Internet of Things Concept for Improving Energy Metering in Power Distribution Networks

ILOH J.P.[1], ODIGBO A.C.[2], MBACHU C.B.[3]
[1, 2, 3] Department of Electrical/Electronic Engineering, Chukwuemeka Odumegwu Ojukwu University, Uli, Nigeria

Abstract- One of the challenges being encountered by energy consumers and distribution companies in Nigeria is the inability of both the customer and the distribution company to monitor and control the customer's energy consumption remotely and in real time. In the current metering scheme, there is no real time bidirectional communication between the customers' energy meters and the utility companies. This work therefore, is aimed at improving energy metering in power distribution networks using the Internet of Things (IoT) concept. Using this approach, the IoT technology enables an internet-based control and monitoring system which automatically processes real time measurement data, displays the results on the energy meter display unit (liquid crystal display - LCD), and sends same results to both the customer's and the utility company's webpage simultaneously. The system also has the ability to process control signals from both the customer and the utility company frontends and take control actions whenever necessary. In this work, the existing JP-01 energy meter model was adopted and enhanced by replacing the ZMCT103C current transformer and the PIC16F873A microcontroller with ACS712 Hall Effect current sensor and ESP32 Wi-Fi enabled microcontroller respectively in the energy meter architecture. The IoT-based energy meter firmware was programmed using the Arduino Integrated Development Environment (IDE). The web application enabling internet communication between the energy meter and remote devices (computers or mobile phones with internet access) was developed using the Firebase platform. Access to the system database was designed in a manner that only users with the unique log in details of the customer or utility administrators can view the meter data over the internet and issue control commands as desired. The IoT-based energy meter prototype was built, tested and the test results were used to evaluate the system performance. During the tests, the energy meter accurately measured mains voltage in volts (V), instantaneous current in amperes (A), instantaneous power in kilowatts (kW) and energy consumed in kilowatt-hours (kWh) and displayed same results simultaneously (in real-time) on the meter's LCD and on the webpages of both the customer's remote device and the utility company's remote device over the internet. Control actions such as TURN ON, TURN OFF and SET LOAD LIMIT were also successfully implemented remotely both from the customer's end and the utility company's end. Thus, with this IoT-based energy metering concept, a real-time bidirectional monitoring and control of the customer's energy consumption was effectively achieved.

Indexed Terms- Arduino IDE, ESP32 microcontroller, Firebase software, Internet of Things (IoT).

I. INTRODUCTION

1.1 Background

Nigeria is presently migrating from an energy metering system dominated by analog energy meters to a system dominated by digital prepaid energy metering system. While the prepaid metering system is gradually gaining wider penetration in the power distribution sector, there are still many customers that are metered using the analog system. On the whole, it has been reported that only about 43% of the electricity customers in the country are metered [1, 2]. For customers still on analog metering system, the utility personnel are required to visit the customers' premises to manually read their meters in order to determine their actual consumption. Due to the logistics involved, it is practically impossible for the utility companies to meet up with the demands of regular monthly visits to customers' premises. The case is worse for the unmetered customers as they are billed using what the power distribution companies refer to as estimated billing system. The estimated billing system is largely despised by the customers as they always claim that they are being overbilled suggesting that they are charged for energy they did not consume. On the part of the utility companies, there are various cases of energy theft in which many customers evade payment of their energy bills either by completely bypassing the energy meter or diverting some their loads away from the metering circuit in order to keep their bills low. All of these culminate in each case either customers' or utility companies' dissatisfaction or both. In other words, the customers do not get the desired services at a fair cost and the utility companies loose huge revenues. It is expected that when all the customers are captured into the digital prepaid metering scheme, these challenges will be brought to the barest minimum. While the country is grappling with the inadequate supply of the prepaid energy meters, there is little or no significant capacity on the local scene for production of these energyi. meters [3].

The next dimension of metering challenges in Nigeria will be with the already deployed digital prepaid metering system. In the current digital metering regime, while the customers on the prepaid metering system enjoy better services in terms of fair billing of their energy consumption, the utility company only relies on the energy purchase information on its database to monitor the customers' energy consumption. There is no remote real time monitoring and control of the energy consumption by both the customers and the utility companies. An enhanced system that will provide real-time remote monitoring and control of customers' energy consumption will not only improve customer satisfaction but also improve utility companies' revenue collection as most cases of energy theft will be detected in real-time remotely.
This paper therefore, introduces the Internet of Things (IoT) concept to the energy metering system in order to provide bi-directional remote communication between the utility company and their customers through the internet for seamless monitoring and control of customers' energy consumption from both the customers' and utility company's ends.

I.2 Problem Statement
While the prepaid metering system currently in use in Nigeria has minimized the energy theft by customers and also improved revenue accruing to the distribution companies (DISCOs), the system does not support real-time bidirectional communication between the DISCOs and their customers. With the current system, both the DISCO and the customer cannot monitor and/or control the customer's energy consumption in real-time without physically being present at the meter location. Thus, cases of energy theft cannot be detected remotely in real-time as online monitoring of customers' energy consumption is not supported in the current metering system.

1.3 Aim and objectives
The aim of this work is to improve energy metering in power distribution networks using the Internet of things (IoT) concept. The specific objectives of the study were to:

i. Adopt an existing energy meter model and modify its architecture using suitable current sensor and Wi-Fi enabled microcontroller
ii. Develop the IoT-based energy meter firmware using Arduino Integrated Development Environment (IDE) and configure the energy meter to access the internet via an Wi-Fi hotspot
iii. Develop the web application for enabling real-time remote monitoring and control of energy consumption via mobile devices such as computers and android phones
iv. Build a prototype of the IoT-based energy meter and produce four units of the meter to set up a demonstration metering system for a mini-power distribution network
v. Evaluate the developed system's performance.

II. LITERATURE REVIEW

2.1 Overview of Internet of Things
The Internet of Things (IoT) is a network of physical items (things) integrated with sensors, software networks, and other technologies that connect to and exchange data with other systems or devices over the Internet. Connecting various things and attaching sensors to them gives previously dumb gadgets a level of digital intelligence, allowing them to relay real-time data without human intervention [4]. Any physical

object can be transformed into an IoT device if it can be connected to the internet to be controlled or to be used to communicate information to other devices. The term, IoT, is used for devices that would not usually be generally expected to have an internet connection and that can communicate with the network independently of human action. For this reason, a personal computer or a smartphone (though filled with sensors) is not generally considered an IoT device. However, a fitness band or other wearable device might be regarded as an IoT device [4].The Internet of Things (IoT) could be a large network that uses a variety of sensing devices such as Radio-frequency identification (RFID), Global Positioning System (GPS), among others to identify, manage, and control devices [5].The block diagram of the Internet of Things (IoT) is shown in Figure 1.

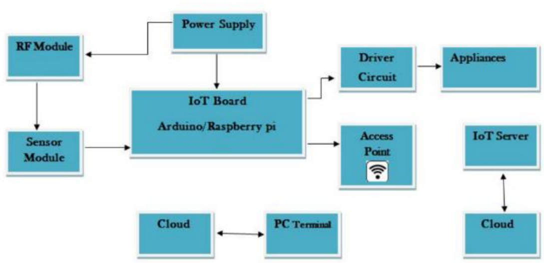

Figure 1: Block Diagram of Internet of Things (IoT) [6]

The IoT Board is the application's heart, where programs can be written and dumped. Depending on the application, the IoT Board could be an Arduino or a Raspberry Pi. The Arduino Suite can be used to dump a program via the I2C Communication Protocol or the Serial Communication Protocol [7]. The Sensor Module will take physical measurements and create a voltage output that will be sent into an analog input on an Arduino/Raspberry Pi board (A0 to A5). A Radio Frequency (RF) module will be utilized to transmit and receive radio signals. The configuration of a network is essential during the IoT application. The Virtual Private Server (VPS) is a simple-to-set-up software-defined server. To control the server, the majority of IoT Cloud servers, such as those from Amazon and Microsoft, use a web-based user interface [8]. The IoT Server allows for monitoring. The data received or exchanged across the gateway server will be securely stored by Big Data Analytics [9].

2.2 Related Works

[10] proposed that IoT system represented an alternative for identification of failures inside the installation and that IoT is a low-cost alternative for determining the energy consumption in real time, thus helping the users to save electric energy.[11]explored the IoT technology in smart electricity metering and billing, and thus concluded that IoT can reduce problems associated with billing consumers living in isolated areas and reduce the deployment of manpower for taking meter readings. In [12], a smart meter was designed and implanted using IoT and highlighted growth of IoT and digital technology suggesting that the future energy grid needs to be implemented in a distributed topology that can dynamically absorb different energy sources. [13] demonstrated Arduino based smart energy meter that removes human intervention in meter readings and bill generation thereby reducing errors. The system uses short messaging services (SMS) for communication of energy consumption information between the user and the utility. The system employed GSM for bi-directional communication. In [14], IoT based smart meter was proposed for achieving efficient energy utilization and could play a very vital role in the development of smart grids. The modelling and working of different units of an IoT based energy metering system were discussed in [15]. With Arduino Uno controller in combination with IoT development board, it was possible to build a metering system that could detect tampering and send the information to the server which will in turn cause the power supply to the tampered meter to be cut off [16]. Further protection features could be incorporated as proposed in [17] in which the meter and subsequently the association will be consequently disengaged by an installed framework embedded in the meter sensor. Light Dependent Resistor (LDR) was placed on energy meter which senses LED blinking pulse. In this framework, a keen vitality meter was introduced in each customer unit. [18] implemented both the meter and a server furnished with GSM module which encourages bidirectional correspondence between the two closures utilizing GSM communication. Shoppers can easily energize their vitality meter by sending a stick number covered up in a scratch card to the server utilizing SMS. [19] illustrated the power readings from digital wattmeter being read using the coupler and transmitted digitally to the Arduino. It automated the process of

measuring the power consumption at homes using IoT. [20] developed a locally made JP-01 energy meter, which could be deployed in the Nigerian Power market.

III. METHODOLOGY

3.1 Materials

The materials used in this work included: the JP-01 Energy meter model, AC712 current sensor, voltage sensing circuit, a switch mode power supply (SMPS) unit, Wi-Fi modem (used as access point or hotspot), ESP 32 development board, liquid crystal display (LCD), Arduino IDE, Google Firebase, Visual Basic software, Proteus software, a load board.

3.2 Methods

The basic concept adopted in the work is illustrated in the block diagram shown in figure 2. The concept simply involves the adoption of the existing JP-01 Energy meter and modifying its architecture to incorporate a Wi-Fi enabled microcontroller in order to upgrade it to an IoT devices.

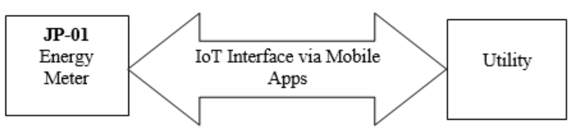

Figure 2: Basic concept adopted for upgrading the existing energy meter to an IoT device

The JP-01 energy meter was modified by developing a by incorporating compatible with the Internet of Things technology for possible remote interfacing with the existing power distribution networks in Nigeria. A detailed block diagram of the existing developed JP-01 energy meter architecture is presented in figure 3.

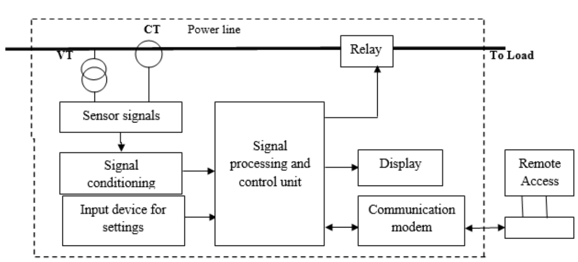

Figure 3: Block diagram of the existing JP-01 energy meter

The locally developed JP-01 energy meter, is capable of accurately measuring the energy consumption of an electricity user. It uses a communication modem (communication port) through which data can be written to a computer or read directly from the meter. The energy meter design does not support any form of internet-based communication and does not incorporate Wi-Fi communication capability. The modified architecture of the energy meter is shown in figure 4 with the shaded portion showing the additional scope of work done in upgrading the system to become an IoT based system.

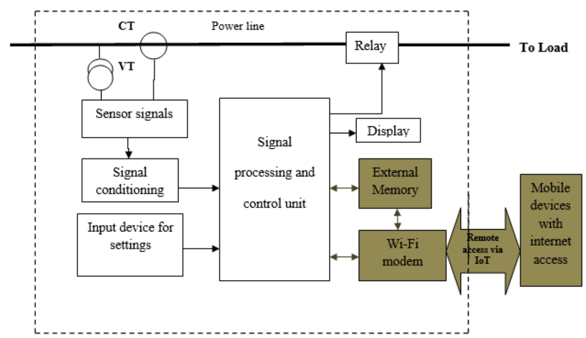

Figure 4: Block illustration of the IoT based energy meter architecture

The communication modem in the existing JP-01 energy meter in Figure 3 was replaced with Wi-Fi based communication, an external memory (external to the microcontroller) for database storage, a Wi-Fi enabled module, a customized web app to be installed on the user's mobile device and an IoT compatible remote access communication protocol providing seamless communication between the user and the utility company.

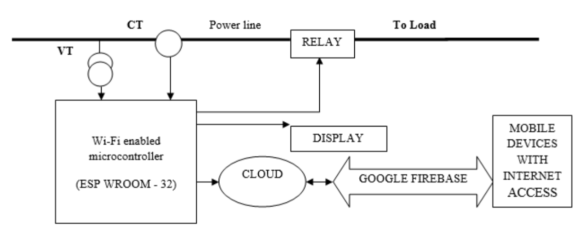

Figure 5: Enhanced block diagram of the IoT based energy meter

The implementation and evaluation of the system was achieved by setting up a 4-household mini-distribution network with an IoT enabled control centre. 4 units of the prototyped IoT based energy meters (one unit for each household) were deployed on the network. Also, 4 units of mobile devices with internet access and having the developed mobile energy metering app on them were used on the network for remote access to each of the meters. With this setup, it was possible to query each of the nodes (energy meters) from the utility control centre. Figure 6 illustrates the architecture of the implementation concept.

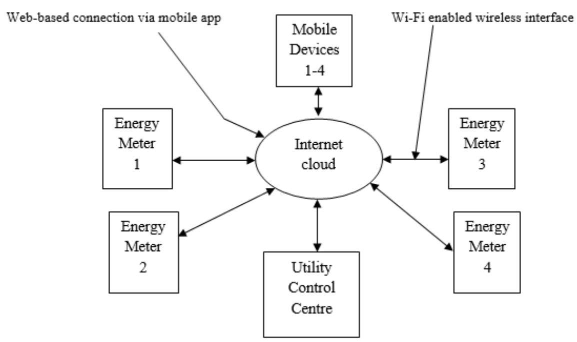

Figure 6: The architecture of the IoT based energy metering system for a 4-user distribution network

IV. SYSTEM DESIGN AND IMPLEMENTATION

4.1 Current Sensing Unit

The ACS712 Hall effect current sensor module (0 - 30A) was selected for current sensing. The module is designed for 5V input. Thus its analog output must fall between 0 – 5V. However, the operating voltage of the selected microcontroller (ESP 32) is 3.3V. It is therefore required that the analog input to the ESP 32 must not be above 3.3V. To ensure that this condition is met, a voltage divider circuit was designed the following values for resistors were calculated: R4 = 2.7k and R5 = 3.3k.

4.2 Voltage Sensing Circuit

A voltage sensing circuit was designed with a resistor network, a bridge rectifier circuit, filtering circuit and a variable resistor. The calculated resistors are R1=R2=150k, R3=1.5k and VR=5 k.

4.3 Power Supply Unit

Due to the expected wide range of operating voltage for the designed energy meter, an SMPS power supply capable of providing regulated 5V DC and 12V DC power supply over the mains voltage range of 85-285V AC was used. The 5V is for powering the ACS712 current sensor module, the microcontroller and the LCD. The 12V DC supply is for powering the relay for controlling the customer's load.

4.4 Selection of Access Point

An MTN 4G LTE mobile Wi-Fi modem was selected and used as access point device. It is characterized by LTE Cat4 high speed download and can connect up to 32 Wi-Fi devices simultaneously. Thus it is suitable for the 4-unit mini-distribution network for evaluating the system. The system can also be expanded in future to take up to 32 IoT energy meters.

4.5 Energy Meter Firmware Development

The programming of the energy metering system involves programming of the ESP 32 development board, development of the mobile app (website) for online monitoring and control of energy consumption and finally, the creation of database for the system. The ESP 32 was programmed using Arduino IDE. The web application was developed using Visual Basic software while the system database was created using Google Firebase.

Arduino IDE is the programming environment used to program the ESP32. The Arduino library is automatically installed as the ESP32 add-ons are installed in the Arduino IDE. Firstly, the required libraries were included; the *WiFi.h* library which connects the ESP32 to the internet and the *Firebase_ESP_Client.h* library which interfaces the boards with Firebase. Also, the sensor, memory, liquid crystal display and other necessary libraries were included.

The Token helper takes care of setting up the authentication method while the Firebase RTDB allows for storage and syncing of data between the meter and users/Admin in real time. Network credentials were included so that the boards can connect to the internet using the preferred local network.

```
// Insert your network credentials
#define WIFI_SSID "MTN_4G_1***19"
#define WIFI_PASSWORD "********"
```

The Firebase project API key was inserted. The authorized email and the corresponding password were inserted. Firebase Objects and other variables were inserted.

The mobile web app for the IoT based energy metering system was developed using HTML and CSS codes.HTML (Hypertext Markup Language) defines where things go, how they are laid out and what is on the page. It determines the structure and contents of a web page. CSS (Cascading Style Sheets) defines the way a web page and its elements are styled or presented. Both were used together to create the final web page, the design and its content.

4.6 Prototyping of the JP-IoT Energy Meter

The hardware of the energy meter was built using the schematic diagram shown in figure 7. The firmware was loaded on the ESP 32with the relevant configurations done. The meter was named JP-IoT Energy Meter. Three additional units of the prototype were produced to set up the 4-unit mini-distribution network.

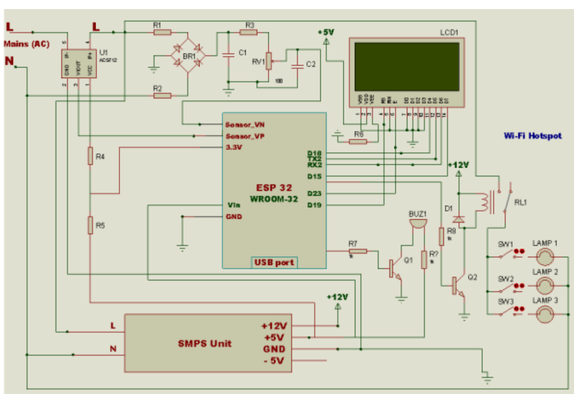

Figure 7: Schematic diagram of the JP-IoT based energy metering system

4.7 System Implementation

The energy meter was designed to sense current (I) and voltage (V), capture their analog values and convert them to their digital equivalents. These values are used to calculate instantaneous power (kW) and total energy consumption (kWh), and the values are stored in a database. This is because ESP32 module has multiple analog pins. The output pin V_{OUT}, of the ACS712 current sensor is connected to the Sensor_VP pin of the ESP32 while the sensed voltage is connected to Sensor_VN. These pins are responsible for analog to digital conversion using the 12-bit ADC in the ESP32. The ESP32 is programmed to display the measured parameters on the LCD. The energy meter through its Wi-Fi station enabled by the ESP32 connects to the internet via the Wi-Fi access point.

After uploading the codes, the building of the IoT based energy metering system for four households commenced.4 units of IoT based energy meters (one unit for each household) were built with varying loads connected to them individually. Power was supplied to each of the demonstration households. Also 4 mobile devices (representing 4 customer devices) plus one device (for Admin/ utility control centre) that have the developed mobile energy metering app were produced with internet access from a the Wi-Fi (hotspot) device, to enable remote access to each of the energy meters.
The utility control centre (Admin) creates unique meter IDs each for the four energy meter users. The Admin can view, monitor and control (turn ON/turn OFF and set load limit of) any of the energy meters in real time via the internet. After creating a meter ID for a user, the Admin must turn on the user's energy meter from the Admin control to enable the user to turn on from the user's end. The Admin also has the ability to query any meter. The data on the energy meters are constantly uploaded and saved to the database of the utility control centre. Previously saved data can be called up later, if need be, by the Admin or the user.

For an energy consumer to gain access to an energy meter, a meter ID must first be created for the meter user by the utility control centre on the energy website. The meter user's email address and password are required for creating a meter ID. The energy meters display Current (I), Voltage (V), Power (kW) and Energy (kWh) on their LCDs. The energy meters are also connected to the internet so that the meter readings can be seen in real time on the mobile devices and the utility control centre. The meter readings change as the loads are varied. The meter users can login to gain access, with their login details, through the web app on their mobile device as long as the mobile device is connected to the internet. The meter user can in real time, monitor and control the energy meter and also view previous records of voltage, current, power and energy. The charts of all the parameters of interest can also be viewed by the user.
The system implementation schematic is illustrated in figure 8. It shows a 4-household demonstration

distribution network involving the 4 IoT energy meters and a Wi-Fi hotspot serving as the access point.

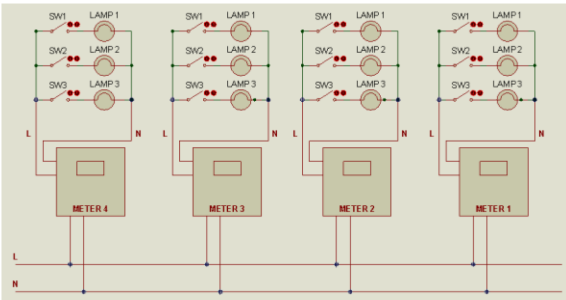

Figure 8: The IoT energy metering system for a 4-household mini-distribution network

V. RESULTS AND ANALYSIS

5.1 No-Load Test

The no load test was conducted to evaluate the performance of the system at the initial turn on. The test was conducted under two scenarios namely: (a) with the hotspot turned off and (b) with the hotspot turned on. When power supply to the system was turned ON with the hotspot off, the meters all beeped and came on but displayed dashed lines as shown figure 9. This shows that the meters initialized successfully but could not access the internet and thus the control signal needed to turn on the loads for each meter was not available.

Figure 9. Energy meter display during no load test with hotspot off

The no load test was repeated with the hotspot turned on. The energy meters started displaying the parameters and their measured values for mains voltage (in Volts), current (in Amps), power (in kW) and Energy (in kWh) as follows: Meter 1 (214 V, 0.01 A, 0.00W and 0.00 kWh); Meter 2 (216, 0.01 A, 0.00W and 0.00 kWh); Meter 3 (215 V, 0.01 A, 0.00W and 0.00 kWh); Meter 4 (214, 0.01 A, 0.00W and 0.00 kWh) respectively. These results showed that the energy meters successfully connected to the internet via the access point and also were able to display the current status of the measured parameters.

5.2 On Load Test

Using the switches provided in the loads, energy consumption was varied for each of the meters and the measured parameters were viewed on both the LCDs of the meters and the on the remote mobile devices via the internet. Each user was able to access the energy meter measurements using the unique login details (email and password) on the web app. Figure 10 shows the measured values displayed on the user's mobile phone and also the measured values displayed on the user's energy meter LCD for House no.1 (Meter 1). Similar performance was recorded in House No.3 (Meter 3) when a computer (laptop) was used to access the energy meter via the internet as shown in figure 11. In both cases, the values displayed on each remote device are exactly the same as the values displayed on the energy meter's LCD.

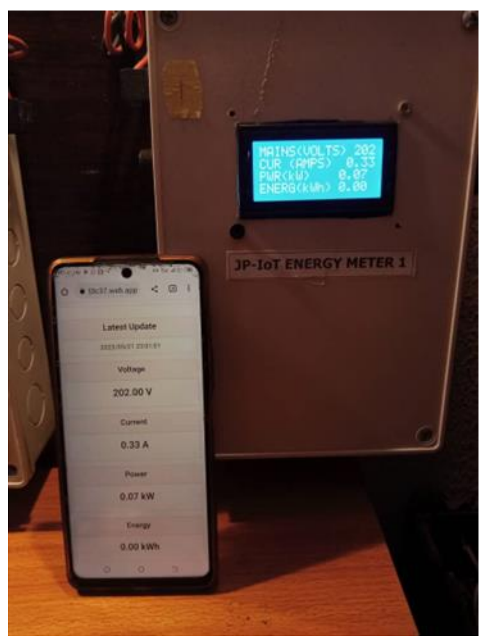

Figure 10: Photo of displays on both the user mobile device (android phone) and the energy meter LCD

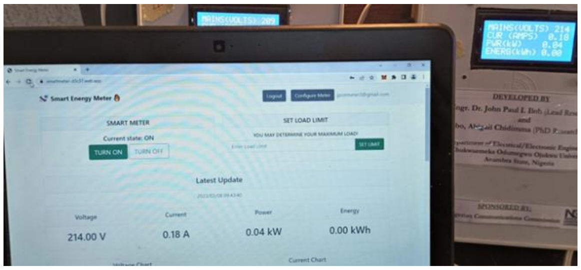

Figure 11: Photo of displays on both the user mobile device (laptop) and the energy meter LCD (Meter 3)

5.3 Set Limit Test

A maximum load limit can be set on the mobile device by the energy meter user. This will cause the energy meter turns off the load once the total power consumption reaches the set value. To demonstrate this feature, the load limit was set at 0.15kW (150W) as shown in Figure 12. As the load kept increasing, the energy meter remained on for as long as the output load value was below the set limit value. The energy meter automatically turned off immediately the load output reached the 0.15kW value. It can be seen from the power chart in Figure 12 that the power value became zero immediately it reached the maximum set limit of 0.15kW. This shows that the energy meter users can actually adjust their consumption style and control the power consumption rate from any remote location provided they have access to the internet.

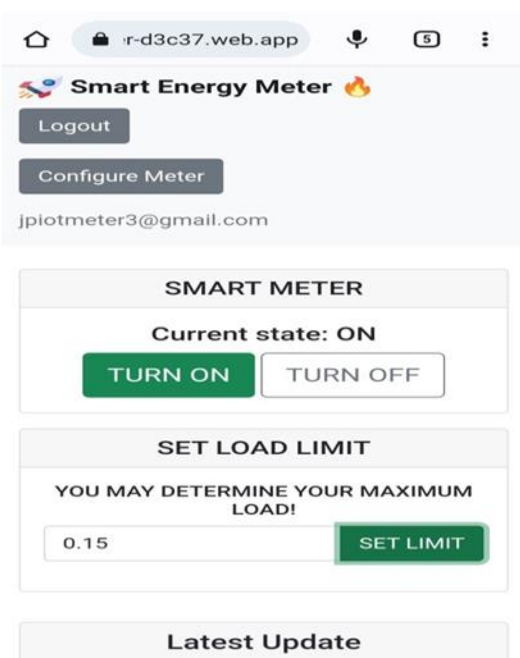

Figure 12: The set load limit test

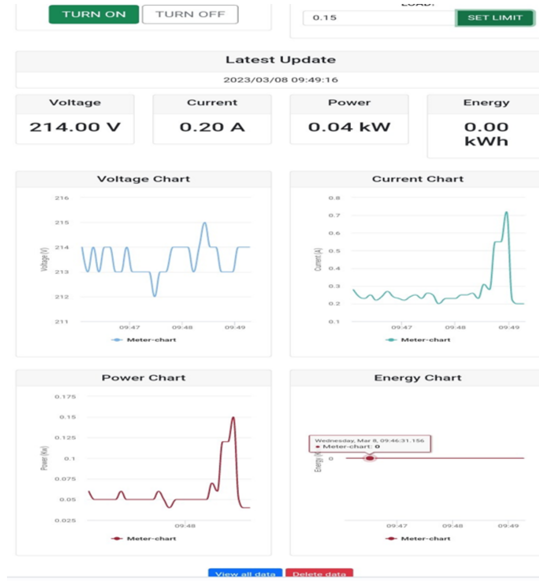

Figure 13: Voltage, current, power and energy charts downloaded from the IoT metering system database

5.4 Admin Control Test

The Admin can log in and view the status of all the energy meters in real time. The Admin can query, turn on or turn off any energy meter. Figure 14 shows the four energy meters with their meter IDs, controlled from the Admin web page. This confirms that the energy meters can be monitored and controlled in real time by the electricity distribution company.

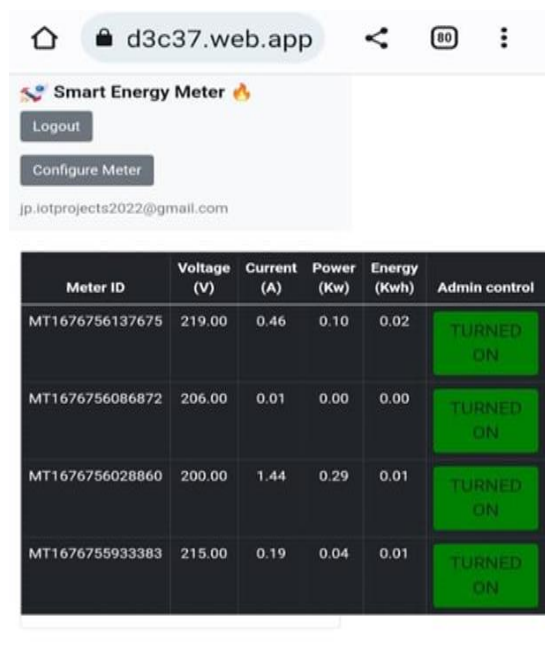

Figure 14: The Admin webpage showing control of the energy meters

5.5 Data Logging Function Test

The displayed data on the energy meter is constantly being updated on the database and can be viewed by the user. The voltage, current, power and energy charts represent the real time data on the energy meter. Previously saved or archived data from the energy meter can be called up in future for any period of time. Figure 15 shows screenshots of previous measurements downloaded from the system's database for one of the meters.

Hide data Delete data

Timestamp	Voltage (V)	Current (A)	Power (Kw)	Energy (Kwh)
2023/04/13 20:01:05	166.00	0.30	0.05	0.00
2023/04/13 20:00:58	167.00	0.28	0.05	0.00
2023/04/13 20:00:52	165.00	0.28	0.05	0.00
2023/04/13 20:00:46	165.00	0.28	0.05	0.00
2023/04/13 20:00:39	167.00	0.29	0.05	0.00
2023/04/13 20:00:33	167.00	0.28	0.05	0.00
2023/04/13 20:00:26	167.00	0.28	0.05	0.00
2023/04/13 20:00:20	167.00	0.30	0.05	0.00
2023/04/13 20:00:14	168.00	0.28	0.05	0.00
2023/04/13 20:00:07	165.00	0.29	0.05	0.00
2023/04/13 20:00:01	162.00	0.29	0.05	0.00
2023/04/13 19:59:55	166.00	0.28	0.05	0.00
2023/04/13 19:59:48	163.00	0.28	0.05	0.00
2023/04/13 19:59:42	162.00	0.28	0.04	0.00
2023/04/13 19:59:36	162.00	0.28	0.05	0.00
2023/04/13 19:59:29	161.00	0.28	0.05	0.00
2023/04/13 19:59:25	163.00	0.28	0.05	0.00
2023/04/13 19:47:33	172.00	0.28	0.05	0.01
2023/04/13 19:47:27	172.00	0.28	0.05	0.01
2023/04/13 19:47:21	176.00	0.27	0.05	0.01
2023/04/13 19:47:14	170.00	0.27	0.05	0.01
2023/04/13 19:47:08	170.00	0.29	0.05	0.01
2023/04/13 19:47:02	171.00	0.28	0.05	0.01
2023/04/13 19:46:57	169.00	0.31	0.05	0.01
2023/04/13 19:45:06	171.00	0.29	0.05	0.01
2023/04/13 19:44:59	171.00	0.27	0.05	0.01
2023/04/13 19:44:53	172.00	0.28	0.05	0.01
2023/04/13 19:44:47	173.00	0.27	0.05	0.01
2023/04/13 19:44:40	171.00	0.27	0.05	0.01

Figure 15: Data logging function of the IoT based energy metering system

CONCLUSION

In this paper, an Internet of Things concept for improving energy metering system in power distribution networks was presented. An IoT-based energy meter was successfully prototyped. The prototype was successfully used to implement a 4-unit mini-distribution network for evaluating the performance of the IoT based energy metering system. This was achieved by the introduction of Wi-Fi enabled microcontroller into the existing energy meter architecture, thereby providing real-time remote monitoring and control of energy consumption by both the power distribution companies and their consumers. The IoT energy metering system is therefore recommended for deployment in the Nigerian power distribution network. It is expected that its deployment will further minimize energy theft and also increase the revenue accruable to the utility companies while ensuring improved customer satisfaction.

ACKNOWLEDGEMENT

This work was supported by the Nigerian Communication Commission (NCC/R&D/RP21/COOU/001).

REFERENCES

[1] Onanuga R. (2016). "54% of Nigeria's electricity consumers have no meters" Sweet Crude Reports: http://sweetcrudereports.com/2016/09/04/54-of-nigerias-electricityconsumers-have-no-meters-sahara-group"

[2] https://africa-energy-portal.org/news/nigeria-only-43-percent-nigerian-electricity-customers-havemeters-nerc

[3] Iloh J. P. I. (2020). Rogowski coils for design of energy meters for Nigeria power market. European Journal of Engineering Research and Science, Vol. 5, Issue 6.

[4] Steve R. (2020), "What is the IoT? Everything you need to know about the Internet of Things right now". ZDNet. https://www.zdnet.com/article/what-is-the-internet-of-things-everything-you-need-to-know-about-the-iot-right-now/

[5] Wu S. D, Wang H, WangR, and FangH. (2018), "A Feature-based Learning System for Internet of Things Applications", in IEEE Internet of Things Journal.Vol.6(2), pp.1928-1937.

[6] Rajesh B. (2019). "A review on the different types of internet of things". Journal of Advanced Research in Dynamical and Control Systems 11(1): 154-158.

[7] Nayyar A., Pur V. and Le D. N. (2017), "Internet of nano things (IoNT) Next evolutionary step in nanotechnology". Nanosci, Nanotechnol, vol.7 (1), pp.4-8.

[8] Miraz M.H., Ali M., Excell P.S. and Picking R. (2015), A review on Internet of Things (IoT), Internet of everything (IoE) and Internet of nano

things (IoNT). Internet Technologies and Applications (ITA), pp.219-224).

[9] Chude-Okonkwo U.A., Malekian R. and Maharaj B.T.(2016),“Biologically Inspired Bio-Cyber Interface Architecture and Model for Internet of Bio-NanoThings Applications”. IEEE Transactions on Communications, vol. 64 (8) pp.3444-3455.

[10] Ramon O.J..B, Juan M.G.L, Emilio B.E, Antonio C.S, Efrain V.L, Sergio S, P and Luis C.A (2020). “IoT-Based Electricity Bill for Domestic Applications”. Vol. 20(21): 6178.

[11] Amruta C, Prasad M, Dinesh V and Vijay K. (2018), “IoT Based Smart Electricity Meter and Billing System”, vol. 05(10), pp. 916-919.

[12] Mohammad H. Y. (2018). Design and Implementation of an Internet of Things Based Smart Energy Metering, 6th IEEE International Conference on Smart Energy Grid Engineering, pp.191-194.

[13] Himanshu K. P, Tanish M and Anshul G (2019), “Ardiuno Based Smart Energy Meter using GSM”. 4th Int’l Conf. on Internet of Things: Smart Innovation and Usages (IoT-SIU), pp. 1-6.

[14] Bibek-Kanti B., Yadav S. N., Kumar S. and Gope S. (2018), “IoT Based Smart Energy Meter for Efficient Energy Utilization in Smart Grid”2nd International Conference on Power, Energy and Environment: Towards Smart Technology (ICEPE), pp. 1-5.

[15] Sasanenikita N, (2017). “IOT based energy meter billing and monitoring system”, *International research journal of advanced engineering and science*.

[16] Pandit S, (2017). “Smart energy meter using internet of things (IOT)”, *VJER vishwakarma Journal of engineering Research*, Vol.1, No.2.

[17] Maitra S, (2008). “Embedded Energy Meter-A New concept to measure the energy consumed by a consumer and to pay the bill”, *Power system technology and IEEE power india conference*.

[18] Depuru SSSR, Wang L and Devabhaktuni V, (2011). “Electricity theft: Overview, issues, prevention and a smart meter based approach to control theft”, *Energy Policy*, Vol.39, No.2, pp.1007-1015.

[19] Giri Prasad S, (2017). “IOT based energy meter”, *International Journal of recent trends in engineering& research (IJRTER)*.

[20] Iloh J.P.I. (2020), “Development of a Locally Made Energy Meter for Nigeria Power Market”, *Completed TETFund sponsored research project.*