Design And Implementation of Cost Effective SMS-Based Online Voting System for Credible election in Nigeria

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Abstract: *The process of voting involves a group, such as an electorate or assembly, coming together to reach a consensus or express an opinion, typically after discussions, debates, or election campaigns. Utilizing a manual method of voting can lead to numerous electoral malpractices and challenges. These may include violent attacks on voters, manipulation of results, vote purchasing, inaccessibility of polling locations, and so forth. These are sufficient reasons that have necessitated the design and implementation of an SMS-based Online Voting System (SBOVS) that effectively addresses most of these issues. It offers a solution for achieving transparent, fair, and trustworthy elections in countries such as Nigeria, as well as in schools and organizations. The motive behind this work is to enable Nigerians to cast their votes without fear of violence and rigging. It aims to use technology, to be specific SMS, to proffer solutions to our electoral challenges. In this system, voters are to cast their votes for the candidate of their choice in the comfort of their homes, by typing their PVC numbers, state of residence, LGA of residence, post, and party to be voted for and sending it as SMS to a particular number using either of the two registered numbers (i.e. one of the two phone numbers registered along with the voter's data during PVC registration). The system will authenticate the phone number along with the PVC number on the INEC database. If the two are found to be part of the data registered for the same person and the individual hasn't yet voted, the voting will be successful and a successful SMS will be issued to the voter. The voter's full name and the current scores of the parties will be included in the SMS.*

Keywords: *Design*; *Election; credibility; Nigeria; SMS-based voting;*

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1.0 Introduction

The history of elections in Nigeria dates back to 1923, following the implementation of Clifford's Constitution of 1922, which established an electoral system to oversee elections for three legislative seats. A major turning point in Nigeria's electoral history occurred with the introduction of party politics under Macpherson's Constitution of 1951, leading to the formation of political parties that competed in elections for regional assemblies (Abdulsalam et al., 2021).

Unfortunately, Nigeria's elections have long been marred by violence, a trend that resurfaced during the most recent general elections in 2023 (Yiaga Africa, 2023). Reports of fatalities varied, with a newspaper citing 39 deaths while the European Union reported 21 fatalities during a media briefing. This violence disrupted voting in certain parts of the country. Low voter turnout was another significant issue during the voting exercise (Ali et al., 2017). In the presidential election held on February 25, 2023, only about 25 million voters participated, representing

28.63% of eligible voters. The low turnout was attributed to inadequate voter education, logistical challenges, and, most importantly, fear of violence (Okafor et al., 2022; Nwangwu, 2023). These challenges could potentially be addressed or minimized through the adoption of the SMS-Based Online Voting System (SBOVS).

The SMS-Based Online Voting System (SBOVS), also referred to as an electronic voting system, enables eligible voters to cast their votes using smartphones and Short Message Service (SMS) technology. Unlike traditional polling stations or computer-based online voting systems, SBOVS allows citizens to participate in elections by sending text messages. SBOVS has the potential to enhance voter turnout, improve accessibility, and reduce the costs associated with traditional paper-based voting systems.

According to a report by *Vanguard* on November 2, 2022, the budget for Nigeria's 2023 general elections was N355 billion. This included allocations of N161.9 billion for operational and administrative expenses, N117.1 billion for electoral technology, and N18.5 billion for capital expenses. Additionally, N2.6 billion was allocated for off-season elections, such as the governorship elections in Kogi, Imo, and Bayelsa. INEC further detailed that $2.6 billion would cover recurring expenses, including printing of ballot papers, forms, and envelopes, as well as logistics, honoraria for officials, security support, and other related expenditures (Sule, 2023).

While SBOVS offers many advantages, including reduced election costs and improved voter engagement, its implementation must address challenges related to security, reliability, and regulatory compliance to preserve electoral integrity. SBOVS prevents vote tampering, voter impersonation, and multiple voting while reducing the need for voters to travel long distances to cast their votes. Additionally, it mitigates issues of ballot box theft, voter fraud, and result manipulation prevalent in Nigeria's traditional voting systems (Toba & Adebimpe, 2018).

Nigeria has already made progress in adopting electronic voting systems. Kaduna State pioneered the use of e-voting during its local government elections in 2018. The benefits of e-voting, such as increased convenience and voter participation, are evident. E-voting addresses voter apathy commonly associated with traditional voting methods by allowing individuals to cast their votes easily, thereby strengthening the democratic process. Furthermore, it eliminates errors caused by poorly designed paper ballots (Odeyemi et al., 2022; Oyelude & Olojede, 2023).

Despite these advancements, existing e-voting systems have not fully addressed the unique challenges of Nigeria's electoral process. In the 2018 Kaduna State Local Government election, the Voter Verifiable Paper Audit Trail (VVPAT) Electronic Voting Machine (EVM) Model EMP2710, custom-built by EMPTECH for KAD-SIECOM, was used. Voters were required to present their Permanent Voter Cards (PVCs) for accreditation before casting their votes electronically. After voting, election officials retrieved printed ballot papers for manual counting by party representatives and officials (Victor, 2018).

Another significant development was the introduction of the Bimodal Voter Accreditation System (BVAS) by INEC in 2021. BVAS is a technological device designed to promote credible elections and prevent rigging. It is used for voter registration, accreditation via QR code or barcode scanning, and post-election transmission of results to the INEC portal. Notably, BVAS does not require internet connectivity during voting, as it only needs internet access for result transmission (Ogundare et al., 2023).

While BVAS represents a significant step forward, it does not address the challenge of voters traveling to polling stations for federal elections. To bridge this gap, this study aims

to design and construct a low-cost, automated real-time voting system that enables voters to cast their votes from their homes using SMS. Votes will be received and uploaded to a server via a Global System for Mobile Communication (GSM)/General Packet Radio Service (GPRS) module. This innovative solution seeks to enhance accessibility, reduce electoral costs, and address existing challenges in Nigeria's voting system.

2.0 Methodology and System Design

2.1 Method of study

In this work, data was collected from past documents that contained findings that are related to Nigerian politics, elections, and democratic consolidation. Secondary sources of data collection were used, which include textbooks, internet sources, articles, etc. Based on these facts, codes were written and compiled for a micro-controller unit (MCU) using MikroBasic Pro for the PIC compiler. Also, WeBuilder was used to design the web pages for easy communication between the MCU and the server via the GSM/GPRS module.

Fig. 1: Bimodal Voter Accreditation System (BVAS)

The SMS-based online voting system consists of two parts: the web and the electronic circuit parts. The web part consists of some Hypertext Preprocessor (PHP) scripts written in Webuilder and residing on a server hosted by Qservers. The PHP scripts are pvcregform.php, votersform.php, scoredisplay.php, and so on. Their web pages can be accessed at http://www.doitniger.com.ng/onlinevoting/ where the username is mr.man and the password is tested (note that the username and password are required by the **umpire** to access the results only). The electronic part consists of a microcontroller unit, which is the heart of the study, a GSM/GPRS module and a few other circuit elements.

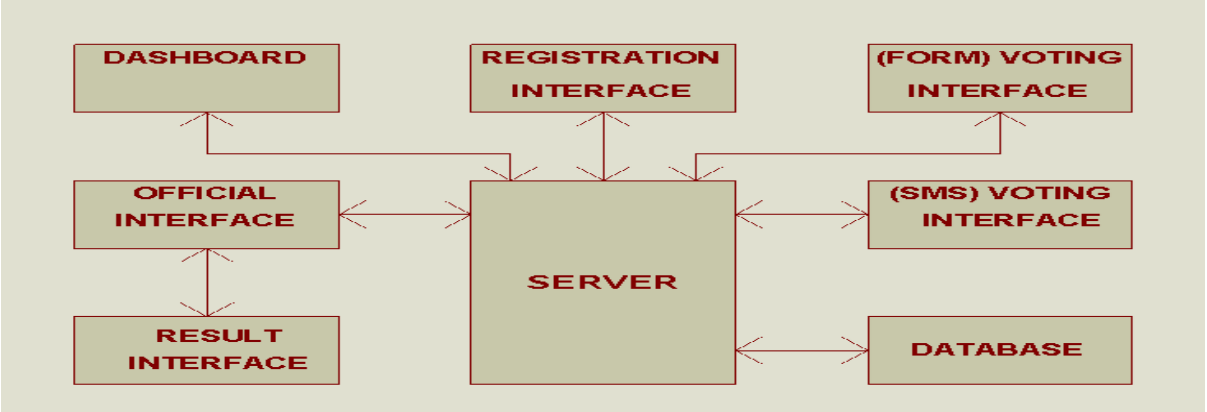

Fig. 2: Software Design Block Diagram

2.2 System design

The design of this study can be divided into two: software design and hardware design.

The software consists of all the software platforms needed for the system's functioning and their interactions. Fig. 2 below shows a

block diagram of the software part of the system.

The dashboard is a desktop software application managing elections. It incorporates the basic features for monitoring and managing voters, administrators and the election. It accesses the data that are contained in the database on a server (Jeberson, et al 2014). The dashboard features tabs for PVC registration, PVC data checking, Online Voting, and an official use tab that requires the **umpire's** username and password for authentication and validation against the values in the database. If validation succeeds, access to the official page is granted, else access is restricted. To access the dashboard, one will have to log on to the dashboard as shown below in Fig. 3.

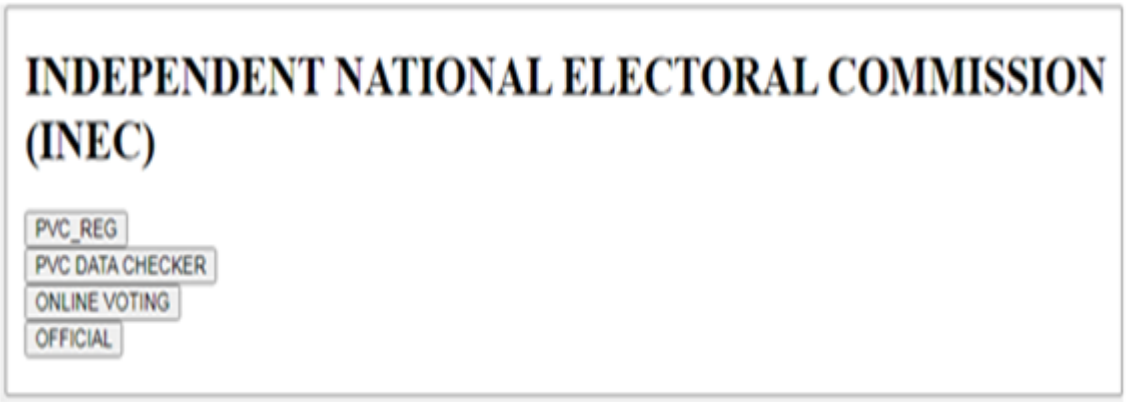

Fig. 3: Dashboard

Registration interface

The voters are registered prior to an election. The URL for the umpire registration database is included in the study for access to the database. The setup of the registration platform consists of a computer running the Windows Operating System, which is used to collect voters' data and store in the database through the server (Burtica et al., 2012). When the "PVC_REG" tab is clicked, a form pops up, as shown in Fig. 4.

Fig. 4: PVC registration form

Data Checking Interface

For a registered individual to cast their vote, the most crucial piece of information they must have on hand is their PVC number. If one happens to forget this number, they can access it by visiting the Website and selecting the "PVC DATA CHECKER" tab. Upon filling out and submitting the form displayed (Fig. 5), the PVC number and other relevant data will be provided.

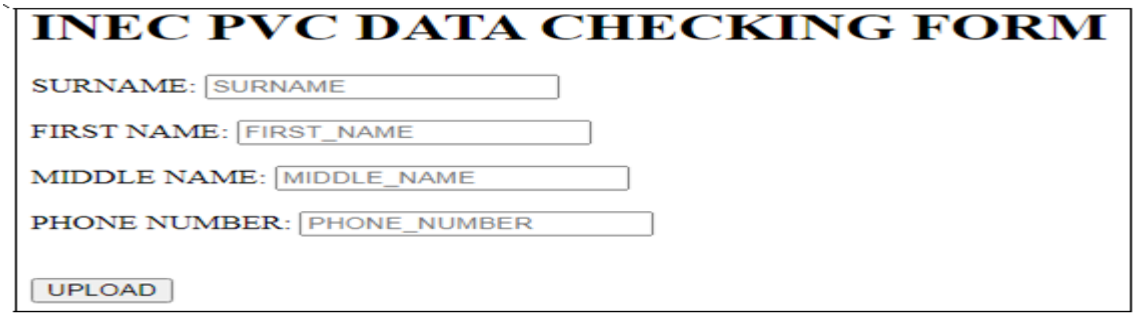

Fig. 5: PVC data checking form

Voting Interface

The voting interface is divided into two parts: online voting and SMS voting. In order to vote online, individuals must first complete an online form by selecting the "ONLINE. The VOTING" tab on the dashboard is located at http://www.doitniger.com.ng/onlinevoting/. Upon clicking this tab, the form below (Fig. 6) will display.

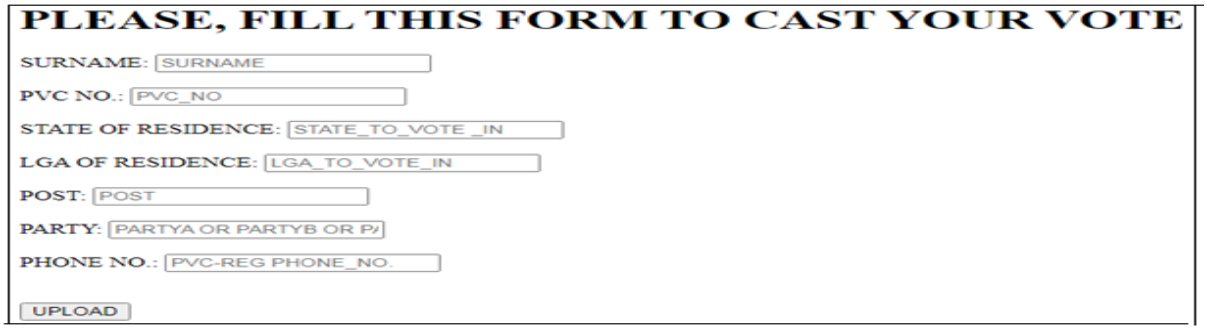

Fig. 6: Online Voting Form

When the form is filled correctly and uploaded, the voter's full name and scores (as at the time the vote was cast) for each of the parties will be displayed on the browser.

SMS Voting

The main motive behind the design and implementation of this study is to enable the electorate to vote at their convenience while curbing electoral malpractices. It is important to note that there are more Nigerians without internet-enabled phones than those with them. As a result, "SMS voting" is preferred over "Online Voting" as it does not require internet connectivity. SMS voting is accomplished by sending voter's data to a specific number in a predetermined format: *VOTE STARTS PVC NUMBER, STATE OF RESIDENCE, LGA OF RESIDENCE, POST, PARTY, VOTE ENDS*

Official Interface

This interface is accessed by clicking the "Official" tab by the umpire only at http://www.doitniger.com.ng/onlinevoting/ where the username is Mr. Man and the password test. The login page is shown in Fig. 7.

If the username and password supplied are correct, the page in Fig. 8, will pop up.

Fig. 7: Login Page

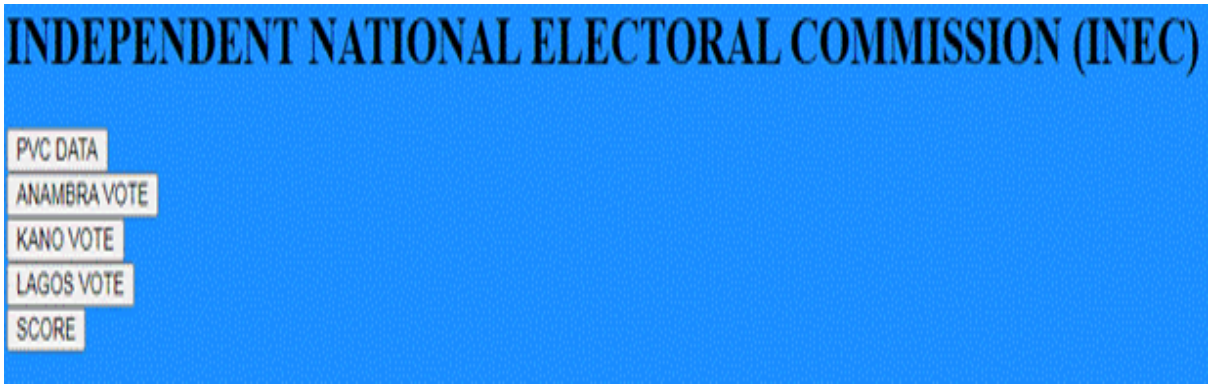

Fig. 8: Result Page

Result Interface

Fig. 8 depicts a web page that allows the umpire to access PVC data, voters' data, and the election results. A database is created specifically for storing voters' data during the election in three Nigerian states - Anambra, Kano, and Lagos. A screenshot of the proof of concept is shown in Figs 9a -9b.

SURNAME	FIRST NAME	MIDDLE NAME	DATE OF BIRTH	SEX	MARITAL STATUS	MOTHER'S MAIDEN NAME	RESIDENTIAL ADDRESS	LGA OF RESIDENCE	CITY OF RESIDENCE
SALAMI	BOLUWATIFE	OLAKUNLE	03/09/2000	MALE	SINGLE	KILOMODEMO	3 OJO STR KOSOFE	AGUATA	OZUBULU
SAHEED	MUHAMMAD	IBRAHIM	15/12/44	M	M	ABU BAKAR	35, BEGUWA STREET	BICHI	KANO
ABEJIDE	BALKIS	AYOOLA	16/6/97	F	M	OLAWALE	7, TUNDEOLA ST	ISOLO	OSHODI
ABEJIDE	ISHMAEL	OLAWALE	16/6/97	M	M	JULIUS	9, TUNDEOLA ST	ISLAND	ISLAND

Fig. 9a: PVC Data

STATE OF RESIDENCE	LGA OF ORIGIN	STATE OF ORIGIN	NATIONALITY	OCCUPATION	PHONE NO.1	PHONE NO.2	PVC NO.	VOTE	TIME	DATE
ANAMBRA	BARIGA	LAGOS	NIGERIAN	POS MANAGER	07052208095	08035371478	00F2 LK43 1329 5733 777	VOTED	6:58:14	14-03-2023
KANO	BICHI	KANO	NIGERIAN	CIVIL SERVICE	08035371478	07044519251	00F3 JK47 3327 7743 778	NOT YET VOTED	22:56:22	10-03-2023
LAGOS	KOSOFE	LAGOS	NIGERIAN	TRADING	08035371478	07044519251	10K5 JK13 2529 5875 125	NOT YET VOTED	12:35:04	11-03-2023
LAGOS	AJEROMI	OYO	NIGERIAN	SINGING	08035371478	07052208095	548LA/2022S	NOT YET VOTED	12:38:27	11-03-2023

Fig. 9b: PVC Data

SURNAME	FIRST NAME.	MIDDDLE NAME	PVC NO.	STATE OF RESIDENCE	LGA OF RESIDENCE	PARTY	POST	VOTE NUMBER	PARTYA	PARTYB	PARTYC	TIME	DATE
SALAMI	BOLUWATIFE	OLAKUNLE	00F2 LK43 1329 5733 777	ANAMBRA	AGUATA	PARTYC	GOVERNOR	1	0	0	1	14:51:30	26-03-2023

Fig. 9d: Voters' data for Anambra State

SURNAME	FIRST NAME.	MIDDDLE NAME	PVC NO.	STATE OF RESIDENCE	LGA OF RESIDENCE	PARTY	POST	VOTE NUMBER	PARTYA	PARTYB	PARTYC	TIME	DATE
SAHEED	MUHAMMAD	IBRAHIM	00F3 JK47 3327 7743 778	KANO	BICHI	PARTYC	GOVERNOR	1	0	0	1	21:26:32	27-03-2023

Fig. 9e: Voters' data for Kano State

SURNAME	FIRST NAME.	MIDDDLE NAME	PVC NO.	STATE OF RESIDENCE	LGA OF RESIDENCE	PARTY	POST	VOTE NUMBER	PARTYA	PARTYB	PARTYC	TIME	DATE
ABEJIDE	BALKIS	AYOOLA	10K5 JK13 2529 5875 125	LAGOS	ISOLO	PARTYB	GOVERNOR	1	0	1	0	12:51:16	26-03-2023

Fig. 9f: Voters' data for Lagos State

2.3 Hardware Design

The Microcontroller unit is the brain of this system. It receives voter's data through SMS sent by the voter in the following format:
VOTESTARTS PVCNUMBER, STATEOFRESIDENCE, LGAOFRESIDENCE, POST, PARTY, VOTEENDS
For instance, when the message (VOTESTARTS 00F2 LK43 1329 5733 777, LAGOS, BARIGA, GOVERNOR, PARTYA, VOTEENDS) is transmitted, the GSM/GPRS module receives the message through the sim card in it, and pass it to the MCU. The data will be extracted and concatenated with the following URL http://doitniger.com.ng/onlinevoting/votersSMSdatauploadforgsm2.php to give https://www.doitniger.com.ng/onlinevoting/votersSMSdatauploadforgsm2.php?pvcn=00F2+LK43+1329+5733+777&stor=ANAMBRA&lgar=AGUATA&epost=GOVERNOR&party=PARTYB&phn=08035371478&submit=UPLOAD and then be uploaded to the server. The PHP script on the server will authenticate, vote on the data, and then send a success or failure SMS to the voter via the GSM/GPRS module and the MCU. However, if the voter has previously voted, a warning SMS would be issued back.
When the mains supply fails, the system will be powered by lithium batteries to complete the present data processing before shutting down until power is restored. During the shutdown time, the buzzer will continually sound an alarm to inform all parties involved. Data and other relevant information are sent to the liquid crystal display (LCD) human readout.
The power supply stage is the final part of the design and includes an 8.4V backup battery, charger, and voltage regulators. The MCU measures the voltage across the battery. If it is low, the alarm circuit will activate. The complete circuit diagram comprises the Power supply stage, Microcontroller Unit (MCU), GSM/GPRS module, Alarm driver and buzzer, Liquid Crystal Display (LCD), and the Web server as depicted by the block diagram in Fig. 11.

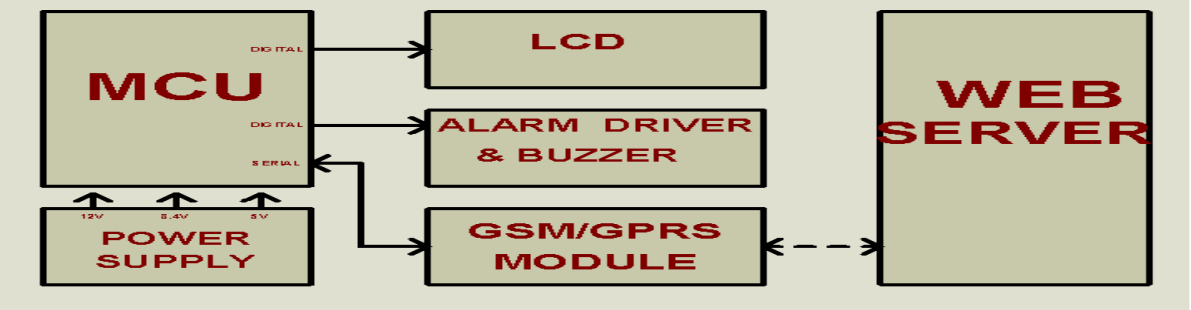

Fig. 11: Block diagram of the electronic circuit of SBOVS

Power supply

This unit comprises of a 220 V/50Hz A.C Switching Mode Power Supply (SMPS) which serves as power supply to the battery charging circuit and other circuit elements such as the microcontroller unit U_1, the GSM/GPRS module U_2 and so on. The power supply gives 12V D.C output, and two of 9V regulators, U_3 and U_4 connected in parallel (to increase current) to reduce the 12V to 9V to charge the batteries. A positive voltage regulator U_5 in parallel with U_6 reduces it further to 5V D.C. The 12V DC powers the buzzer and the charging circuit, while the 5V DC powers other circuit elements like the microcontroller unit and the liquid crystal display. Capacitor C_1 filters the output voltage and C_2 decouples are likely to spike to the ground (Bird, 2003; Theraja, 2008).

8.4V from the lithium-ion backup battery is fed to the two 5V D.C regulators U_5 and U_6 through R_1 which serves as a fuse to protect the power supply from damage in case there is a short circuit in the main circuit (Fig. 12). When there is mains voltage failure, the circuit uses the backup battery to process the current data completely before shutting down. That is, it will not process any other received SMS or voter's data until power is restored. Hence, mains failure must be detected. This is achieved by using the MCU's analogue to digital converter (ADC); voltage to the ADC should be reduced using scale-down resistors to prevent the module from damage. The scale-down resistors R_9 and R_{10} form a potential divider network which divides the output voltage from the 7809 regulators U_3 and U_4 to a safe value for the MCU, this safe value is 5V or lower.

Their values are calculated as follows:

Let R_9 = 1k and V = 20V

$I_{R9} = V_{R9} / R_9 = 5 / 1K = 5mA$

$R_{10} = V_{R10} / I_{R10} = (V – V_{R9}) / I_{R10} = (20 – 5) / 5mA = 3K$

The nearest preferred values for R_{10} are 3.3k and 2.7k. However, 3.3k was used.

R_7 and R_8 are equivalent to R_9 and R_{10} respectively both in values and functions. Resistor R_{11} reduces the charging current to a safe value for lithium-ion batteries BAT1 and BAT2, this protects both the batteries and charger U_3 in parallel with U_4. V_{R9} is fed to ADC0 of the MCU, while V_{R10} is fed to ADC3 for measurement and decision-making.

Battery charger

This is made up of two 9V regulators connected in parallel to double the output current, which ultimately charges the battery and powers the entire circuit. The regulators receive 12V from the SMPS power source. The maximum charging voltage is 4.2V 3800mAH for each of the two lithium-ion batteries, BAT1 and BAT2.

Total charging voltage is 4.2V x 2 = 8.4V

Assuming the batteries discharge from 8.4V to 6.4V,

Let charging current = 1A

Charging voltage = 9V - diode drop = 9V - 0.6V = 8.4V

R_{11} = (charging voltage - (discharged) battery voltage) / charging current

$$= \frac{(8.4V - 6.4V)}{1A} = \frac{2V}{1A} = 2\ Ohms$$

Microcontroller unit

The microcontroller used for this study is PIC18F4620 with 40 pins and 64kB code memory and 39.68 data memory. The rules for transistor-transistor logic (TTL) ICs are strictly adhered to such that the input pins are properly grounded with suitable resistors. Pin configurations of PIC18F4620 are illustrated in Fig. 12. Pin 1 is the reset pin while pins 13 and 14 are for clocking. Using information available in the PIC18F4620 datasheet, the value of R_2 which interfaces the +5 V supply and pin 1 of PIC18F4620 is chosen to be 10 kΩ. The crystal oscillator X_1 oscillates the microcontroller at a frequency of 10 MHz which enables the programme counter in the micro-controller unit (MCU) to operate and thereby reads the instruction codes line by line. Without the crystal, the micro-controller unit will not function except it has been conFig.d to operate with

its internal RC oscillator. In addition, the values of the smoothening capacitance C_3 and C_4 are chosen to be 33pF each according to the datasheet of the micro-controller unit. These capacitors decouple noise that is likely to be generated by X_1 to the ground. Firmware for the MCU was written and compiled in MikroBasic Pro for PIC, the hex file was copied to the MCU using PICkit2.

This chip was chosen for its small size, its numerous output ports, portability, and low current consumption. No decoder or multiplexer is required. It is a simple yet powerful microcontroller. Users would just have to learn 35 single-word commands to program the device. It is easy to program and reprogram (up to 10,000,000 cycles). Furthermore, the function of the MCU in this study are to respond quickly to high or low signal voltage at any of its inputs. Additionally, it receives SMS from voters via the GSM/GPRS module and uploads them to the server. Subsequently, it sends the voter an SMS indicating success or failure via the GSM/GPRS module. When the battery becomes low, it sends a digital control signal that activates the warning buzzer. Likewise, the MCU transmits data to the Liquid Crystal Display (LCD) for human reading and troubleshooting.

Alarm Driver and Buzzer

The alert system comprises both audio and visual displays. For audio alerts, a 12 V buzzer is used to create audio sensitization. The buzzer takes the control signal from the microcontroller pin which is at +5 V, 25 mA. The 25 mA from the microcontroller is not enough to drive the buzzer loudly and therefore, there is a need for a driver circuit that comprises an NPN transistor (Q_1) used for amplification and limiting resistor R_{12}. When the digital signal is high, Q1 will conduct and the buzzer will be energized but when low, Q1 will not conduct and therefore the buzzer will be de-energized (Fig. 12).

Liquid Crystal Display

A 16 by 2 liquid crystal display (LCD) was utilized to visually represent the processes occurring within the MCU. The display is powered by a +5 V direct current supply and is a flat-panel electronic visual display that utilizes the light-modulating properties of liquid crystals. Liquid crystals do not emit light directly but are capable of displaying arbitrary images, as seen in a general-purpose computer display, or fixed images that can be shown or concealed.

Printed Circuit Board (PCB) layout

In circuit design, PCB layout is an important phase in which the electrical schematic is converted into a physical board layout. This technique comprises placing components and routing traces on the PCB to verify that the circuit performs properly and effectively. The PCB layout for the SMS-based Online Voting System is shown in Fig. 12.

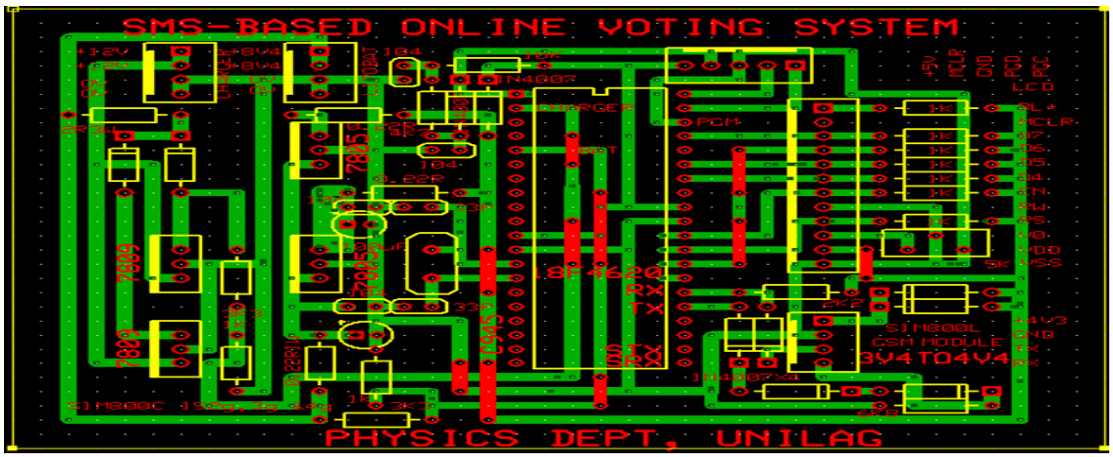

Fig. 12: PCB layout

GSM/GPRS module

The GSM/GPRS module serves as an interface between the MCU and the web, necessitating the use of serial communication (Universal Synchronous Asynchronous Receiver Transmitter (USART)) protocol for communication with the MCU. The transmit and receive pins of the module operate at a logic level of approximately 3V, whereas the transmit and receive pins of the MCU operate at a logic level of around 5V. Consequently, a method for converting these levels is necessary. This was accomplished through the use of diodes and resistors. The transmit pin of the MCU was linked to the receive pin of the module through three diodes (D_1 to D_3) and a resistor. These diodes reduce the incoming 5V by 0.7V each, resulting in a logic level of 2.9V. Resistor R_3 serves as a safeguard against short-circuiting, while R_5 grounds the module's input. Conversely, the transmit pin of the module was connected to the receive pin of the MCU via diode D_4, which is pulled up by resistor R_4 (see Fig. 13).

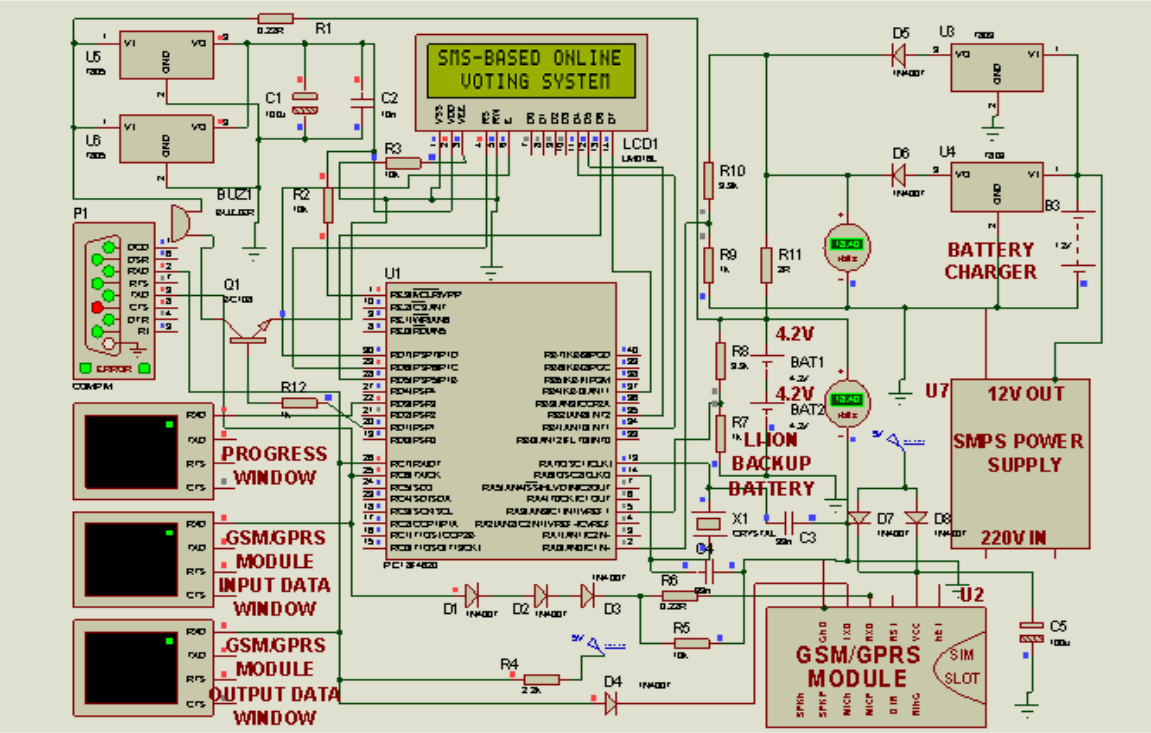

Fig. 13: Complete Circuit Diagram of SMS-based Online Voting System

Packaging

The voting device was coupled and packed in a plastic transparent cuboid container of dimensions 17cm by 12 cm by 9cm. The plastic container was used to avoid any kind of shock. The LCD screen is mounted on top of the container.

Web server

The web server is capable of connecting to the Internet and facilitating physical data exchange with other devices connected to the web. One of its primary functions is to manage the access of web users to hosted files through the domain names of websites stored and to transmit the content of these hosted websites to the end user's device (Hoxmeier & DiCesare, 2000). Essentially, whenever a browser or MCU requires a file hosted on the web server, the browser initiates a request for the file using HTTP. When the request is received by the appropriate hardware web server, the software HTTP server will accept the request, locate the requested document, and transmit it back to the browser or MCU using HTTP. If the server is unable to find the requested document, it will respond with a 404 error message (Fig. 14).

When a voter's data is received, the MCU will transmit it to the web via the GSM/GPRS modulein the following format:

https://www.doitniger.com.ng/onlinevoting/votersSMSdatauploadforgsm2.php?pvcn=00F2+LK43+1329+5733+777&stor=ANAMBRA&lgar=AGUATA&epost=GOVERNOR&party=PARTYB&phn=08035371478&submit=UPLOAD

The HTTP, PHP and CSS codes that run on the server were written in WeBuilder.

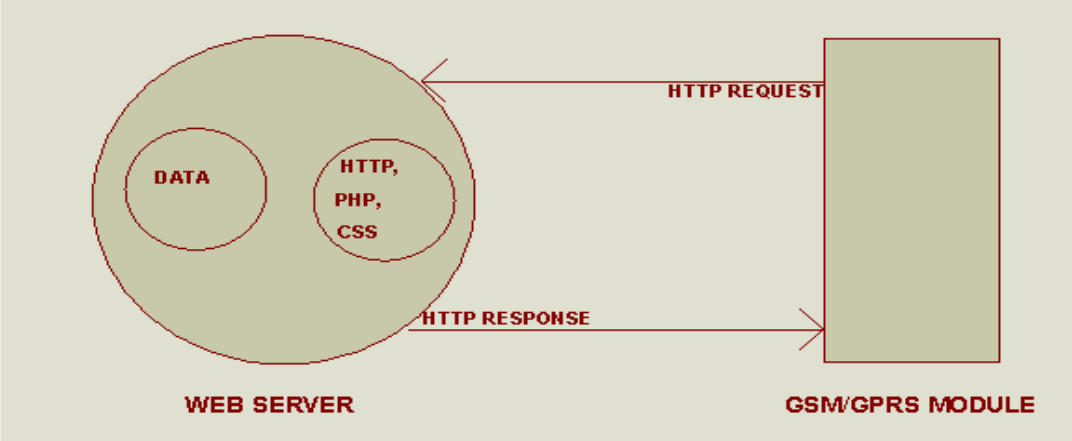

Fig. 14: Web server

3.0 Result and Implementation

3.1 Result of SMS voting system designed and constructed

The SMS voting system was successfully designed and constructed, meeting all project objectives. The system is capable of receiving and processing SMS votes, offering real-time feedback, and ensuring voting integrity and security. The system was extensively evaluated to ensure its dependability and precision. The test cases involved the reception and precise processing of SMS messages, as well as the accurate counting and storage of votes. Real-time feedback is provided through the LCD, and the system is capable of handling power outages and other disruptions without losing data. This study demonstrates the potential of using SMS-based solutions to enhance the accessibility and efficiency of electronic voting (Fig. 15).

Fig. 15: SMS voting system

3.2 Implementation

After developing the web pages and simulating the electronic circuit on Proteus software, a GSM/GPRS module was connected to Proteus using a USB to TTL converter as an interface. A voter, who had previously registered on the PVC platform sent his data as SMS to the SIM card in the module "Message received" was displayed on

the LCD. After a few seconds, success and score SMS was received. This confirmed that the study was working as designed. Following this, the module was connected directly to the circuit board and the test was repeated, resulting in a successful outcome. The PVC data is displayed below (Fig. 16a-16c).

SURNAME	FIRST NAME	MIDDLE NAME	DATE OF BIRTH	SEX	MARITAL STATUS	MOTHER'S MAIDEN NAME	RESIDENTIAL ADDRESS	LGA OF RESIDENCE	CITY OF RESIDENCE
SALAMI	BOLUWATIFE	OLAKUNLE	03/09/2000	MALE	SINGLE	KILOMODEMO	3 OJO STR KOSOFE	AGUATA	OZUBULU
SAHEED	MUHAMMAD	IBRAHIM	15/12/44	M	M	ABU BAKAR	35, BEGUWA STREET	BICHI	KANO
ABEJIDE	BALKIS	AYOOLA	16/6/97	F	M	OLAWALE	7, TUNDEOLA ST	ISOLO	OSHODI
ABEJIDE	ISHMAEL	OLAWALE	16/6/97	M	M	JULIUS	9, TUNDEOLA ST	ISLAND	ISLAND

Fig. 16a: PVC Data

STATE OF RESIDENCE	LGA OF ORIGIN	STATE OF ORIGIN	NATIONALITY	OCCUPATION	PHONE NO.1	PHONE NO.2	PVC NO.	VOTE	TIME	DATE
ANAMBRA	BARIGA	LAGOS	NIGERIAN	POS MANAGER	07052208095	08035371478	00F2 LK43 1329 5733 777	VOTED	6:58:14	14-03-2023
KANO	BICHI	KANO	NIGERIAN	CIVIL SERVICE	08035371478	07044519251	00F3 JK47 3327 7743 778	NOT YET VOTED	22:56:22	10-03-2023
LAGOS	KOSOFE	LAGOS	NIGERIAN	TRADING	08035371478	07044519251	10K5 JK13 2529 5875 125	NOT YET VOTED	12:35:04	11-03-2023
LAGOS	AJEROMI	OYO	NIGERIAN	SINGING	08035371478	07052208095	548LA/2022S	NOT YET VOTED	12:38:27	11-03-2023

Fig. 16b: PVC Data (Contd)

Single Voting

When the voter's data was transmitted to the module, a message was promptly returned to the voter after a brief delay.

Voter data: *"VOTESTARTS 00F2 LK43 1329 5733 777, ANAMBRA, AGUATA, GOVERNOR, PARTYA, VOTEENDS"*

***Response*:**

"16

+HTTPREAD: 166

INEC: Dear SALAMI BOLUWATIFE your submission number = 36, PARTYA =16, PARTYB =12, and PARTYC = 8 as at the time you voted, thanks for voting for the man of your choice

OK"

SURNAME	FIRST NAME.	MIDDDLE NAME	PVC NO.	STATE OF RESIDENCE	LGA OF RESIDENCE	PARTY	POST	VOTE NUMBER	PARTYA	PARTYB	PARTYC	TIME	DATE
SALAMI	BOLUWATIFE	OLAKUNLE	00F2 LK43 1329 5733 777	ANAMBRA	AGUATA	PARTYC	GOVERNOR	1	0	0	1	14:51:30	26-03-2023
SULAIMAN	ADEPEJU	OLAKUNLE	55F7 JK43 1329 5733 845	ANAMBRA	ANAMBRA EAST	PARTYB	GOVERNOR	2	0	1	1	14:54:02	26-03-2023
ADEOLA	BUKOLA	MATHEW	1234 UT43 1329 5733 798	ANAMBRA	AWKA NORTH	PARTYB	GOVERNOR	3	0	2	1	18:09:39	26-03-2023
JOHN	JOSEPH	EMEKA	43MS LK78 6523 3907 888	ANAMBRA	AGUATA	PARTYB	GOVERNOR	4	0	3	1	18:19:09	26-03-2023

Fig. 15c: Voters' data for

Anambra State

Double Voting

The voter was requested to cast their vote again, and the subsequent SMS was received.

Voter data: *"VOTESTARTS 00F2 LK43 1329 5733 777, ANAMBRA, AGUATA, GOVERNOR, PARTYA, VOTEENDS"*

***Response*:**

"14

+HTTPREAD: 143

INEC: Our dear voter with 00F2 LK43 1329 5733 777, your first submission was successful, multiple voting is not allowed. Pls, don't try again.

OK"

3.3 Discussion

The device was tested and the outcome satisfied the intention of the study. Works as intended during the design work, since voters' data for Anambra state works during the test, data for the remaining two states i.e Kano and Lagos states will work if sent correctly as SMS. The manual voting system in Nigeria has proven ineffective in addressing the fundamental issues required for a fair and reliable voting process, leading to voter apathy among some citizens. The implementation of the E-voting system aims to address the challenges of proximity constraints and time delays while ensuring secure and accurate vote recording. The system utilizes GSM phones or any internet-connected device for casting votes from any location. It has undergone comprehensive testing in voting accuracy, durability, responsiveness, battery life expectancy, and security through simulation and mini-voting sessions, proving to be successful. It was observed that the system demonstrates fault tolerance at all endpoints, including registration, the voting platform, and the server. This system enables extensive voter participation at minimal or no cost, significantly reducing apathy among voters. Numerous efforts have been made to enhance the electoral process by boosting voter engagement, particularly in Nigeria. These endeavours have been informed by established strategies and solutions, this study model introduces the concept of voting in any part of the world (after PVC registration) without the need of polling units.

Cost implication of design and construction of SMS voting system

The total cost for the design and construction of a unit of the SMS voting system was twenty-three thousand six hundred naira (N23,600). This cost is less than 7% of the amount required for the purchase of one unit of the BVAS (N526,250/ $1,142.85). BusinessDay has reported that the estimated market cost for the device is $795 (equivalent to N366,089.55 at the exchange rate of N460.47/$) on Amazon, where it is being sold under a different name, SecuMind Tablet Biometric CX2920. However, it was stated by INEC that 200,000 units of the device were received at a total cost of $228.5 million (N105,250,000,000). At a rate of $795 per device, the 200,000 devices would amount to $159 million (N73,217,910,000), representing a 30.4 percent reduction from INEC's budget of N105,250,000,000 for BVAS devices.

4.0 Conclusion

Given the swift advancement of computer technology and the Internet of Things (IoT) across various sectors and their application in information management, this study proves beneficial in the context of electoral processes. The Smart Ballot Online Voting System (SBOVS) offer a platform for conducting efficient and equitable elections at various levels within the university, including faculty, departments, and school-wide elections. The importance of a Secure Biometric Online Voting System (SBOVS) to society, particularly in Nigeria, lies in its ability to provide the Independent National Electoral Commission (INEC) with a cost-effective and equitable means of conducting elections, eliminating the need for traditional ballot boxes and papers. The secure and

flexible database management system ensures the protection of data and information to ensure the credibility of elections. It guarantees the right of individuals to move freely on election day so that they can carry out their daily activities. By implementing remote voting, individuals are granted the opportunity to cast their votes at their own convenience. Additionally, this system will allow INEC to streamline the process of collating and announcing election results, as these tasks are automated within the database. Moreover, it bridges the gap between the number of registered voters and those that voted. Additionally, it will close the difference between the number of voters who cast ballots and those who are registered to do so. Since votes are counted as soon as they are cast, this will help to reduce election violence and remove invalid and duplicate votes.

The following recommendations are proposed for optimal system performance: The voting device (SBOVS) should be operated in a dry environment with a consistently stable internet connection. Power should be supplied to the device through an external backup system like an inverter. In this study, PVC number and other registered data on INEC PVC database, sent as SMS, was used for authentication, it is recommended that fingerprint or facial appearance captured on a voter's phone and uploaded, should be used for authentication. If an individual loses their phone or registered phone number, there must be a method for updating it to a new phone number on the INEC database via the Internet or by sending an SMS. This process should be completed at least one hour prior to the start of the voting process. Date of birth should also be among data needed for authentication. So that those that are not up to 18 years will not be allowed to vote.

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Ethical Approval

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HB designed the work while the manuscripts were jointly written by HI, ISA and ENE.