Development Of Smart Control System for Improved Energy Management in Futo Senate Building

DIJEH OBINNA CHINEME[1], DAMIAN OBIOMA DIKE[2], S. O. OKOZI[3], MATTHEW OLUBIWE[4]
[1, 2, 3, 4] *Department of Electrical and Electronic Engineering, Federal University of Technology Owerri, Imo State, Nigeria*

Abstract- Advancement of technology has caused a rapid increase in modern appliances. The world as we know it is moving from time consuming manual process to a more advanced smart control system. Almost every circuits especially power supply circuitry uses inductors and transformers all of which draws a higher current than specified by the manufacturer. Oversizing or under sizing can cause effect like fire outbreak or reduces the lifespan of the piece of equipment like batteries and inverter indirectly costing more money to replace the equipment. In view of this therefore, this research proposes a smart control system that monitors, regulates, oversees and compares the available energy source and the electrical loads to balance the available energy demand with supply using shedding of loads in critical situation based on priority scheduling. Arduino IDE software was used to design the smart control system for monitoring and decision making, while Proteus software was used for the simulation and analysis using Senate building in FUTO as a case study. A hardware prototype was designed and implemented with electronic components, so as to validate the proposed system control. The results demonstrated that the proposed design allows for well-organized shedding during peak load period in terms of priority. The Smart Control system helped in tracking and optimizing energy consumption to conserve usage in the Senate Building FUTO. The payback period of this proposed system if utilized in Senate building is 2 months. This proposed system reduces time consumption in manually switching off load equipments, robust and reliable.

Indexed Terms- Total Connected Load Current (C_{ABC}), Section A&B Load Current (C_{AB}) Section A Load Current (C_A), Renewable Energy Source Current (C_{RES}). Battery voltage (V_B)

I. INTRODUCTION

The world is relying on non-renewable resources for residential energy supply through public utility services, despite the increasing integration of renewable energy sources in the electricity generation process. In this framework, residential consumers are compelled to minimize their energy usage in order to benefit from government incentives that encourage efficient public energy utilization by adjusting the time of energy usage and efficient devices, like LED lamps [1].

Efficient energy consumption provides a balance between available energy supply and demand. Energy conservation refers to efforts made to reduce energy consumption which can result in increased financial capital, environmental quality, human comfort, among others [2].

When electricity was first introduced in the late 19th century, the major resource that was used to produce electricity was non-renewable. Humans kept using these limited resources inefficiently without realizing that these resources will deplete to a small amount sometime in the future. With the ever growing economy of the world, it is nearly impossible to rely solely on these resources for a long-term duration, the reason being these resources are depleting rapidly [3]. A major reason to look for alternate resources is that non-renewable sources are environmentally unfriendly. The Intergovernmental Panel on Climate Change (IPCC) has found that emission from fossil fuels are the dominant cause of global warming. In 2018, 65% i.e around three-quarters of global greenhouse gas emission came from fossil fuels and industries [4] and they also comes at a large cost to human health: at least five million deaths are attributed to air pollution each year [5]. Global warming and high levels of CO_2 in the atmosphere have forced us to think about alternative for these resources.

II. OBJECTIVE

Advancement of technology has caused a rapid increase in energy demand of modern appliances as almost every circuit, especially power supply circuitry uses inductors and transformers all of which draw huge inrush current. Solar panels efficiency reduces with time as a result of exposure to UV light and adverse weather conditions. If a system is not well sized, it can cause fire outbreak or reduces the lifespan of the batteries, indirectly costing more money to replace. Therefore, to mitigate the aforementioned problems a smart control system that monitors and compares the renewable energy sources power output and the electrical load based on its priorities is proposed. This smart control system not only reduces human intervention, but its resilient and reliable.

The main objective of this research is to develop a smart control system for specific renewable energy management in FUTO. To achieve this, the following secondary objectives will be carried out.

i. Development of a smart control system block diagram.
ii. Development of a system algorithm and flowchart of the system.
iii. Development of a circuit diagram for the smart control system.
iv. Load demand, resource assessment of Senate Building, FUTO.
v. Development and implementation of a software program for the sequence of operation.
vi. Construction of Smart Controller.
vii. Test the effectiveness of the proposed system solution at improving energy efficiency

III. LITERATURE REVIEWED

Many researchers in the past have been involved in research work on development of smart controller. Based on the studies carried out by these researchers and their contribution to the advancement of this research topic, the motivation for further research in this area was initiated in this thesis. In this section, review of several research papers written by various seasoned authors on smart controllers are presented.

[6] proposed a home load management system for distribution utilities to prevent unnecessary load shedding during peak hours. The Arduino-based smart load management system was simulated and tested using Proteus software. It was a very cost-effective load management system. This system's hardware was less complicated and can be applied easily on the heavy load consumer houses. The system design could switch off the heavy load during peak hours without any human interference and encourage the consumers to use these heavy loads during off-peak hours. The cost-effectiveness, easy implementation, SMS notification, and only a 1-month payback period if it reduces 50% of load during the 4-hour peak time are key features of the proposed home load management system. Such projects are necessary for both the consumers as well as a utility as both can benefit from this. It is highly recommended to both consumer and electric utilities to control the use of heavy home load during peak and off-peak hours as well as a considerable amount of saving for both domestic and commercial consumers was achieved by employing this. This proposed system can lead the electric utilities to avoid load shedding in peak hours due to an imbalance between demand and supply, and the consumer can avail the benefit in the form of less billing. The estimated cost of the system was around 43$ and 28$ with and without Global System for Mobile Communications module for message notification.

[2] successfully developed a modular IoT-based Home Energy Management System, giving users the capability to regulate the electrical consumption of their appliances. This proposed system provided handlers the convenience of regulating appliances from anyplace, provide a modern energy management approach for both urban and rural areas and also integrate the increase of non-smart devices into the energy-efficient IoT space. The proposed system was also effectively deployed in three real environments that are reflective of possible use cases (offices, moderate energy consumer and high energy consumers). The outcome indicated that Homergy produced weekly energy savings of 0.35 kWh for the single-user office, 0.5 kWh for the low-consuming house and a 13-kWh improvement over existing smart-devices-only systems in the high-consuming house.

[7] proposed a system that seeks to execute a precised home energy management system. The proposed home management system was designed to control the power requirements between the home appliances and the power supply components needs to meet the multi-agent system home load demand. To device a correct system operation and meet each device's power demand, a Real Time Energy Management System was implemented and discussed through some required tasks using the Multi-Agent System (MAS). Each agent will be determined according to some criteria to implement the appropriate design and meet each device's power demand. The obtained results showed that the proposed system meets the general objectives of real time energy management system by improving system performance by speeding up response times and enhancing synchronization between all components during high peak and low peak periods.

In this study, the authors [1] presented a wireless home energy management (HEM) system that enables the automatic regulation of home appliances to lower energy consumption in other to aid energy users. The technique consists of multiple intelligent sockets that measures the energy that is used up by the connected appliances and are capable of executing on/off commands. The system includes other supporting modules for supplying data to a central smart controller, which uses a rule-based on home energy management algorithm. The control instructions were designed, such that the way of life of the user would be preserved while the energy consumption and day to day energy cost were reduced. The experimental results showed that the central smart controller could efficiently receive data and control several devices. The system was understood to afford tangible reductions of 23.5 kWh and $2.898 in the total day to day energy consumption and bill of the considered household setup, respectively. The proposed home energy management system guarantees to be particularly helpful for households with a high daily energy consumption.

[8] introduced an intelligent energy management system in a single residential building in which renewable energy sources, distributed renewable generation and distributed energy storage system were integrated to an intelligent controller which helped in switching the residential loads ON and OFF based on operating constraints of each device in order to reduce the total operating cost. He further interconnected residential greenhouse to further reduce the peak demand, carbon emission and the total operating cost of connected houses. The ability of the nano grid to receive power from neighboring nano grid gives it opportunity not to depend on the grid for energy during the peak period which resulted in efficient energy management in the residential house.

[9] developed a smart energy monitoring system that includes Arduino, WI-FI, energy meter. The proposed system automatically reads the energy meter and gives home automation over an app developed and power management was done over this application. The proposed smart energy monitoring system consumes less energy and it reduced manual work. The developed system could receive monthly energy consumption from a distant location directly to centralize office. In this way, there was a reduced human effort needed to record the meter reading.

[10] presented the step-by-step procedure of smart home automation controller system that can access and control home equipments from an isolated location. For this proposed system, Internet connectivity module was connected to the primary supply unit of the home system which can be accessed through the Internet. For wireless connectivity, the static IP address was used. The proposed home automation system was based on multimodal application that can be operated and used using voice recognition command of the user using a web-based application or the Google Assistant. The proposed model was experimentally shown with help of connecting the three bulbs. The system could act as a helping hand for the old age and differently disabled people.

[11] developed a Smart Home Energy Management System (SHEMS) to operate home appliances in an optimum approach. It is aimed at reducing the consumption energy by detecting the residents' activity and identifying it among three states: Active, Away, or Sleep. The proposed system was designed with an algorithm that is based on Hidden Markov Model (HMM) in order to estimate the probability of the home being in each of the above states. The proposed system uses the Wi-Fi technology for data

transmission inside home and the GSM technology for external communication. The proposed system and its algorithm was successfully tested and 18% of energy saving were obtained. The system was designed by using the most contemporary and cheap technology with a simple architecture. The proposed SHEMS provided feedback of the home appliances for the residents so he/she can be able to monitor the home from anywhere via SMS.

[12] presented a design, implementation and testing of an embedded system that incorporates solar and storage energy resources to a smart home. The intended system provides and manages a smart home energy necessity by installing renewable energy; and scheduling and arranging the power flow during highest demand and lowest demand period. In addition to that, a two-ways interaction protocol was developed to allow the home owner and the utility provider to better improve the energy flow and the consumption efficiency. A prototype for the proposed system was designed, implemented and tested using a controlled load bank to simulate a scaled random real house consumption behavior. Three different scenarios were tested and the results and findings were reported. It was proven that communication between the utility server and home gateway result in managing the peak. Incorporating the renewable energy source conserved about 33% of the home energy bill.

[13] presented a hybridized intelligent home renewable energy management system (HIHREM) that combines solar energy and energy storage services with the smart home was developed based on the demand response and time of consumption pricing was applied to programs that offer discounts to consumers that reduce their energy consumption during high demand periods. The method proposed was intended to minimize the cost of smart home electricity by exploiting renewable energy use. In the model, it was supposed that the energy consumption of all appliances is constant at every interval and it is not constant every time. This showed that the proposed energy scheduling method minimizes the energy consumption by 48% and maximizes the renewable energy consumed at the rate 65% of the total energy generated. The proposed efficient control procedure reduces the complexity and controls home energy consumption. To control the electric energy of residential customers, two-time scales can be used which are the day ahead and real-time. In a daily case, the user operating plan (or generic future time horizon) was established based on data forecasting over the next 24-hrs cycle. In all the above respects, the proposed hybridized intelligent home renewable energy management system method has high performance when compared to other existing methods.

[14] presented a new method for energy management system with a capability to manage the consumed power according to storage, produced and demand power without changing the quality of life. The proposed system was designed and implemented to conduct a validation for all the expected power situations. The results show that the system ensures optimal management for the consumed energy by taking into consideration the availability of power. A new strategy was presented that differentiate the house's appliances into three levels of priority based on the user selections with the critical appliances considered to have a high priority. This strategy was adopting a dynamic level of limitations to switching between the loads' priorities decisions based on the available power, and the predicted weather for the two days ahead. The results show a promising system that able to increase the reliability of the PV standalone system.

IV. MATERIALS AND METHOD

A. MATERIALS

The following hardware materials were used in the design and implementation of a smart control system for improved renewable energy management in FUTO Senate Building.

i. Power inverter
ii. Battery
iii. Polycrystalline photovoltaic panel
iv. A charge controller
v. Microcontroller (Arduino Uno)
vi. Current sensor
vii. Voltage sensor
viii. 5V 10A 4 channel relay module
ix. Liquid Crystal Display
x. Transformer
xi. Resistors

xii. Diode
xiii. Voltage regulator
xiv. Capacitors

The following software were used to develop a smart controller for improved renewable energy management in FUTO

i. Arduino C++ programming language
ii. HOMER Software
iii. Proteus 8 Professional

B. METHODS

The design of a smart control system for improved renewable energy resources in FUTO senate building architecture provides the operational model for easy injection of energy into the senate building. Figure 1 shows the block diagram of the micro-grid energy demand.

Hydro power energy coming from Otamiri river which is a high AC voltage source is been reduced by a transformerless voltage division unit, then fed directly to the analog to digital converter for easy voltage reading by the micro-controller. The current sensor detects the electric current coming from its input and generate a signal proportional to the current. The generated signal is then fed to the smart controller. The controller then monitors the changes that takes place at its analog pin 0 to ensure that any form of voltage fluctuation from hydro energy unit is monitored accordily.

Likewise, Solar PV panels produce a DC voltage which is fed to the DC/AC power converter/ inverter. The converter then converts the DC voltage coning from the PV panel to AC volage. The converted voltage is fed to the micro-controller through analog to digital converter. The battery bank which gives out DC voltage from its input is connected to the input of a voltage sensor, which determine, monitor and measure the voltage from the battery bank. The generated signal is then fed to the smart controller. The smart controller with the signals gotten from the current and voltage sensors does a priority check to determine which section of the senate building should be powered.

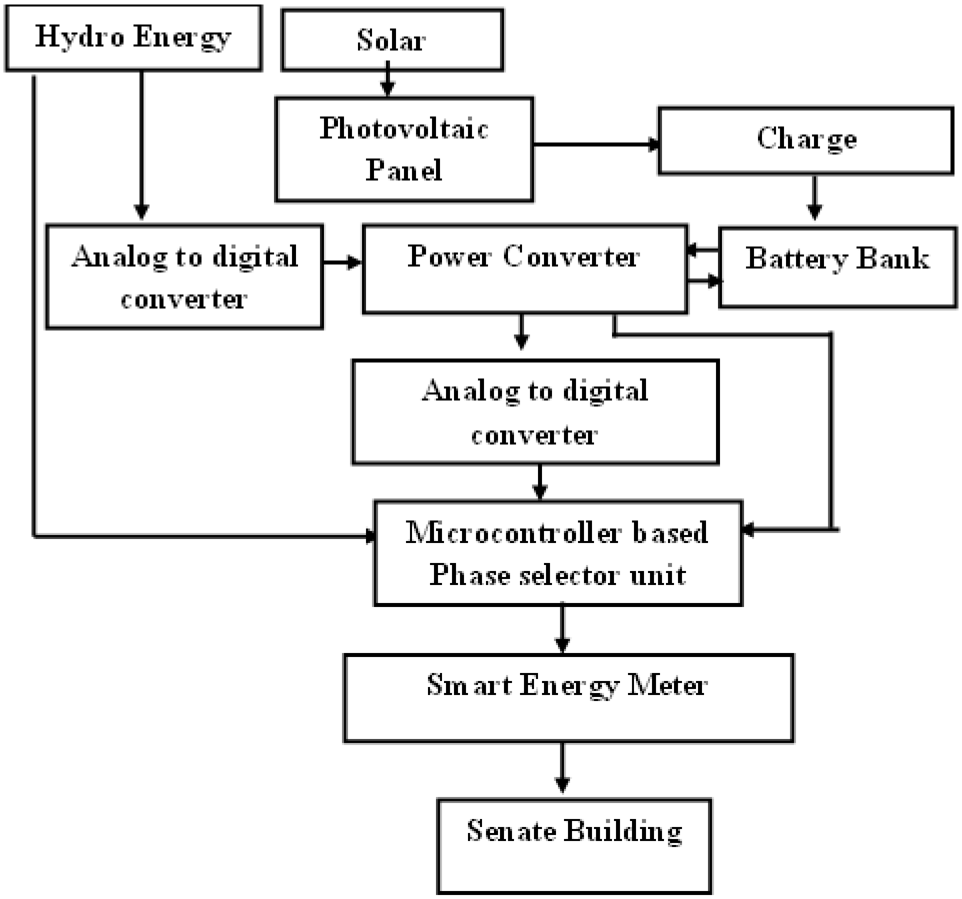

Figure 1: Micro-grid Energy Demand Optimization Block Diagram

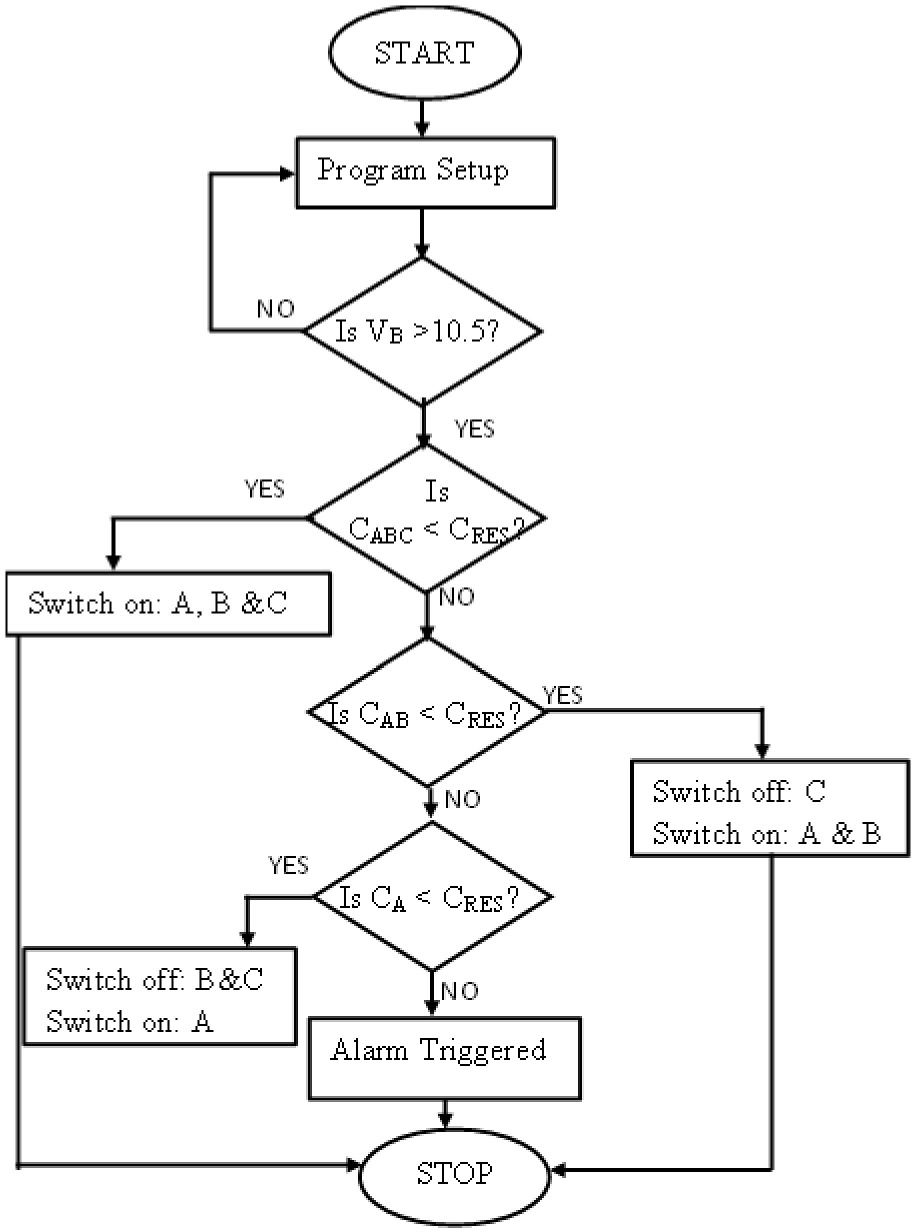

Fig. 2: Operational flowchart for the prototype system

Figures 2 shows the operational flowchart starting with the controller program setup. The signal flow starts with the checking of the available power source, battery level and current drawn by each load. Whenever any load draws too much current that is greater than 25A, the system trips the relay connected to that load. After a while, it checks the disengaged port to compare the current demand of the load on the port, and if it has been reduced, then the load is allowed to remain in the on state. Also, if there is no power from the inverter source or the battery level is low, the hydro is first set to power the vice chancellor's office based on load priority. Fig 3 shows the circuit diagram of the proposed system.

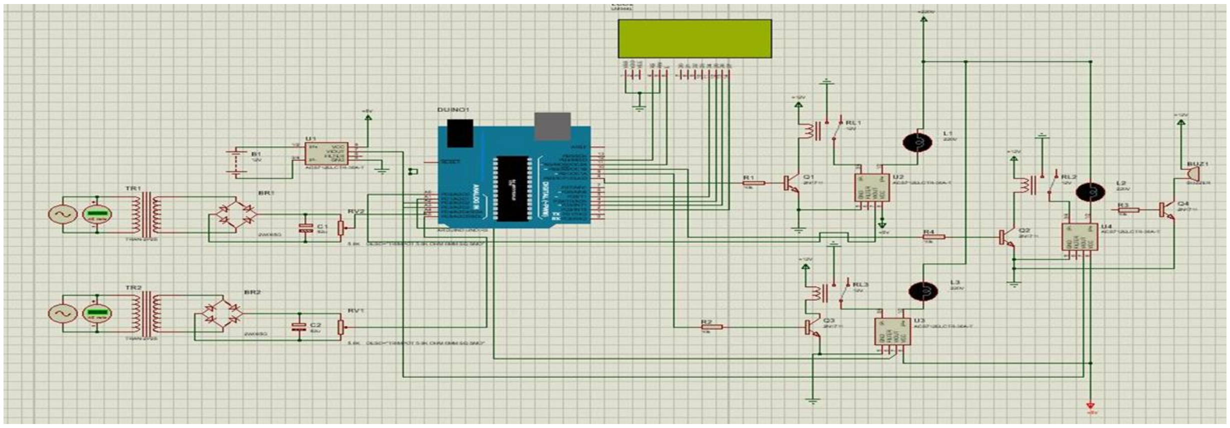

Fig 3. Circuit Diagram of Smart Control System for Senate Building, FUTO

COMPONENTS SPECIFICATION

a. Arduino Microcontroller (Arduino Nano)

The Arduino's microcontroller properties are detailed in Table 1.

Table 1. Properties of the Arduino Nano Microcontroller

Properties	Values
Microcontroller	ATmega328
Operating Voltage	5V
Input Voltage	7-12V
Digital I/O Pins	22(6 of which are PWM)
Flash Memory	32kB
Clock Speed	16MHz
Power Consumption	19mA

b. Four-channel Relay Module: The relay module serves as a link between the high-voltage home circuit and the low-voltage from the Arduino. The relay module pins is isolated from its internal low-voltage digital signal circuit by opto-coupling. The relay's contact capacity is 10A 250V AC / 10A 30V DC, whilst the Digital circuit operates at 5V 20mA (DC). The module is well-suited with the Arduino's 40mA General-Purpose Input/Output (GPIO) pins, and with common household AC appliances. The Normally Open (NO) port of the relay is placed between the source and the load i.e the senate building. This way, current can only flow when the smart micro-controller is at the "High" state. A "High" from the Arduino GPIO GPIO pin activates the relay and switches the appliance on.

c. 10A PWM Charge Controller

d. 12V, 7.5Ah Lead Acid Battery

e. 20W polycrystalline PV panel

Table 2. Properties of Polycrystalline PV panel

Properties	Values
Peak Power	20W
Open circuit Voltage	21.4V
Short Circuit Current	1.32A
Power Allowance Range	5%
Max Power Voltage	16.94V
Max System Current	1.18A

f. 500W power inverter with 12V input DC voltage and 220VAC output voltage

g. LCD 20 x 4 pixels, 5V input power

h. Fixed resistor [120Ω]

$$I_B = \frac{V_B - V_{BE}}{R} \quad 3.1$$

Where:

$V_{BE} = 0.7V$ (Base-Emitter Voltage)

V_B = Base Voltage = 5V

I_B = Base current = 40mA

Therefore:

$$R = \frac{V_B - V_{BE}}{I_B}$$

$$R = \frac{5-0.7}{0.04} = 107\Omega$$

i. Smoothing Capacitor 82μf/12V

$$V_c = \frac{I}{2\pi f c} \quad 3.2$$

$$C = \frac{I}{2\pi f V_c}$$

$$C = \frac{0.310}{2\times 3.142\times 50\times 12}$$

$$C = 82.2\mu F$$

j. Rectifier diode 1N4007 (1A,2W)
k. Transformer

$$\frac{L_p}{L_S} = (\frac{N_P}{N_S})^2 = (\frac{V_P}{V_S})^2 \quad 3.3$$

Where:

$V_P = 220V$
$V_S = 12V$
$L_P = 4H$ (Assumed)
Therefore:

$$L_S = L_P(\frac{V_S}{V_P})^2 = 4\times(\frac{12}{220})^2 = 0.0119H = 11.9mH$$

V. LOAD DEMAND ASSESSMENT

Estimation of hourly electrical energy demand (energy demand profile) of a given facility is paramount in the optimal energy management of renewable energy system, since the renewable energy sources are normally transient in supply.

Quantitative research method was used for this study. A survey through the university senate building was carried out and checklist were developed to generate information on the electrical load profile. The information collected from the survey was now tabulated to the total loads of the building. The facility studied is Senate building of Federal University of Technology Owerri (FUTO).

The estimate daily load profile of the facility is shown in Figure 4. From the load profile, it can be seen that the maximum demand occurs during a daytime from 10 am to 4 pm for the offices, which corresponds to the working hours in the University. 34% of the total offices/ room across the area of survey where surveyed and visited. A typical senate load classification is given in Table 3, and the AC power rating of some appliances along with their power ratings is mentioned in Table 4.

VI. LOAD PROFILE FOR SENATE BUILDING

Table 3 Total Load Profile Specifications for Senate Building

Equipment	Qty	Power (W)	Total Power (kW)	Hours/days		kWatt-hour	
				Day (9am-5pm)	Night (6pm-6am)	Day	Night
Air Conditioner	131	1120	146.7	8 Hrs	-	1,173.80	
Standing Fan	8	42	0.336	8 Hrs	-	2.7	
Ceiling Fans	133	80	10.6	8 Hrs	-	85.1	
Others Lighting points	46	60	2.8	8 Hrs	-	22.1	
Security Lights I	12	18	0.22	-	12 Hrs		2.6
Security Lights II	24	50	1.2	-	12 Hrs		14.4
Computers	268	300	80.4	8 Hrs	-	643.2	
Printers/ Photocopier/ Scanners	22	570	12.5	4 Hrs.	-	50.2	

Printers/ Photocopier/ Scanners	89	1000	89.0	4 Hrs.	-	356.0	
Printers/ Photocopier/ Scanners	66	1450	95.7	2 Hrs.	-	382.8	
Total peak load			449.2kW			2,793.6 kWh/day	17 kWh/day
Senate building daily load						2,804.6kWh/day	
Senate building yearly load						729.2 [MWh/year]	

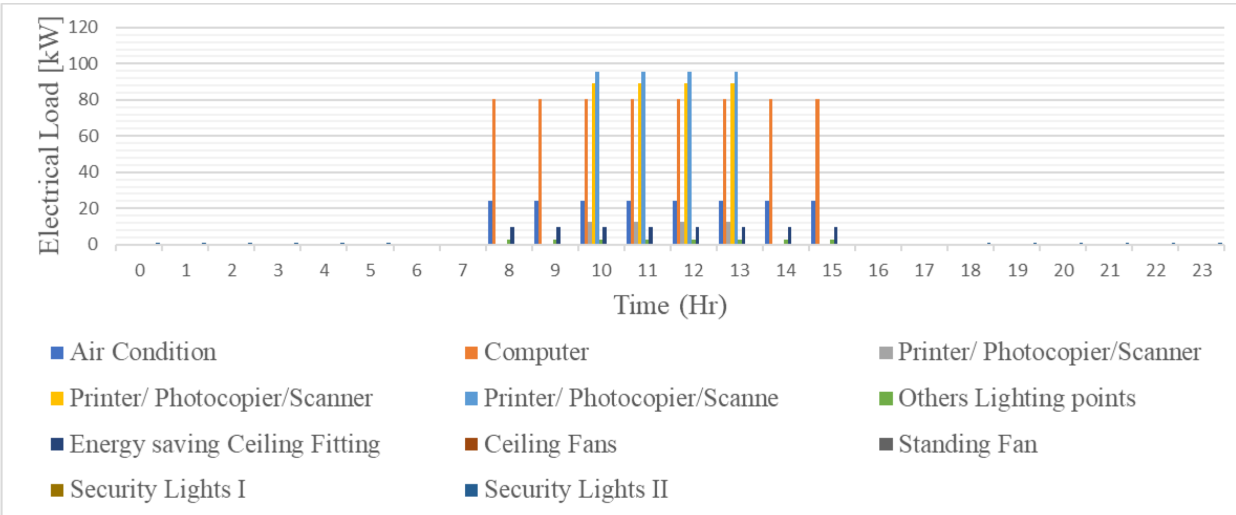

Figure 4 Estimated average daily load profile for Senate building

Table 4: Load data for the renewable power supply for the entire building in terms of priority

Priority Level	Unit	Quantity	Total Power (kW)	Duration Of Usage (Hr)	Energy Consumption (KWH)
Priority One (VC floor)	Air condition	28	31.36	8	250.88
	Energy Lamp	237	14.22	8	113.76
	Computer unit	105	30.9	4	123.6
	Printer/Photocopier	27	27.0	4	108.0
	Photocopier	2	2.9	2	5.8
	Total		106.4		602.04
Priority Two (Registry floor)	Air condition	55	61.6	8	492.8
	Energy Lamp	148	8.88	8	71.04
	Computer unit	82	24.6	4	98.4
	Printer/Photocopier	26	26.0	4	104
	Photocopier	2	2.9	2	5.8
	Total		123.98		772.04
Priority three (Bursary)	Air condition	48	53.76	8	430.1
	Energy Lamp	167	10.02	8	80.16
	Computer unit	81	24.3	4	97.2
	Printer/Photocopier	34	34	4	136.0

	Photocopier	2	2.9	2	5.8
	Sub-total		124.98		749.26
	Basic total		355.36		2,123MWH

Note: = Reserve/ emergency overload is 25% of basic total load

$$\frac{25}{100} \times 355.36 = 88.84 \quad 3.4$$

Therefore, the Senate building Total energy demand is

$$355.36 + 88.84 = 444.2KW$$

VII. HARDWARE IMPLEMENTATION

A prototype of the energy management system is built using a project-based scenario with one ACS 712 current sensors to determine the connected renewable energy sources [solar and hydro]. For testing, implementation, and evaluation, the protype current values were factored to the scale 1:888 to perform a safe, practical demonstration.

Three lamps of 10W, 15W and 5W were connected to portray the different load sections (A, B & c) scenarios for the experiment. During off-peak times, the three lamps can be turned ON and OFF any time, but during peak hours, only a specified amount of the load can be used depending on priority. In this case, a total limit of 0.5A was set to check the proposed design's implementation, if the load exceed this limit the buzzer is triggered.

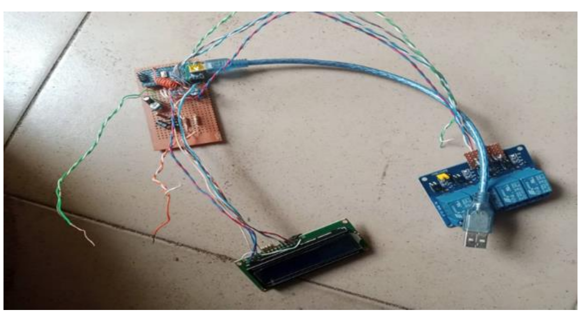

Figure 5: Implementation stage of a smart controller for renewable energy management in FUTO

The input terminal of the relay module were connected to the digital pin of the micro-controller which are triggered individually in accordance to the program code driving the system. Similarly, the current sensing unit is connected to the analog pin1 of the controller. This helps to measure the current drawn by the connected loads in each sections of the FUTO senate building. The control been the heart of the system, displays the action that are taken place in the LCD for easy virtualization.

VIII. UNIT TEST FOR CURRENT SENSING CIRCUITRY

The current drawn by the load were tested with the aid of multimeter and Arduino serial monitor. Table 3.6 shows the current values based on the current demand of the entire sections (Section A, B &C).

Table 5: Current value based on the current demand

Section A	Section B	Section C	Action	Current
OFF	OFF	OFF	Buzzer ON	$I_L>0.5$
ON	OFF	OFF	Section A ON	$0.3\leq I_L\leq 0.5$
ON	ON	OFF	Section A&B ON	$0.15<I_L<0.3$
ON	ON	ON	All Sections ON	$0.05\leq I_L\leq 0.15$
OFF	OFF	OFF	No Power Source	$I_L<0.05$

IX. RESULTS AND DISCUSSION

SIMULATION RESULTS AND DISCUSSION FOR THE SMART CONTROLLER ARCHITECTURE

The simulation result shows the LCD screen during different scenarios.

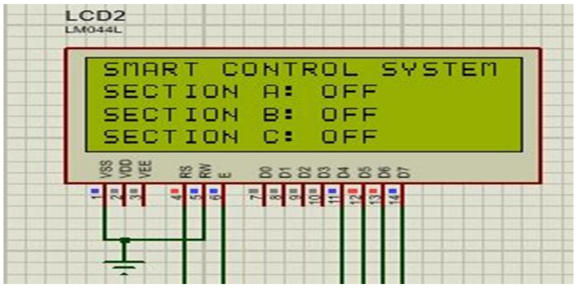

Figure 6 (A): The Simulation Result for the Initial State of the Smart Controller

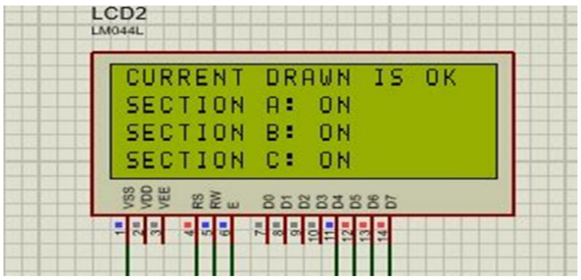

Figure 6(B): The Simulation Result When the Power is Within the Acceptable Range of the Smart Controller

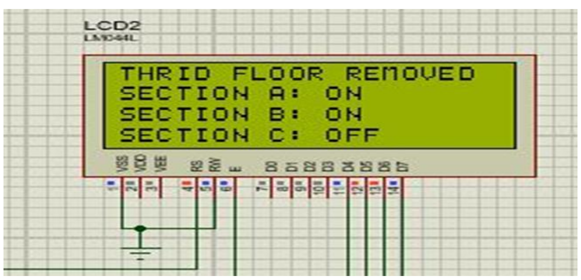

Figure 6(C): The Simulation Result When the Power is Not Within the Acceptable Range of the Smart Controller and Section C is Tripped OFF

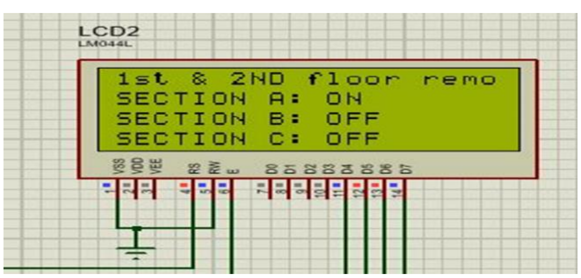

Figure 6(D): Simulation Result When the Power is Not Within the Acceptable Range of the Smart Controller and Section B&C is Tripped OFF

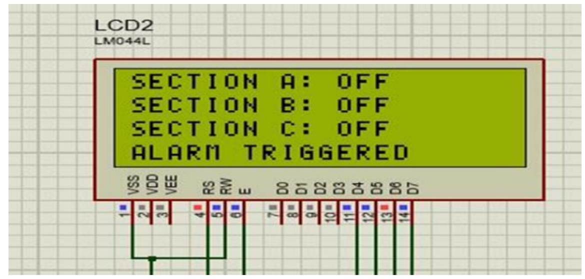

Figure 6(E): Simulation Result When the Alarm system is Triggered

Figure 7 shows the outputs from the LCD screen during the OFF state.

Figure 7a: Initial State when all load is off

Figure 7b: All Sections in OFF state

Figure 8 shows the when the current drawn by the sections connected to the smart controller is okay, i.e within the range of value.

Figure 8a: All loads ON when the current drawn by each section is within the range.

Figure 8b: All Sections in ON state

Figure 9 shows during peak period, where the current demand from the building exceeds the allowed range, in this case 0.5A. The Smart Controller checks the Senate Building total load current and compares it with the input renewable sources. The smart controller automatically disconnects section C of the senate building, which is the ground floor. This can be seen in Figure 9.

Figure 9a: During peak hour Section C turned OFF

Figure 9b: Sections A & B only in ON state

If the total current is still above the limit, the smart Controller again checks the total current. If the load current is still higher than the sanctioned load, it disconnects the section B load that is first floor, as shown in Figure 10.

Figure 10a: Section B & C of the Senate Building turned OFF to meet the load requirement

Figure 10b: Sections A only in ON state

Figure 11 demonstrates the state of the system when Alarm is triggered. This occur when the total load demand exceeds the input renewable energy source coming from the battery and section A alone load demand still exceed the input renewable energy demand.

Figure 4.14: Alarm Triggered

A cost analysis to check the financial saving with the proposed Smart Controller for Improved Energy Management in Senate Building FUTO is implemented.

Using EEDC consumption bill for the month of September 2021, the unit prices is ₦32.93 per kWh (1 kWh= 1Unit). Table 4.1 shows a table of energy consumption with and without this smart controller for an average of one hour. The current estimate was gotten through the serial monitor for the with Smart Controller and then with multimeter for the without Smart Controller for five different sets of connected load.

CONCLUSION AND RECOMMENDATION

A Smart Controller for energy management system for Senate Building was developed. These systems monitors and balance the energy source and electrical load by load shedding the less prioritized section of the building is proposed in this research. The Smart Controller System was effectively built, giving the building the ability to control the electrical consumption of their appliances. The Arduino based smart controller for energy management system was simulated and tested using Arduino IDE and Proteus software's. The design provides a virtual display that helps to visualize which section of the system is ON/OFF. The Senate building in FUTO was divided into three sections (section A, B and C) and selected for the prototype experiment. The result showed that the smart controller and the connected section of the building interact effectively for optimum energy utilization. The proposed system can be a cost-effective energy management system. The hardware protype can be applied easy to heavy buildings due to its easy to use. The Smart Controller can easily switch off the heavy sections of a building without human intervention.

The cost- effectiveness and easy application are key features of the proposed Smart Controller Energy management system. This project is essential for both individual household as well as the power utility as both can benefit from this research work.

Hence, it is highly recommended to both individual household and electric power utilities sector to control the use of hefty electrical load during peak and off-peak hours as well a substantial amount of cutback in finance for both household and industrial consumers is achieved by using this. This prototype design is solely implemented with only solar PV panel as hydropower system is not functioning at the time of this thesis.

Further research needs to be conducted to improve the system's designs by adding the wireless monitoring of renewable energy source using android phone and sensitization of individuals on the need for energy management.

REFERENCES

[1] H. Shareef, E. Al-hassan, and R. Sirjani, "Wireless Home Energy Management System with Smart Rule-Based applied sciences Wireless Home Energy Management System with Smart Rule-Based Controller," no. June, 2020, doi: 10.3390/app10134533.

[2] E. A. Affum, K. A. Agyekum, C. A. Gyampomah, K. Ntiamoah-sarpong, and J. D. Gadze, "Smart Home Energy Management System based on the Internet of Things (IoT)," vol. 12, no. 2, 2021.

[3] Z. Maheshwari, "AN APPROACH TO MODELING AND OPTIMIZATION OF INTEGRATED RENEWABLE ENERGY SYSTEMS (IRES)," 2013.

[4] ClientEarth, "Fossil fuel and Climate Change: the fact." 2020, [Online]. Available: www.clientearth.org.

[5] H. Ritchie and M. Roser, *Energy Mix*. 2018.

[6] M. Bilal, B. Saad, and M. S. Saleem, "Design of home load management system for load rationing in Pakistan," no. September 2020, pp. 1–17, 2021, doi: 10.1002/eng2.12312.

[7] Y. A. L. Sultan, B. S. Sami, and B. A. Zafar, "Smart Home Energy Management System A Multi-agent Approach for Scheduling and Controlling Household Appliances," vol. 12, no. 3, pp. 237–244, 2021.

[8] A. Ajao, "Intelligent Home Energy Management Systems for Distributed Renewable Generators, Dispatchable Residential Loads and Distributed Energy Storage Devices," 2017.

[9] N. Sulthana, "Smart Energy Meter and Monitoring System using IoT," vol. 8, no. 14, pp. 50–53, 2020.

[10] S. K. Vishwakarma, P. Upadhyaya, B. Kumari, and A. K. Mishra, "Smart Energy Efficient Home Automation System Using IoT," *2019 4th Int. Conf. Internet Things Smart Innov. Usages*, no.

February, pp. 1–4, 2020, doi: 10.1109/IoT-SIU.2019.8777607.

[11] B. Mubdir, A. Al-hindawi, and N. Hadi, "Design of Smart Home Energy Management System for Saving Energy," vol. 12, no. 33, pp. 521–536, 2016, doi: 10.19044/esj.2016.v12n33p521.

[12] A. El-hag, M. Bahadiri, M. Harbaji, and Y. A. El, "Energy Procedia Smart Home Renewable Energy Management System," *Energy Procedia*, vol. 12, pp. 120–126, 2011, doi: 10.1016/j.egypro.2011.10.017.

[13] Y. Ma and B. Li, "Hybridized Intelligent Home Renewable Energy Management System for Smart Grids," pp. 1–14, 2020.

[14] A. Solihin, "Design of a Smart Energy Management System for Photovoltaic Stand-Alone Building Design of a Smart Energy Management System for Photovoltaic Stand-Alone Building," 2020, doi: 10.1088/1757-899X/881/1/012158.