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Development of An Enhanced Home Automation System For Energy Saving Using GSM, Internet of Things and Bluetooth Technologies

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***Abstract*—Residential electricity usage accounts for a large portion of Nigeria's electricity consumption due to the rising population and the increasing rate of urbanization. However, much attention has not been given to electricity conservation in the country. In response to this, several recent research studies are tailored towards ensuring a rapid reduction in home energy consumption through various alternatives, including energy-efficient technologies given the current state of inadequate electricity supply worldwide. In this research work, an enhanced home automation system (HAS) for energy saving using GSM, IoT and Bluetooth technologies is developed. The system comprises a temperature sensor, motion sensor, GSM, Bluetooth and Wi-Fi Modules. Others are light dependent resistor (LDR), Solar System, Overvoltage Sensor, an AC Mains and a microcontroller. HAS design and simulation were done using proteus software. The Results shows that in a situation where renewable energy is incorporated into the home automation system to power the appliances alongside the mains supply, 32.79% of energy is conserved.**

Keywords—Residential electricity, Home automation, Renewable energy, Microcontroller, Proteus software, Arduino IDE and Wireless communication

I. INTRODUCTION

The Nigerian power grid is faced with numerous problems [1], the major ones being the growing energy demand, which is currently estimated at 19,100MW [2] and which by far is higher than the current transmission capacity of about 5,103MW [3]. This is as a result of the increasing population size. The country's population at the moment is over 170 million, and with a population growth rate ranging between 2.5 and 2.7% per annum, the population in the next 20 years is expected to grow to 310 million by 2035 [4]. This huge disparity between the available electrical energy and the demanded energy has created an energy mismatch between the quantity of energy supplied, and the energy demanded. If the grid is to meet all the peak demands, it will be strained, thereby exposing it to the danger of collapse. Therefore given the insufficient energy supply, serious measures are needed to limit peak periods of energy demand and curtail any kind of energy losses that may arise from the consumption of electricity. Another is the inefficient use of the available power as a result of power losses along the transmission lines and energy wastage amidst shortage at the residence of the consumers, and this is going to be the focus of this research. Residential buildings globally take up a substantial amount of the total electrical energy produced, and about 30-40% of the total global electricity consumption as at 2018 emanated from the residential sector [5]. In developing countries such as Nigeria, residential electricity consumption is up to 60% [6]. A substantial portion of residential electricity consumption is used for lighting, television, radio, refrigeration, ironing, and air-conditioning, just to mention a few. Even though these devices provide the householders with the necessary comforts and convenience, the energy wasted when the user neglects to turn them off or are left in standby mode is a source of global concern. In recent times, the use of high-efficiency lighting systems alone in residential sectors has helped save a significant amount of electrical energy. Thus, achieving savings of 30 to 50% in lighting costs [7], but its main disadvantage is a short life cycle. Customer load consumption can be controlled by direct and indirect means.

Direct load control involves using an automation device to control loads directly. This control device can either be a simple circuit that applies a pre-programmed schedule for a single load or a more complex device that communicates with a house automation system and smart meter and controls various loads. Although the direct load control approach requires technological development and additional costs for infrastructure, the cost of controlling loads with a device is less than the cost of constructing a new power plant or the set up and use of an energy storage system [8].

In this paper, an enhanced home automation system with an energy management algorithm and a hybrid wireless communication system have been developed for consumer residence in Nigeria. The choice of a hybrid wireless communication is for redundancy (to reduce the chances of total system failure), thus enhancing the reliability of the overall system. The HAS will help monitor and manage the energy consumption of home appliances to reduce energy waste and improve the overall home energy efficiency. Instead of shedding off or shifting some loads during the periods of peak demands as done in the previous research to reduce residential consumption, photovoltaic (PV) with storage has been connected with the home automation device to allow for the automatic transfer of some critical loads (security lights, indoor lights, ceiling fan and television) to it in order to reduce loads on the main grid, thus reducing consumer cost of energy consumption [9] and also providing backup supply to the automation device to enhance its reliability. PV with storage has been considered in this research for backup supply to the home automation device as well as serving as an alternative to utility supply due to its huge magnitude, wide-spread availability, versatility, and its environmentally friendly nature.

II. RELATED WORKS ON HOME AUTOMATION

Shadi Abras was among the early researcher to present the principles of home automation system dedicated to power management [9]. Piyare and Tazil in subsequently came up with the design and implementation of a low cost but yet flexible and secure cell phone (running on Symbian operating system) based home automation system [10]. Since then, several works have been carried out on home automation systems employing various types of wireless communication protocol to improve the reliability of the automation devices. Bluetooth based system has been designed for the physically challenged to enable them control home appliances and devices wirelessly to fulfil their needs and by extension improves living standard at home. However, Bluetooth based designs suffers from distance boundaries [11]. Similar work was done to produce a user friendly graphical user interface (GUI) automation system, using an android phone and an Arduino Mega 2560-R3 board for monitoring and controlling home appliances [12]. Recently [13], a home automation device with home energy management algorithm was developed using smart plug designed with controllable power switches [14]. Although the device was successfully used to cut down the overall home power consumption and thus a reduction in peak demand by 18%, the use of controllable switches to reduce voltages introduces harmonics into the system. [15]Carried out a paper review on home automation system and highlighted that Bluetooth is more preferred by researchers for use in establishing a wireless connection with the automation device due to its cost effectiveness and that additional component such as heartbeat and overvoltage sensors could be incorporated into future home automation devices to enhance their functionality. To keep household power consumption below demand limit (DL) during demand response (DR) events, [16]developed a home energy management (HEM) algorithm with DR to manage power consumption at the appliance level. Although the strategy was used successfully to reduce consumer demand during peak periods, DR strategy inconveniences the electricity user. Therefore, there is the need to incorporate distributed generation sources to supplement the mains and also to cut down cost of energy consumed by the user. To allow home automation, researchers have adopted the most suitable technique for home automation designs [17] Discussed some of the basic architecture of home automation system, their characteristics and the various types of smart home built up using various technologies and their associated challenges. The paper also pointed out that the classification of home automation systems are based on the technology (Wi-Fi, android, Zigbee, cloud, Raspberry Pi, Bluetooth etc) used in their build up. To allow for remote monitoring and control of multiple home appliances from any location, [18] developed IoT based smart home system using a node microcontroller unit (NodeMCU) as a Wi-Fi based gateway to link different sensors and update their data to Adafruit input/output cloud server. The system was very useful in reducing power consumption; however, it is prone to hacks, thus making user's home vulnerable to attack. To further improve the reliability of wireless communication in home automation system, [19] developed a smart energy saving system for Uganda public university using the SMS communication in GSM as a wireless communication medium due its wide coverage and availability to help monitor and control appliances to reduce the electrical energy expenditure of the university.

III. METHODOLOGY

A. SYSTEM BLOCK DIAGRAM AND DESCRIPTION

The block diagram gives the general schematic of the system and how the various components connect with each other and with the central controller, as shown in Fig. 1. The key components of the block are the power supply, microcontroller, sensors, serial communication modules, relay and the solar system.

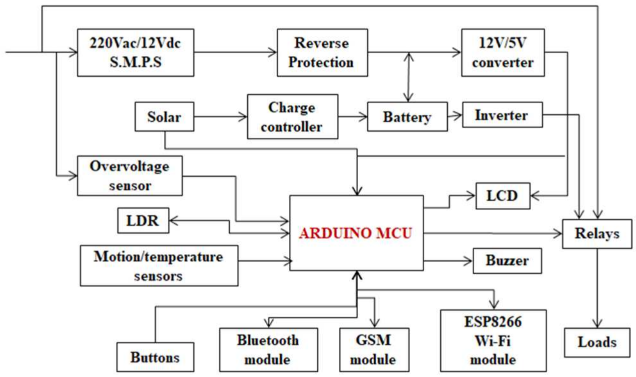

Fig. 1 Block diagram of the HAS

- Power Supply

A 220Vac/12Vdc switch mode power supply (SMPS) adaptor is chosen for powering the automation system. The choice of SMPS over the linear regulated power supplies is due to its high efficiency, better output, voltage regulation, compact size and capability to provide isolation between multiple outputs.

- Controller Unit

This unit connects all the other units, and it can send and receive the command from devices connected to it if properly programmed. It can be programmed, erased and reprogrammed at any given instant.

- Sensory Unit

This unit consists of the temperature sensor for sensing room temperature, a motion sensor for detecting movement within the home, an overvoltage sensor for sensing a rise in supply voltage and light dependent resistor (LDR). The output of these sensors goes into the controller for necessary actions.

- Serial Communication Unit

The wireless communication modules adopted in this research are Bluetooth, GSM and ESP8266 Wi-Fi modules. Through these wireless mediums, the user can communicate with the automation system from far and near, depending on the distance apart. But for the sake of simulation, serial communication was achieved by using a serial COM-port driver which serves as an interface that allows for wireless communication between proteus environment and Arduino integrated development environment (IDE).

- Relay Unit

The relay was used as an electromagnetic isolated switch, allowing a small signal from the microcontroller (5V) to control high voltage AC (220V) to turn on or off appliances. But since the two electronic devices operate at different voltages, a transistor was incorporated to serve as an interface between the two devices to enable the controller to operate the relay successfully as shown in Fig. 2.

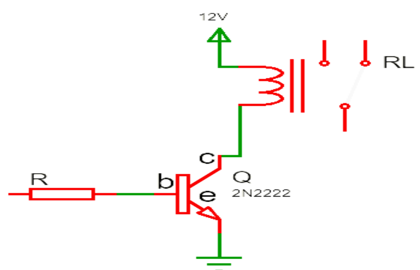

Fig. 3 Relay unit

To determine the resistance value of the base resistor (R_b), collector current (I_c), and base current (I_b), the values were first determined as follows;

$$I_c = \frac{V_r}{R_r} \quad (1)$$

where V_r is the relay voltage and R_r is the coil resistance
From the above expression,

$$I_c = \beta I_b \quad (2)$$

where β is the gain of the transistor

$$I_b = 2\left(\frac{I_c}{\beta}\right) \quad (3)$$

Finally,

$$R_b = \frac{V_b}{I_b} \quad (4)$$

where V_b is the base voltage

- Solar Unit

This unit is not only providing supply backup to the automation system but also serving as power supply alternative to the utility. The components of the solar unit have been adequately sized to power some basic home appliances during peak periods and when utility supply is unavailable. The Solar unit components were sized as follows;

  - Total Energy Demand (TED)

$$TED\,(VAh) = \frac{TEC\,(wh)}{Pf} \quad (5)$$

where TEC is the total energy consumed and *Pf* is the power factor
Solar Array Power (SAP)

$$SED\,(wh) = \frac{(ED)_{daytime}}{PR} \quad (6)$$

where SED is the solar energy demand and PR is the performance ratio

Note: performance Ratio of PV is 65%

$$SAP(W_p) = \frac{SED}{peak\ sun\ hour} \quad (7)$$

$$number\ of\ panels = \frac{SAP(W_p)}{selected\ pv\,rating(W_p)} \quad (8)$$

- Inverter capacity

$$IC\,(VA) = \frac{\text{peak load(wh)}}{Pf} \quad (9)$$

where IC is the inverter capacity

$$ISC\,(VA) = \frac{1}{100} \times IC \quad (10)$$

where ISC is the inverter standby consumption

$$IED = ISC \times hours\ of\ use \quad (11)$$

where IED is the inverter energy demand

$$I_i\,(VAh) = \frac{inverter\ output}{inverter\ efficiency} \quad (12)$$

where I_i is the inverter input

$$Total\ consumer\ energy\ demand = I_i + IED \quad (13)$$

- Battery bank capacity

$$BC\,(Ah) = \frac{BD \times DoA}{DoD \times system\ voltage} \quad (14)$$

BC, BD, DoA, DoD and ED are battery capacity, battery discharge, days of autonomy, depth of discharge and energy demand, respectively.

$$battery_{number} = \frac{BC\ in\ Ah}{selected\ battery\ rating\ in\ Ah} \quad (15)$$

- Solar charge controller (SCC)

A charge controller should be able to operate a current that is at least 20% greater than the maximum power point current (I_{mpp}) of the array.

$$SCC = total\ I_{mpp} + 20\%$$
$$total\ I_{mpp} = battery_{number} \times I_{rated\ current} \quad (16)$$

- Cable sizing

To maximize power losses and cost of cable, the maximum voltage drop on DC side of PV installation should not exceed 3%.

$$change\ in\ voltage(\Delta V) = \frac{2LI}{A \times \alpha} \quad (17)$$

Where *L* is the cable length, *I* is the current flowing through the cable, *A* is the area of the cable and α for the conductivity of copper (58mS/m).

B. FLOWCHART

After developing a functional block diagram for the automation system, an algorithm for appliances monitoring, control and energy management strategies was then designed and presented in flowchart form, as shown in Fig. 3. The power management strategy lies in the ability of the automation device to monitor and control home appliances automatically based on the dictates of motion sensor, temperature sensor, and LDR or remotely using wireless communication devices such as Bluetooth, GSM or IoT. The home automation system is able to coordinate the home appliances in such a manner that an appliance knows when to turn ON or OFF, thus, making it smart. For instance, a lighting system within the home should come up when it is dark, and movement is detected and turns off if otherwise with the help of an LDR. While in the case of a lighting system outside the home (security lights), they should turn ON when it is dark and turn OFF when it is bright without relying on the motion. As for the heating and cooling systems, their operation depends on the room temperature and motion. That is, the device should be able to activate the cooling system if the temperature goes above the threshold and the presence of a person is detected or the heating system if the temperature falls below the threshold. In any case, the user can still put the appliances ON or OFF if need be from any location using either the Bluetooth device, IoT or GSM.

C. CIRCUIT DESIGN

Circuit design was then carried out using Proteus 8.4 software. The design process entails selecting appropriate components from the Proteus library and connecting them to form the desired circuit, as shown in Fig. 4. The Proteus has 2D model for creating components that are not available in its library. The 2D model was used to create TV, solar panel, inverter, charge controller, frame for security light, air conditioner, cooker, current and voltage sensors.

D. CODING

Coding was done using C-language and compiled using the Arduino IDE.

E. SIMULATION

Six home appliances were considered for the simulation as shown in Table I. Simulation was carried using Proteus 8.4 software, as shown in Fig. 4. To achieve serial communication, comport driver was used as an interface between Proteus and Arduino IDE.

IV. RESULTS AND DISCUSSION

From the simulation carried out, results obtained are presented in Table II. The power consumed while the home automation system was on inverter represents the saved power since it is from a free source. The ability of the home automation system to swiftly turn off an appliance when it is not needed and to automatically transfer some of the appliances to inverter when the condition for load transfer is met as given in Fig. 4 were responsible for the energy savings. For instance, between 11pm and 5am there was no consumption from mains even though people were at home because around that period, there was enough energy from inverter and the home automation system has automatically transferred some loads to it and automatically switched off those that were not needed around those periods, since the home occupants should have gone to bed. From the graph in Fig. 5, it could be observed that power saving was highest between 7pm and 9pm because all the appliances were active but some were kept on inverter while the heavy ones were kept on mains. The ones on inverter represent the saved power while the ones on mains represent the power the consumer will pay for. Without such arrangement, the consumer will be pay for the entire power consumed within that period. The inverter is sized to carry only the light loads (security lights, indoor lights, ceiling fan and television) and not the entire home appliances. Thus in the absence of mains, air conditioner and electric cooker will be automatically turned off by the HAS. The inverter is designed to carry a total load of 2,920 watts. Therefore the HAS is programmed to constantly compare the running loads with the total loads and in the event were the running loads exceed the total loads, the system will automatically shut down the inverter system to prevent it against overload.

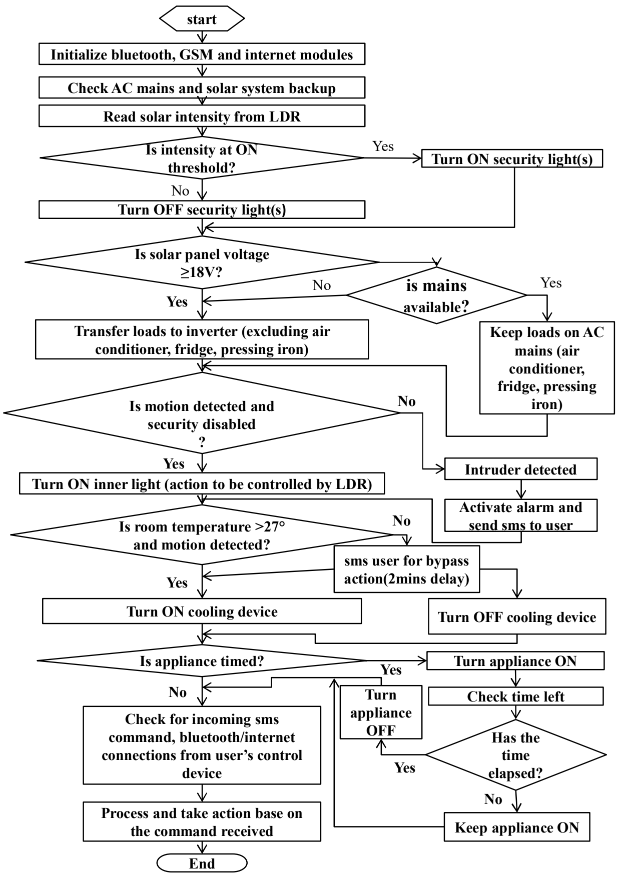

Fig. 3 Flowchart for appliance control and energy management

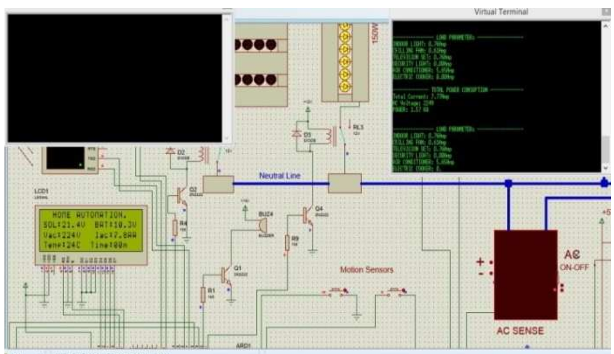

Fig. 4 Simulation process

TABLE I. SELECTED HOME APPLIANCES

S/N	Home appliances		
	Loads types	*Quantity*	*Rating (Watts)*
1.	Security light	2	150
2.	Indoor light	2	75
3.	Ceiling fan	1	120
4.	Television	1	150
5.	Air conditioner	1	1200
6.	Electric cooker	1	1000

TABLE II. SIMULATION RESULTS

Period (Hrs.)	Power consumption management		
	Working appliances	*Power (mains) kW*	*Power (inverter) kW*
7pm-9pm	Indoor lights, security lights, ceiling fan, television, air conditioner, electric cooker	2.89	2.16
9pm-11pm	Security lights, ceiling fan, air conditioner	1.14	0.42
11pm-1am	Security lights, ceiling fan	0.00	0.42
1am-3am	Security lights, ceiling fan	0.00	0.42
3am-5am	Security lights, ceiling fan	0.00	0.42
5am-7am	Ceiling fan, electric cooker Indoor lights	1.02	0.27
7am-9am	Ceiling fan, television, electric cooker	1.02	027
9am-11am	Ceiling fan, television	0.00	0.27
11am-1pm	Ceiling fan, air conditioner, electric cooker	2.16	0.12
1pm-3pm	Ceiling fan, television, air conditioner	1.14	0.27
3pm-5pm	Indoor lights, ceiling fan, television, air conditioner	1.14	0.42
5pm-7pm	Indoor lights, security lights, ceiling fan, television, air conditioner, electric cooker	2.16	0.72

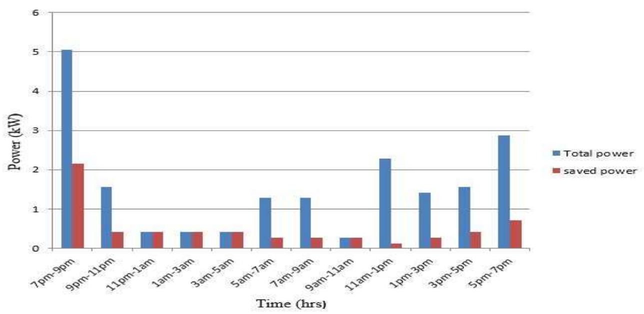

Fig. 5 Comparison between the total power consumed and saved power

V. CONCLUSION

This research has provided for an effective monitoring, control and power management of home appliances at all times and from any location using bluetooth, GSM and IoT. For a more effective appliance power management, a properly sized PV with storage was also incorporated to serve as power backup for the HAS as well as an alternative to mains during peak and off peak periods. The home automation system has succeeded in saving home energy consumption by almost 50%

REFERENCES

[1] M. A. Zehir and M. Bagriyanik, "Demand Side Management by controlling refrigerators and its effects on consumers," *Energy Convers. Manag.*, vol. 64, pp. 238–244, 2012, doi: 10.1016/j.enconman.2012.05.012.

[2] A. V. Adebayo, P. K. Ainah, and O. Apata, "The Insight and Foresight of the Nigerian Power Transmission System: An Overview," *2020 IEEE PES/IAS PowerAfrica, PowerAfrica 2020*, 2020, doi: 10.1109/PowerAfrica49420.2020.9219845.

[3] B. Y. Oruwari and H. Otombosoba, "Constraints To Efficient Electricity Supply In Nigeria," pp. 33–36, 2021.

[4] T. R. Olorunfemi and N. Nwulu, "A Review of Demand Response Techniques and Operational Limitations," *2018 Int. Conf. Comput. Tech. Electron. Mech. Syst.*, pp. 442–445, 2018.

[5] A. B. Abdullahi, "Impact Assessment of Wheeling Renewable Distributed Generation to Residential Load," no. December, pp. 9–10, 2021.

[6] H. Shareef, M. S. Ahmed, A. Mohamed, and E. Al Hassan, "Review on Home Energy Management System Considering Demand Responses, Smart Technologies, and Intelligent Controllers," *IEEE Access*, vol. 6, pp. 24498–24509, 2018, doi: 10.1109/ACCESS.2018.2831917.

[7] K. Olaniyan, B. C. McLellan, S. Ogata, and T. Tezuka, "Estimating residential electricity consumption in Nigeria to support energy transitions," *Sustain.*, vol. 10, no. 5, 2018, doi: 10.3390/su10051440.

[8] A. Zairi and M. Chaabene, "A review on home energy management systems," *2018 9th Int. Renew. Energy Congr. IREC 2018*, no. Irec, pp. 1–6, 2018, doi: 10.1109/IREC.2018.8362475.

[9] Yadu Krishnan, "Smart Home Energy Management - the Future of Energy Conservation: A Review," *Int. J. Eng. Res.*, vol. V9, no. 07, 2020, doi: 10.17577/ijertv9is070134.

[10] R. Piyare and M. Tazil, "Bluetooth based home automation system using cell phone," *Proc. Int. Symp. Consum. Electron. ISCE*, no. June 2011, pp. 192–195, 2011, doi: 10.1109/ISCE.2011.5973811.

[11] A. E. Amoran, A. S. Oluwole, E. O. Fagorola, and R. S. Diarah, "Home automated system using Bluetooth and an android application," *Sci. African*, vol. 11, p. e00711, 2021, doi: 10.1016/j.sciaf.2021.e00711.

[12] A. Aisha Badrul Hisham, M. H. I. Ishak, C. K. Teik, Z. Mohamed, and N. H. Idris, "Bluetooth-based home automation system using an android phone," *J. Teknol.*, no. 3, pp. 57–61, 2014, doi: 10.11113/jt.v70.3463.

[13] D. Campus, "A Home Energy Management Algorithm with Smart Plug for Maximized Customer Comfort," pp. 0–3, 2015.

[14] I. Kaur, "Microcontroller Based Home Automation System with Security," *Int. J. Adv. Comput. Sci. Appl.*, vol. 1, no. 6, 2010, doi: 10.14569/ijacsa.2010.010610.

[15] R. Marimuthu, A. K. Singh, S. Balamurugan, and K. Aroul, "Home automation using bluetooth - A review," *ARPN J. Eng. Appl. Sci.*, vol. 11, no. 21, pp. 12867–12870, 2016.

[16] D. Purohit and M. Ghosh, "International Journal of Computer Science and Mobile Computing Challenges and Types of Home Automation Systems," *Int. J. Comput. Sci. Mob. Comput.*, vol. 6, no. 4, pp. 369–375, 2017, [Online]. Available: www.ijcsmc.com.

[17] M. B. Hayat, D. Ali, K. Cathrine, M. Lana, and N. Ahmed, "Solar energy — A look into power generation , challenges , and a solar - powered future," no. September, pp. 1–19, 2018, doi: 10.1002/er.4252.

[18] A. Abdulkareem, T. E. Somefun, O. K. Chinedum, and F. Agbetuyi, "Design and implementation of speech recognition system integrated with internet of things," *Int. J. Electr. Comput. Eng.*, vol. 11, no. 2, pp. 1796–1803, 2021, doi: 10.11591/ijece.v11i2.pp1796-1803.

[19] L. Nkamwesiga, J. J. Kazibwe, and P. Male, "Arduino Based Smart Energy Saving System in Ugandan Public Universities: A Case Study of Muni University, Uganda," *Int. J. Innov. Res. Dev.*, vol. 8, no. 6, pp. 235–248, 2019, doi: 10.24940/ijird/2019/v8/i6/jun19080.