328 microcontroller, a 28-pin wide DIP (Dual-In-Line) package chip was used. This chip was selected because it is robust and the DIP package interfaces for prototyping. This same microcontroller is available in a surface mount package.

## 2.2 Method

Parameters ranging from functionality, economical value and accessibility were important factors that were put into consideration during the design of this work computer-based power management system.

The design is achieved through process automation with the aid of computer program which is based on .Net Microsoft software, which gives an edge for a centralized control while utility is monitored in real time. The interoperability communication parameter is Wireless Fidelity (Wi-Fi) based while every access point communicates with the central control unit. This approach has the edge of real time utility tracking while cost can be pre-estimated based on prior utility timeline range.

### 2.2.1 Circuit Design

The circuit design is clearly illustrated in Figure 2 and each box plays an important role in ensuring wireless communication is achieved between the power management system and the personal computer.

- i) Power Supply: A Direct Current Source that powers the Microcontroller and other chips and Actuators being a regulated full bridge rectified 5 Volts supply.
- ii) Microcontroller: The Central processor of the Powerline transmission architecture with which pulse width modulated Data of a defined frequency is relayed from a transmission point to

subscription end points in a coordinated sequence. Hence, the analysis of ADC (Analog to Digital Conversion) and IO (Input/Output) signals which are being transmitted to the appropriate quarters through logical addressing protocols can be encrypted against adulteration via the microcontroller.

iii) Wi-Fi Module: This enables efficient wireless transmission of Data from the Computer system and other close ranged devices in the absence of LAN cable to the Powerline architecture.

iv) Subscribers' Microcontroller Unit: By Virtue of the Pulse Width Modulation of signals at defined frequency, the signals are captured at different endpoints by this designated Microcontroller units.

v) Restricted Lines: On the basis of transmission of Signals through Powerline basically through active electric lines cables, utmost precaution approach is essential, only a chosen line is designated and other lines are referred to as restricted.

vi) Normal Lines: This the chosen line of communication through which Pulse width modulated signals at designated frequency are sent from one end to subscription points.

vii) Transducers: These are component parts with which signals received are relayed into human logical perspective through controls.

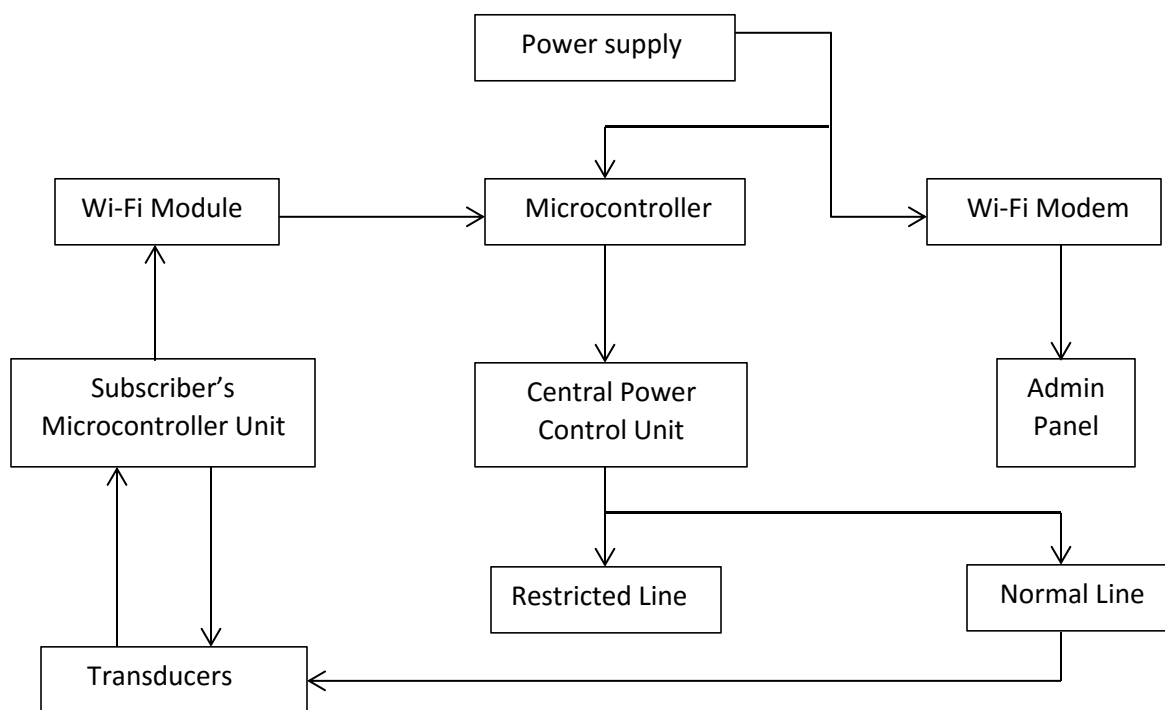


Figure 2: Block diagram of the power management system

The rectifier circuit peak inverse voltage (PIV) can be defined as the maximum voltage across the rectifying diode in the reverse direction. For the full wave rectifier employed in this design, the PIV rating of the diode should be at least 1.5 to 3 times the peak voltage  $V_{sm}$ . For this design, 1.5 was used as the multiplier factor as given in equation (1).

$$\begin{aligned}
 \text{PIV rating of the diode} &= 1.5 \times V_{sm} \\
 &= 1.5 \times 21.21V \\
 &= 31.82V
 \end{aligned}
 \tag{1}$$

To get the output voltage, equations (2) and (3) are applied.

$$V_{dc} = V_{av} = \frac{2V_p}{\pi} \quad (2)$$

$$V_{rms} = \frac{V_p}{\sqrt{2}} \quad (3)$$

where

$V_{dc}$ ,  $V_{av}$  is the average or DC output voltage,

$V_p$  is the peak value of half wave,

$V_{rms}$  is the root mean square value of output voltage

$$V_{dc} = \frac{2 \times 31.82}{\pi}$$

$$= 20.25V$$

Recall,  $V_{rms} = \frac{V_p}{\sqrt{2}}$

$$= \frac{31.82}{\sqrt{2}}$$

$$= 22.5V$$

The current rating of the rectifier unit can be mathematically calculated using equation (4).

$$I_s = \frac{I_p \times V_p}{V_s} \quad (4)$$

$$= \frac{66.67 \times 10^{-3} \times 220}{15}$$

$$= 997.82 \times 10^{-3}$$

$$= 998mA$$

Since the maximum secondary current is 998mA, a full wave bridge was used. Therefore, IN5399 diodes were used in accomplishing the design.

### 2.3 Operation of the Computer-Based Power Management System

The primary aim of the system is automation and control of power system. The control is actualized through a microcontroller, which coordinates the overall activities of the system ranging from detection of power availability to interoperability communication from central control unit through a Wi-Fi module (ESP8266) with which internal operation process results are being sent across to the central control unit (Adetona et al., 2018b). The central processing unit of the system is based on microcontroller which by default operates on DC (Direct Current). This is actualized by rectification of alternating current (AC) with bridge rectification layout of diodes to achieve a full wave rectification which is filtered through 1000 $\mu$ F to ostracize ripples off the supply. A 9-0-9 transformer was utilized to step down the voltage signal for effective operation in relation to the voltage regulator supply (7805). The terminals of the transformer are being factored as a result of voltage drop in the mains which has great effect on the supplied induced current at the secondary side of the transformer. The voltage regulator ensures that the voltage supplied to the microcontroller does not exceed 5V in order to avoid the system being affected. To further filter noise, a 0.1 $\mu$ F capacitor is introduced between  $V_{cc}$  and the ground terminal of the voltage regulator. In order to ascertain that the abrupt reset of the microcontroller does not

occur, a limiting resistor is introduced between the Master clear (MCLR) and the positive terminal of the voltage supply. In order to actualize the interoperability access of the system, a Wi-Fi module is used which communicates via UART protocol. The Wi-Fi module is capable of being an access point (AP) while it can also access Wi-Fi stations dependent on its operability configuration prior to being mounted on the main board. This configuration is based on AT commands thereby getting a unique Service Set Identifier (SSID), Internet Protocol (IP), operability mode, channel configuration etc. The baud rate with respect to magnitude of data being processed is set to 115,200 bits per second.

For access and control of the system, information is being transmitted in an Extensible Markup Language (XML) format which can be processed by a browser and other interfaces while designated systems like phones and computer systems can send commands and get feedbacks from the system. The executable window operating system software is written to control and obtain feedbacks from the system device. In order to actualize this, a C# application is written using Micro Visual Studio factoring Graphical User Interface (GUI) in place for ease of access and operation. The communication is based on either the device being on the same network with the system or the system connects to the device via designated static IP of the power management system.

## 2.4 System Implementation

### 2.4.1 Circuit board printing

Proteus ISIS was used in the implementation of the design. A concrete implementation procedure is presented as shown in Table 1. The 3D aerial view in Figure 3 and the Gerber view in Figure 4 shows the component placement and the PCB routing, respectively.

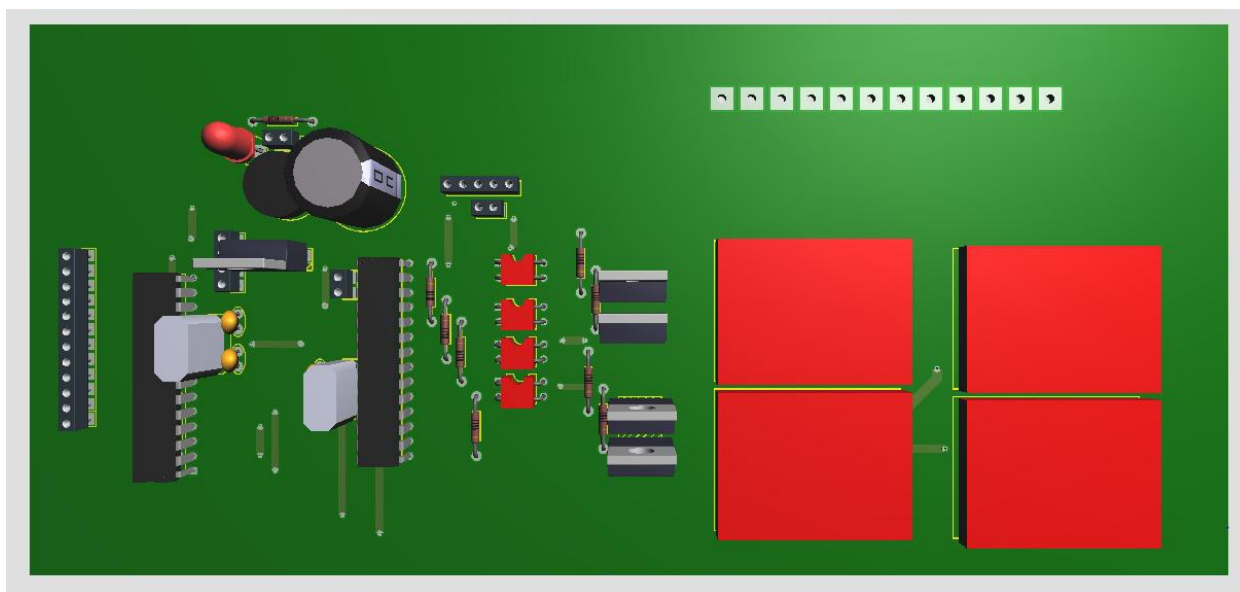


Figure 3: 3D Aerial View

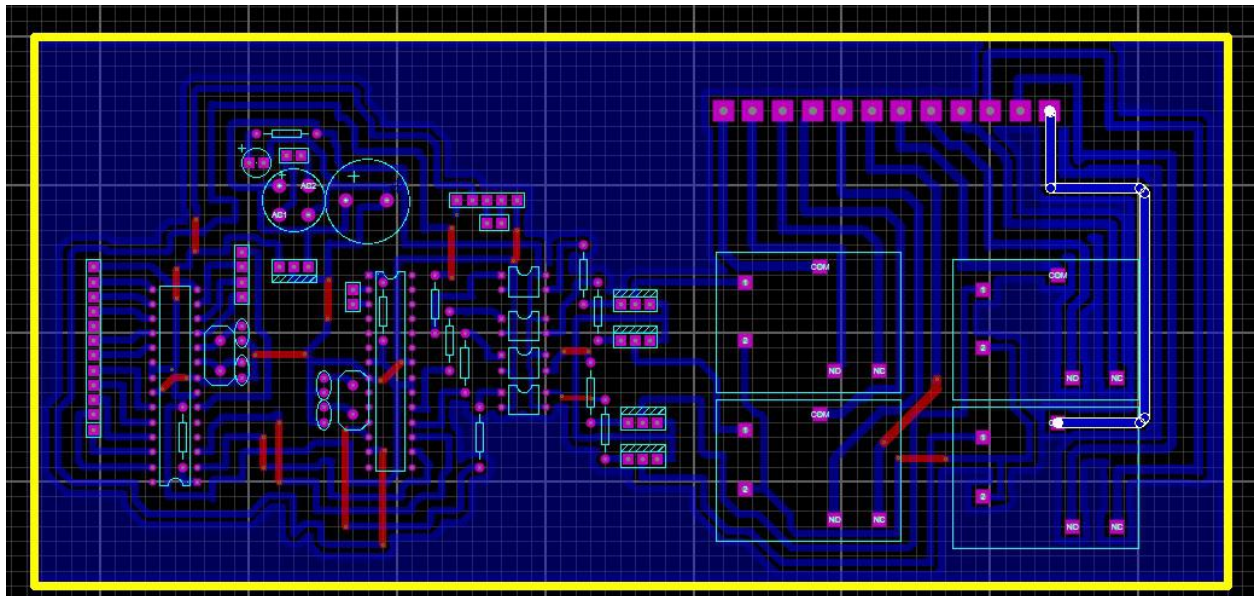


Figure 4: Gerber view

During this design, a toner printer was used in printing the routed circuit on a glossy paper where the copper prints were properly traced to effectively connect the circuit components obtained after careful design and calculations were completed. The resistance of the resistors, the capacitance of the capacitors, and the workability of all the other discrete components were verified before they were all used in the design.

The complete circuit was first simulated with Proteus by lab center electronics, found to be working satisfactorily, before the actual components were assembled on a bread board. It was only after the testing of the project has been done and its workability verified that the components were then transferred to a Vero board and soldered carefully. The resistors, capacitor, the integrated circuit and diodes were first placed on the board, before the bigger components like the relay and voltage regulator were placed and soldered carefully. Finally, the transformer was mounted and tested for functionality.

Table 1: Implementation procedure for the power management system

A	Schematic Design	This is the process of presenting the circuitry in a graphical way which can be simulated prior to the real-life implementation thereby being able to ascertain that the design will conform to the design intention using Proteus ISIS professional.
B	Component placement	This is the immediate process after the transition to the Gerber design phase of which if prior simulation is made facilitates easy navigation of routing thereby making auto routing, process actualized taking anticipated size of design into consideration.
C	Routing	This is the process involved in tracking the path of component connections geared towards establishing current flow from one point to another



D	Board Edging	This facilitates logical design and resource efficiency through designation of design boundaries.
E	Board Registry	This is the process involved in transferring design from printed format to the onboard physical output actualized through heat transfer with the aid of laundry iron which aids to ascertain effective contact between tonner printed glossy paper and the copper clad.
F	Etching	This is the process involved in being able to actualize the track on the printed circuit board through chemical reaction between the copper on the clad and a ferric chloride solution thereby Iron displaces the copper from the surface of the clad. Thus, leaving the toner-plated regions.
G	Drilling and Component mounting	Based on the design convention being of through-hole conformity, the holes are drilled while components are fixed.
H	Soldering	This is the process of establishing connection between individual components and the board with the aid of soldering lead so as to allow the free flow of current.
I	Continuity Testing	This is aimed at being able to ascertain that there is no discontinuity in connection in relation to the processes undergone in the course of implementation of the device with the aid of a digital multi-meter
J	Code Burning	In order to actualize computer simulated environment, the code which was written in C++ is converted into hexadecimals which in turn is being embedded into the microcontroller for real life behavioral automations.

### 3.0 Results and Discussion

The software designed was installed on the system with windows 7 operating system. This brings about a wireless connectivity between the microcontroller, ESP8266 and the application. When the system activated by plugging to the source of power supply, the clicking of the power up icon on the app makes the bulb to come up and clicking the power down button, makes the bulb to go off. This in turn helps in managing the load in the building as illustrated in Figures 5 and 6.

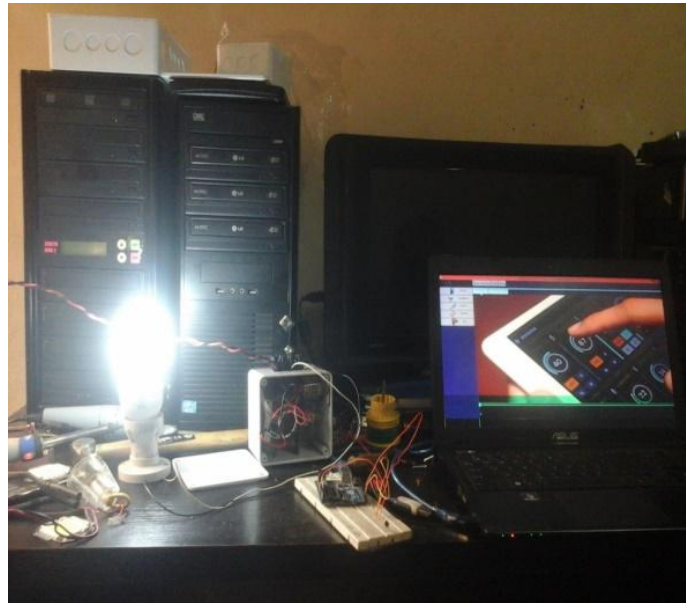


Figure 5: When Power Up icon is clicked

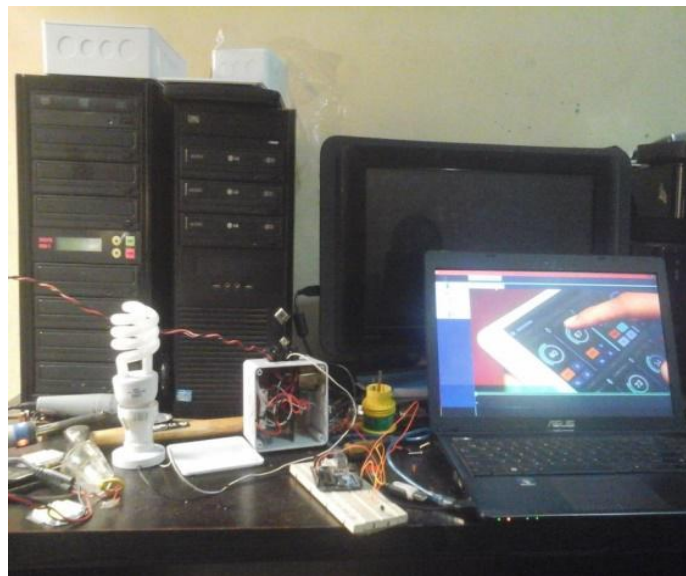


Figure 6: When Power Down icon is clicked

For the purpose of this design, a 7W energy saving bulb was used as shown in Figures 5 and 6. This bulb represents the electrical appliance in the house. When the power up icon is clicked, the bulb is ignited and when the power down icon is clicked, the bulb goes off. This is illustrated in the interface shown in Figure 7.



Figure 7: Interface of the system designed for power management

To further expand the results, the transformer voltages and current were measured as shown in Tables 2 - 4.

Table 2: Actual and measured voltages of the transformer

Transformer Voltages (V)	Actual Voltage (V)	Measured Voltage (V)
Primary Voltage ( $V_p$ )	230	215
Secondary Voltage ( $V_s$ )	15	13

Table 3: Actual and measured current of the transformer

Transformer Current (I)	Actual Current (mA)	Measured Current (mA)
Primary current ( $I_p$ )	16.67	16
Secondary current ( $I_s$ )	1000	990

Table 4: Comparison of measured and actual power

Power	Actual Power (W)	Measured power (W)
Input power ( $P_i$ )	15.33	14.19
Output power ( $P_o$ )	15	11.7

#### 4.0 Conclusion

A computer-based power management system was designed and implemented in a home. This design shows that load can actually be managed and controlled using application software, thereby making life more convenient and comfortable. The computer-based smart home application seamlessly interacts with the Wi-Fi module ESP8266, which functions as an access point. Users could control and monitor home power supply using this computer application. A more economical way to implement the smart home power system is provided by an Arduino microcontroller. This system can be used for effective wireless communication by integrating all the devices in wireless mode. With the deployment of this system, wastage of electricity is greatly reduced. This system could be very useful to the aged and disabled people because it is user friendly, and it can be used as an alternative to existing switches in homes that often produce sparks which can result in fire accidents.

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