A Novel Mobile and IOT Enabled Application for Smart Energy Meter

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Abstract- Smart Energy Meters have significantly helped in easy reporting of energy consumption and the measurement of the same, since their introduction. They have replaced mainstream method of the house-to-house energy consumption data recording, but they are still reading with a lot of data inconsistencies between participating parties (energy suppliers and consumers). The purpose of this research is to develop a mobile web application with Internet of Things (IOT) and short message service (SMS) for consistent, transparent recording, monitoring of energy consumed, amount billed, infrastructure theft and meter control. Arduino, sensors and relay modules are some of the hardware components used with communication application programming interface (API) accessed through the Wi-Fi module. The communication between the hardware and the server is the response based on different commands, which includes turning on and off, setting threshold, requesting consumption and even paid for consumed power. The app will enable the consumer monitor their current energy consumption through the web and android interface and remotely turn the meter on and off. Stored data can be retrieved at any time.

Keywords- Arduino, Billing, IOT, Power Consumption, Smart Electricity meter, SMS, Web Application.

1 INTRODUCTION

Smart Energy Meter is an electronic device which helps in easy recoding and reporting of energy consumed.

Smart Energy Meters have successfully helped ameliorate a lot of problems associated with energy management, recording and monitoring. It has also helped reduced the non-scalable method of man-power intensive house-to-house energy check, but there are still a lot of problems, the major one being transparency. The existing method involves energy recording by the supply or distribution companies (DisCos). They measure energy used in KWh and calculate the amount to pay based on an agreed-upon power charge which at the present time of this report is about 36 Naira. The whole process is one-sided if the consumer is not aware of being cheated, overcharged or even undercharged and Smart Energy Meters can be used by customers to facilitate and optimize usage of electricity (Saikumar et al., 2020).

This paper presents the use of easily available yet viable components coupled with advancements in software and web application development to create a manageable and configurable smart energy meter that interfaces with an android and web application, a Light Emitting Diode (LED) display, and a Global System for Mobile Communications (GSM) module. The LED displays the current reading in KWh. The estimated billing will be displayed, the android and web application will provide a remotely accessible display and control. This ensures the user can quickly query the current reading and calculate the bill, a threshold value can also be remotely set so that the meter can be turned off when the value is reached, hence wastage is minimized.

An encoded message can be sent to the processor through the web and android application to manipulate meter remotely. It is also important to monitor electric meter remotely (Sawade et al., 2017), our work provides remote monitoring and theft detection. Extensive work has been done on the smart energy meter; however, this paper serves as an advancement in linking internet of things with energy meter.

2 REVIEW OF RELATED WORKS

Khalid et al. (2015) reported their work on domestic energy meter, which is based on remote monitoring and control of energy meter. Their research was able to ease the problem of house to house reading of electric meter by the electricity marketing department. This is automatically done by the smart meter through the use of microcontroller technology which continuously monitors the meter readings and aids remote control and monitoring through the GSM module.

GSM based automatic meter reading system using ARM controller was proposed (Kulkarni, 2012; Aniedu et al., 2016) and achieved the design of energy meter as one that continuously generates pulses and counts the rate of energy consumed. In this type of meter, a timer or counter module is used, universal asynchronous receiver-transmitter (UART) and pulse width modulation (PWM) module to interface a GSM modem and energy meter, an automated meter reading (AMR) processor-based board and a 32-bit processor with on-chip analog to digital converters (ADC).

The light-emitting diode (LED) on the digital energy meter blinks for a specific number of times indicating energy consumed. As these pulses are gotten by the ARM based system, it counts the pulses, these pulses are then read by the system by counting the specific number of pulses and updating the counter by a unit indicating energy consumed.

Ashna, & George (2013) and Nicholas (2015) proposed a

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meter which uses infrared (IR) sensor unit to measure consumption of current. The Electronic Billing (EB) meter has a rotating unit where the IR transmitter is placed. The photo diode of the receiver is also placed within the IR receiver so it can be used to find the number of rotations thereby getting the current consumption.

The current consumption gotten from the above setup helps in monitoring the energy consumed by specific user. Since the unit taken is a numeric value, and its reduced continuously, it eventually reaches a minimum value and then notify the user with an alarm and a LC Display. The user can add more unit by sending a message to the EB section, the needed value is sent to the ARM controller by GSM and the ARM updates the obtained value in the memory, thereby recharging without unnecessary interactions.

Choi & Hong (2014) talked about some metering devices and systems that are already developed and deployed into different households for remote metering applications and that can be used for AMR. They argued that neither of the meters considered optimized energy use and convenience of use and configuration.

They proposed a smart metering device that has functions for efficiency and easy accessibility. The paper concludes that power consumption of smart metering itself will be reduced through the implementation of their study, some of the suggestions from this paper have been utilized in designing our smart meter. They gave suggestions on how to overcome the communication barrier currently being experienced by users using the smart grid power structure, they looked into smart metering infrastructure (SMI) communication networks that make the current metering infrastructure somewhat archaic and inefficient.

The use of advanced metering infrastructure (AMI), proposed by Munisami et al. (2012) described how energy is being managed, how to increase its operating efficiency and how to enable information flow for supporting the energy-saving schemes. The authors discussed ways that the AMI system can be implemented. They were also able to show that the archaic days of quarterly manual drive-by for meter reading cannot meet the needs of the modern Smart Grid. A technology that enables consumers view information of the consumed energy called Zigbee was also proposed by the authors. The technology serves as a link between the in-home display for the consumer and the meter, empowering the consumer through information.

Also, Nargotra et al. (2013) presents a new metering system called the GSM based power meter and control system (GPMC) which helps to keep track of the daily meter reading and then sends the same with a user identification number to the consumer and the electricity marketing department. The associated electricity e-billing system keeps track of these records and generates the appropriate bill when the month ends, this bill is forwarded to the user for necessary actions by the server. The Meter also has a distribution control system feature that helps monitor consumers' appliances and control the power remotely. It is able to perform all the afore

mentioned activities due to the use of a single-phase Class 1 IEC61036 standard compliance digital kWh power meter.

3 METHODOLOGY AND SYSTEM DESIGNS

3.1 METHODOLOGY

The design idea is based generally on using easily accessible and available technology, we used the Arduino processor to interface between our communication mechanisms (LED, GSM and Wi-Fi) and electronic components like the ACS712 Current Sensor, Relay Module etc. The current through the load is measured with the ACS712 Current sensor. This sensor works based on the principle of hall effect, by generating a hall voltage that is directly proportional to the current flowing through it. The generated hall voltage is what the Arduino uses to estimate the current. Passive infrared (PIR) sensor allows to sense motion. It is used to detect theft in the design of the smart meter. PIR are small in size, not expensive, consume low-power, easy to use and don't wear out.

The webpage and android application provide the necessary interface for the user to access the data on the server, this it does by actively requesting the current and recording it in the database. when a request comes in from either the webpage or the android app, the server-side code is used to retrieve this data from the database and sent back to the customer or supplier as the response. This active data is what gives the smart meter the real-time availability that this research work is about. Figure 1 shows the logic and control flow between the smart meter and the internet.

Fig. 1: Logic and control flow between the smart meter and the Internet

The webpage is also equipped with features that allows user send data to the server. The data include the set threshold value, control values, as well as other values that can be defined by the user. The request for either setting or getting is made through either the GSM or Wi-Fi module by connecting to an SMS API (Twilio) as shown in Figure 2. This API has some method that our application can send request to and get response back. Then with this pre-defined method, we can send SMS from our web portal and our android app by just registering our mobile number and then using the registered number to send commands to our microcontroller. The controller is then programmed to

respond based on the different commands it gets which includes turning on, off, setting threshold, requesting consumption, and even paying for consumed power. The Arduino accesses the sent data from the server using the same Wi-Fi Module. Necessary actions can then be taken on meter with the help of the relay module, which has a basic function of switching off and switching on the load.

Fig. 2: Web Application Dashboard for managing the smart meter remotely

3.2 COMMUNICATION SCHEMES

i. **Wi-Fi:** The web application communicates with the SMS API through the ESP8266 Wi-Fi module, this ensures that the user doesn't have to spend money sending text-messages as they can just connect to a Wi-Fi and control their meter from there. This will also ensure low cost of operation which will further drive acceptance of the technology.

ii. **GSM:** The authors used the GSM communication module in sending and receiving SMS between the different applications (Web and Android) and the microcontroller. This is a measure put in place in a case where the user does not have access to internet and therefore cannot use the Wi-Fi Module. This is dependent on the user's network and only requires the user to send appropriate commands to the registered phone number on the micro-controller. This is another advantage of saving cost of operation of the smart meter. As seen in Figure 3, sending a series of simple commands to the meter can control the meter and also get energy readings and cost from the meter.

3.3 COMPONENTS DETAILS

i. **Arduino Microcontroller:** The Arduino is a microcontroller open-source platform for building and controlling electronics research works. It consists of a circuit board that is programmable, often referred to as a microcontroller as shown in Figure 4. A piece of software or integrated development environment (IDE) that runs on the computer, helps programmers write computer codes for the board.

Fig. 3: SMS communication between smart meter and user's mobile device

Fig. 4: Arduino Board

ii. **Wi-Fi Module:** The Wi-Fi Module used for this research work is the ESP8266, a self-contained SOC that is integrated with a Transmission Control Protocol/Internet Protocol (TCP/IP) protocol stack enabling the microcontroller to access the Wi-Fi network. It can either help host an application or offload Wi-Fi networking functions while communicating with other application processors.

Fig. 5: Wi-Fi Module

It comes pre-programmed with a bunch of AT commands and the set firmware; this means it can be connected to an Arduino device thereby getting as much Wi-Fi ability as can be gotten from Wi-Fi Shield.

iii. LED Display: The Light Emitting Diode technology is a screen display where panels of led are used as light sources. LED devices emit light when current flows through them and this can be used to display meaningful messages or information to the user. Many electronic devices both small and large use LED display to serve as a medium of communication between the user and the system.

Fig. 6: Led Display

iv. Relay Module: Relays are electromagnetic switches that are operated using relatively small electric current and can be used to turn on or off larger electric current. The relay uses the principle of solenoid i.e., a wire coil that is temporarily magnetized as electricity passes through it. The work of the relay is to act as a bridge, that makes sure it is possible for small currents to activate large currents, this means relays can act as switches or as amplifiers. In this research work, the authors used relays as switches that are controlled by the Arduino microcontroller.

Fig. 7: Relay Module

v. SIM 900 GSM Module: GSM or GPRS modules are chips or circuits used to establish a medium of communication between mobile devices or a computing machine and a GSM or GPRS system. The SIM900 has an SMT module which can be embedded in the customer applications and a complete Quad-band GSM/GPRS solution. It is an industry standard interface that delivers full GSM/GPRS850/900/1800/1900MHz performance that can be used for voice, SMS, data, and fax in a small form factor without consuming too much power.

Fig. 8: SIM 900 GSM Module

vi. ACS712 Current Sensor: The ACS712 Sensor is a cheap and a very suitable electronic device for AC and DC sensing. It is used in industrial communication systems and for commercial purposes for accurate sensing and measurement of current. It has a low-offset linear Hall sensor circuit coupled with a copper conductor located at the surface of the die as shown in Figure 9.

Fig. 9: ACS712 Current Sensor

When current is applied, it flows through this copper conduction, the path created then creates a magnetic field that is sensed by the inbuilt Hall IC that is then converted to the appropriate voltage. The device accuracy can be further increased by increasing the proximity of the magnetic signal to the Hall transducer.

3.4 PROCEDURE FOR BUILDING THE SMART METER

The ACS712 is connected to the Arduino by connecting its Ground pin to ground on the Arduino, the out pin to an analogue pin on the Arduino, (say A0), then the VCC is connected to 5v on the Arduino as the sensor is powered by 5V. The Relay Module is connected to the

Arduino by connecting the VCC to 5v, the In pin to any digital pin on the Arduino say pin11 and the ground is connected to ground. The GSM Module is connected to receive and send serial impulse from the Arduino. This is achieved by connecting GND to the GND(-ve terminal of the battery), VCC to the +3.7v supply (+ve terminal of the battery), the transmission pin (Tx) to a digital pin defined to be the Arduino receiving pin (Rx), and the receiving pin (Rx) to a digital Pin defined to be transmission pin (Tx). The Wifi module is connected to the Arduino to enable serial communication in a similar manner as the GSM. The only difference is that the Wifi module is powered directly by the Arduino which supplies the module with 5v. The LDR Sensor is connected to the Arduino. The LCD is connected to the Arduino by making the following connections. VSS to GND, VDD to +5v, VD to Potentiometer middle Pin (to control the contrast of display), RW to GND, A to +5v, K to GND. The remaining pins are connected to the digital pin of the Arduino defined in the code. The Neutral wire from the mains supply is connected to one end of the relay (the COM opening), and another connection is made from the normally closed port (NC) to one of the ACS712 port. A connection is also made from the other port of the ACS712 port to the neutral end of the socket.

Figure 10 shows the wiring and the soldered components for the smart meter and figure 11 shows the smart meter in operation. Figure 12 is the system architecture while figure 13 is the relay internal circuit diagram

Fig. 10: Wiring the soldered components

Fig. 11: Smart meter in operation

Fig. 12: System architecture

Fig. 13: Relay Internal Circuit Diagram

5 CONCLUSION AND RECOMMENDATIONS

5.1 CONCLUSION

This paper has been able to highlight the benefits of a technologically advanced smart energy meter. We have been able to enhance the meter with three modes of recording and monitoring energy consumed through easily assessable hardware devices like the Arduino processor, Wi-Fi and GSM Module. These devices will help both the supplier and the consumer to easily monitor the smart meter through their smart devices and also communicate with each other when they needed to communicate with each other.

The constructed smart energy meter is a major advancement when compared to the conventional meter. Table 1 below summarizes the major comparison of the smart meter to the conventional meter. The Cost analysis shows that the meter values cost #12,700, which is a relatively cheap amount for the functions (Control and Management) it is expected to perform when compared to the present meters available in Nigeria. The smart meter allow access to energy consumption anytime, anywhere through SMS, remotely turn on and turn off

meter to make and break power connection respectively. The threshold for energy consumption can be set through SMS and get immediate SMS notification anytime the meter is being tampered with and allow quick access to energy consumption rate over the internet. It also does for detailed analysis (through chart and graphs) of energy consumption rate.

Table 1. Convectional meter vs constructed smart meter

Feature	Convectional meter	Constructed Smart Meter
Communication type	None	GSM and WIFI
User Interface	LCD	LCD and Mobile phone
Cost	Expensive	Relatively Cheap (#12,700)
Data Collection	Manual	Server and SMS
Energy Control Method	No Control	Relay Control
Energy Management Method	None	Threshold Setting
Anti-theft Feature	None	Exists

As technology advances, we will continue to see more innovative ways by which transparency can be improved further. The current design that we have will help increase the access to reliable data on power consumption.

5.2 RECOMMENDATION

Smart meters have already begun to take the space of mechanical meter reading devices, and their widespread acceptance is as a result of their ability to work with little to no human intervention. Although this research work has been able to solve some problems facing its use, however some other factors can still be considered, issues like theft control and tamper proofing can still be tackled. This will ensure that unauthorized elements don't get access to the meter and this will also help minimize unremitted usage due to tampering.

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