Towards Design and Evaluation of Automated Metering, Power Management and Monitoring System

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ABSTRACT

There are several electrical power losses affecting economy of the power Distribution Company. In developing country like Nigeria the percentage of Non-technical losses has been quite high affecting the availability of electrical power supply in the country. One of the biggest challenges facing us today is caused by increase in energy consumption and how we can make consumers aware of their electricity usage and provide them with options to manage usage and reduce waste. The present method is based on manual monitoring and poor power management. We propose automated metering, power management and monitoring system called "ATMPM" system for effective monitoring of electrical power parameters and energy consumed by appliances at different loading conditions and period of the day. This paper describes the preliminary development on design methodology of the ATMPM through a wireless transceiver, flexible Home energy planner and web-based system. When the ATMPM system is fully implemented it would perform proper power management, adequate communication (on consumers mobile phone), and effective monitoring and control option. All meters being monitored and readings recorded automatically on centralized wireless based system, it would reduce chance of human errors. It will make consumers more aware of their electricity usage. It will eliminate non-payment of electricity bills; electricity theft saving huge amount of time and money.

Keywords: Electrical power, Wireless; automated energy metering system, Home energy planner& Web-Based System

iSTEAMS Cross-Border Conference Proceedings Paper Citation Format
Edemirukaye Ukeh Orodje & Apeh Simon T. (2018): Towards Design and Evaluation of Automated Metering, Power Management and Monitoring System. Proceedings of the 13th iSTEAMS Multidisciplinary Conference, University of Ghana, Legon, Accra, Ghana. Pp 189-202

1. BACKGROUND TO THE STUDY

Power authority is saddled with the responsibility of generation, transmission and distribution of electricity to ensure that power is available to electricity consumers. Our focus is on a section of Low Voltage power distribution network (Olugbenga et al, 2013) The availability of Constant electrical power supply is one of the driving forces behind the development of any country (Apeh S.T and Mokogwu C.N, 2013). In spite of the billions of naira invested by the federal government on prepaid meters some customers today don't have meters.

There have been incessant power outages, voltage drop and rise during peak and off–peak periods on the Low Voltage (LV) distribution network. In fact, power outages have assumed a very high embarrassing dimension in Nigeria. The available power generated is not enough to meet the demands of the users leading to constant uneven load-shedding and blackout (Arobieke O et al, 2012). Some residential areas enjoy power supply while others do not, Consumers are not aware of their consumptions and no way to manage consumptions while using existing appliances.When giving power to some part of the town, the power authority is not reflecting on the wastage by electricity consumers when during the day security lights bulbs will be on not using but wasting power (Anvari- Moghddam et al, 2015).

There is no serious monitoring and feedback on the power distribution network for electricity consumers. The rate of non-technical losses in developing countries like Nigeria is quite high which ranges from electricity theft to non-payment of electricity bills. To overcome these disadvantages and to complement the efforts of power management initiative under way in various countries a research paper title "design and evaluation of an automated metering, power management and monitoring (ATMPM) system which can be implemented in Nigeria is hereby proposed.

In the proposed system, the pre-paid energy meters will have proper power management, adequate communication, and effective monitoring and control option. If the amount falls below a certain minimum amount, then a message will be sent to the consumer on mobile phone. With all meters being monitored and the meter readings recorded automatically on centralized wireless monitoring system. There will be no chance of human errors. It will make consumers more aware of their electricity usage saving huge amount of time and economically viable. The authors wish to emphasize that some basic calculation and results of the ATMPM system are not present in this paper but will be published elsewhere. This paper only reports on the preliminary development towards the design and evaluation of ATMPM system.

1.1 Statement of Problem

Poor power management and uneven load shedding , Inappropriate Monitoring on the electricity consumption, Ineffectiveness of revenue collection from consumers by power distribution staff, Inadequate communication between the Electricity provider and customers , Inflexible Customer power consumption planner and Creation of an effective standby power detection on the appliances measured.

1.2 Objective

The aim of this research is to design and evaluate an automated Metering, Power Management and Monitoring System with the following objectives:

iii. To design an automated Electrical power metering system
iv. To design an intrusion detection and tamper-proof system.
v. To design web-based system for power management and monitoring (which includes fraud and fault detection system).
vi. Design a flexible Home energy Planner
vii. To design a load dependent and load shedding
viii. Evaluation of the system

1.1 Relevance Of The Study

A new system where all meters can be monitored on centralized wireless based system with proper power management. Modern technologies to monitor reliability of power supply on the electricity consumption. With the help of home energy planner to allow end–users being able to determine timing schedules to turn appliance on and off automatically with a web-based system for easy payment of electricity bills.

2. RELATED WORKS

Okhueleigbe et al (2017), carried out the utilization of under Frequency Load Shedding (UFLS) and under Voltage Load Shedding (UVLS) Schemes in Improving Voltage Level at Injection Substations" in this work indices were used in achieving a more comprehensive, effective, and reliable load shedding strategies using ETAP 12.6 in running the load flow analysis, it shown that during peak period all 63 buses did run till they got to the accepted voltage level in Nigeria that is + or - 6%. Fabiano Salvadori et al (2015) carried out Monitoring in Industrial Systems Using Wireless Sensor Network with the use of intelligent Sensors Modules (ISMs) and the Remote Data Acquisition Units (RDAUs). The objective was achieved. Nguyen et al, (2013) Energy intelligent Buildings based on User Activity. They summarized and compare several studies on building energy and comfort management (BECM) systems, where simulation results show up to 58% savings on energy for lighting and 10-40% for HVAC system. Apeh S. T. and Mokogwu C.N (2013) developed a home power management system. The PIC16F887 Microcontroller was programmed to provide 24 hour real-time timing power consumption management according to user-supplied timing parameters made available to the programmed Code with the help of the PCF8583 real time clock.

The home power management system developed under test produced outputs which exhibited good correlation with the input supply. Whereas the input to the device was 186V, the output for ports 1, 2, 3, 4 and 5 were respectively 187V, 185V, 184V, 185V and 183V which is a satisfactory input-output correlation. The unit also exhibited good implementation of the timing algorithm for all programmed outputs. It switched "ON" and "OFF" at the set times for the regulated ports showing that power was managed as desired in accordance with the inputted timing parameters. This flexibility in an automation system is one strong point of this device.

3. PROPOSED RESEARCH METHODOLOGY

3.1 The Research Design

The research objective was accomplished through the process described in figure 1 the design workflow is broken down into stages each consists of activities that would be carried out iteratively as shown in the flow diagram in figure 1 until the final desired outcome will be achieved. The first stage specifies comprehensive analysis of the billing problem follow by material selection and proposed design techniques which includes designing the prepaid meters with inbuilt wireless transceiver as shown in figure 5, designing the home energy planner as shown in figure 8, creating a database for billing and historian, designing fault reporting, fraud and fault detection system, web-based system (see use-case diagram shown in figure 5) for system monitoring and power management that will be used to achieve the research objectives. Thereafter proceed to integration and simulation of the complete system for evaluation process then live comparison of the energy consumption in KWH, billing and reports generated on a centralized wireless monitoring station.

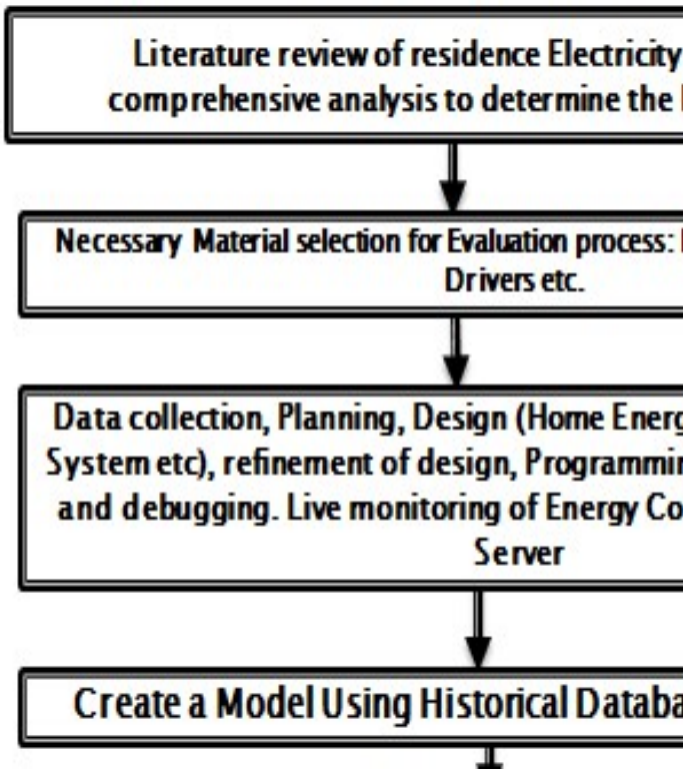

Figure 1: Flow diagram showing proposed design methodology

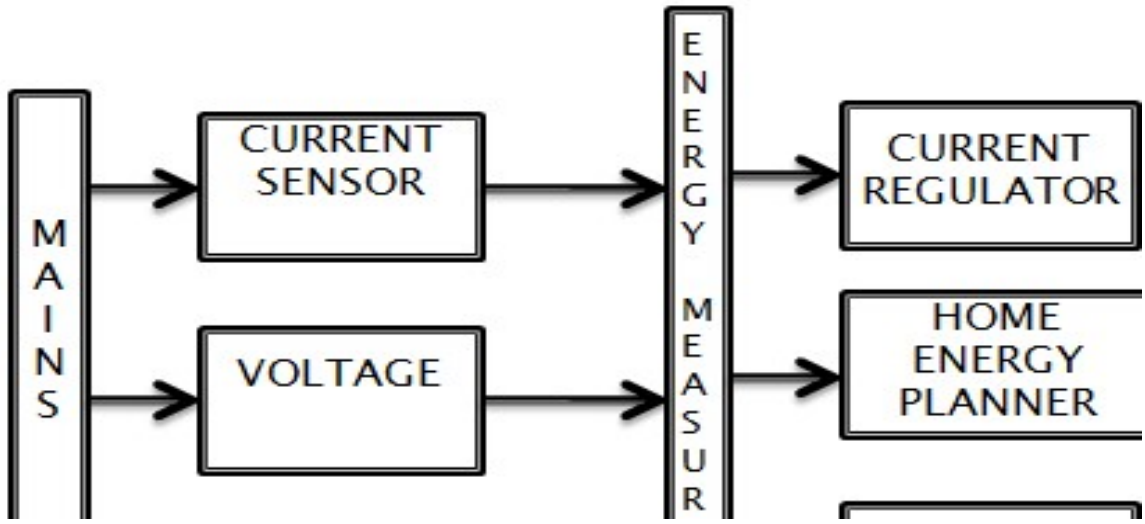

Figure 2: Proposed block diagram of the end-user automated metering power management and monitoring system

3.2 Proposed design of end-user ATMPM system

This stage of design is concern with the materials and methods for the hardware of the end-user system. The activities include the selection of current sensor that will sense the amount current drawn by consumer load, potential transformer that will measure the amount voltage across the entire circuit and the metering integrated circuit (IC). In the proposed metering IC design, analog to digital signal conversion would be carried out, phase correction and multiplication of current and voltage is performed by energy metering IC. This IC which will measure the power consume then convert it to frequency for the microcontroller to read (see figure 2 and 5) before reporting through the wireless transceiver (LoraWAN) to transmit information at a distance of 100km to the monitoring station.

3.2.1 The Current sense unit

The current sense unit is designed to sense the amount of current flowing along the supply line. It consists of a current transformer connected in series with the load and a voltage attenuation network (see figure 4a and figure 4b)

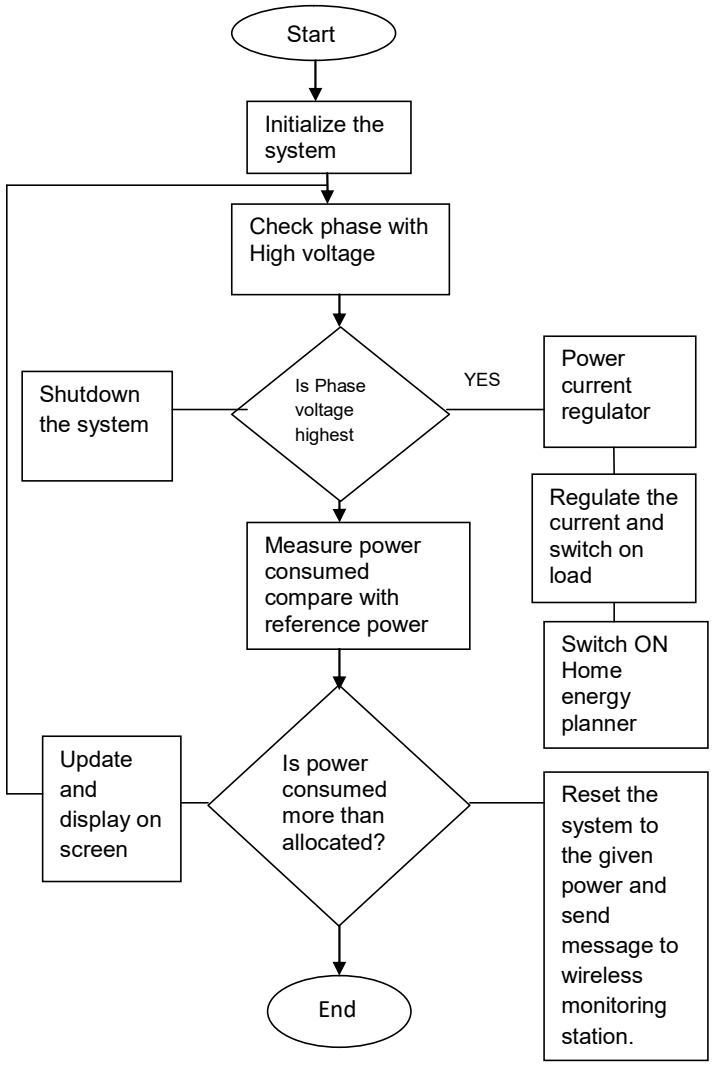

Figure 4.3: Proposed flow diagram of power management of the end-user

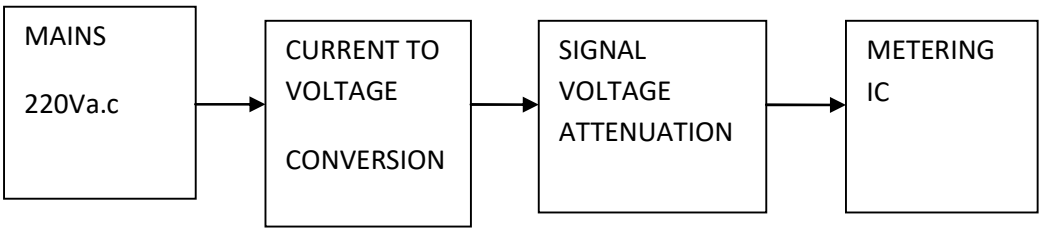

Figure 4.4a: Proposed Block diagram of the current sense

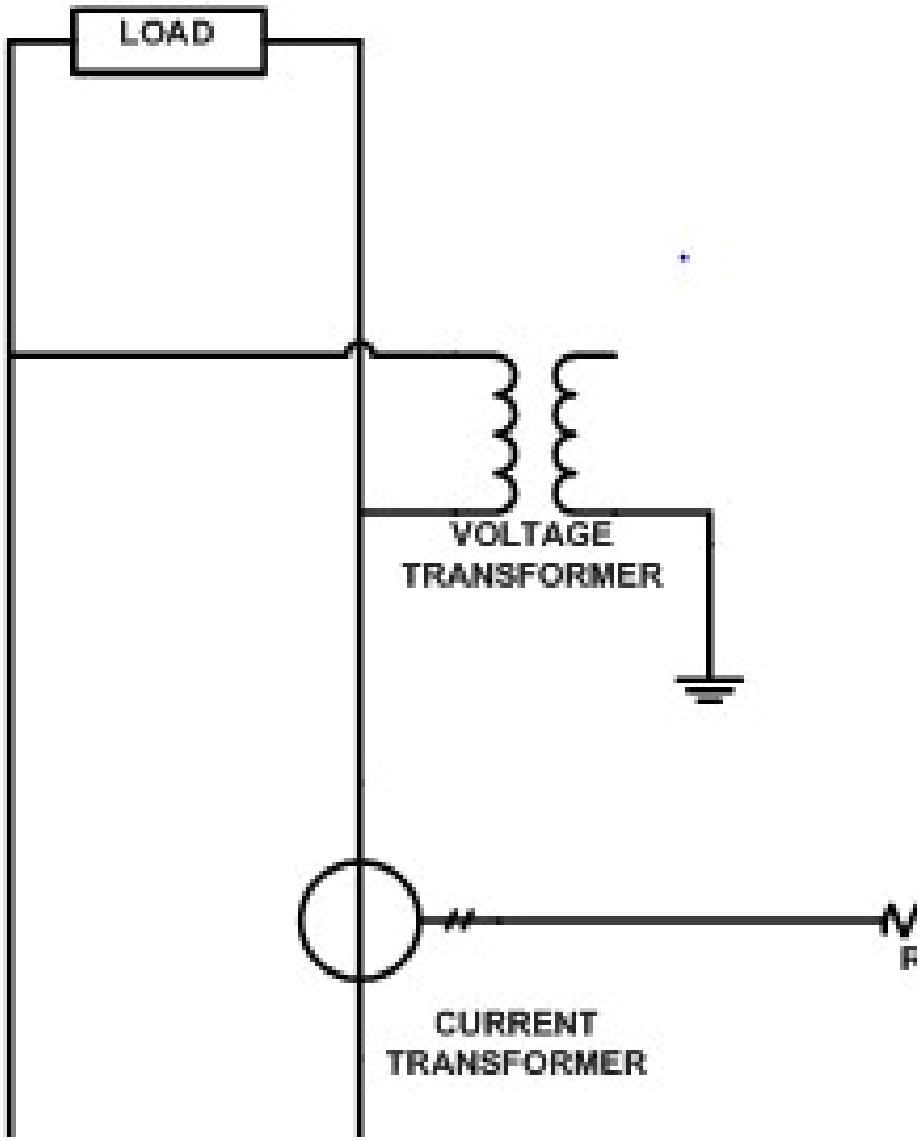

Figure 4.4b: Proposed circuit diagram of current sense unit

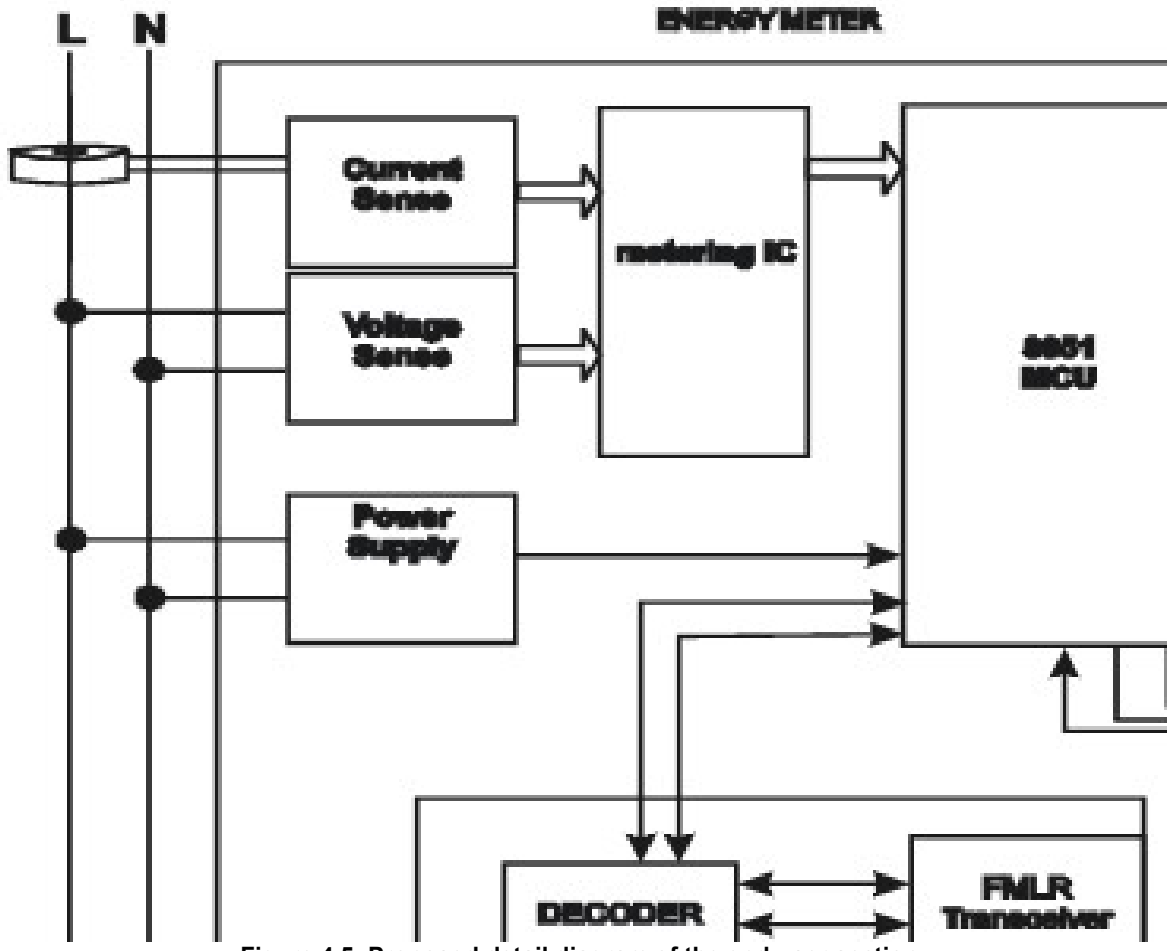

Figure 4.5: Proposed detail diagram of the end-user section

The proposed real power calculation method also holds true for nonsinusoidal current and voltage waveforms. Using the Fourier Transform, instantaneous voltage and current waveforms can be expressed in terms of their harmonic content.

$$v(t) = V_0 + \sqrt{2} \times \sum_{h \neq 0}^{\infty} v_h \times \sin(h\omega t + \alpha_h \ldots\ldots\ldots\ldots\ldots \quad (1)$$

Where:
$v_{(t)}$ = the instantaneous voltage, V_0 = the average value, V_h = the rms value of voltage harmonic and h = phase angle of the voltage harmonic (Merabet L et al, 2013).

$$i(t) = i_0 + \sqrt{2} \times \sum_{h \neq 0}^{\infty} I_h \times \sin(h\omega t + \beta_h \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

Where:
$i_{(t)}$ = the instantaneous current, I_0 = the dc component., I_h = the rms value of current harmonic, h = the phase angle of the current harmonic (Merabet L et al, 2013).

3.3 Monitoring station and web-based system

The monitoring station and web-based system are mostly software with written programme and design interface in computer laptops. The software selection would based on some numbers of factors which include availability of design artifacts, availability of source codes, licenses, programming language, popularity, industry types, diversity of sizes of the systems, user-base, platforms and web-technologies used and diversity of functionality provided. Preference would be given to web-based systems whose source code is readily available without license limitations.

3.3.1 Proposed design consideration for the web-based technologies

In the area of the web –technologies, the use of scripting programming language is proposed for both front end and back end design such as HTML, CSS, PHP, MYSQL, JAVA SCRIPT and SUBLIME TEXT. As part of the website design the proposed use-case diagram for the web-based system is shown in figure 4.7.

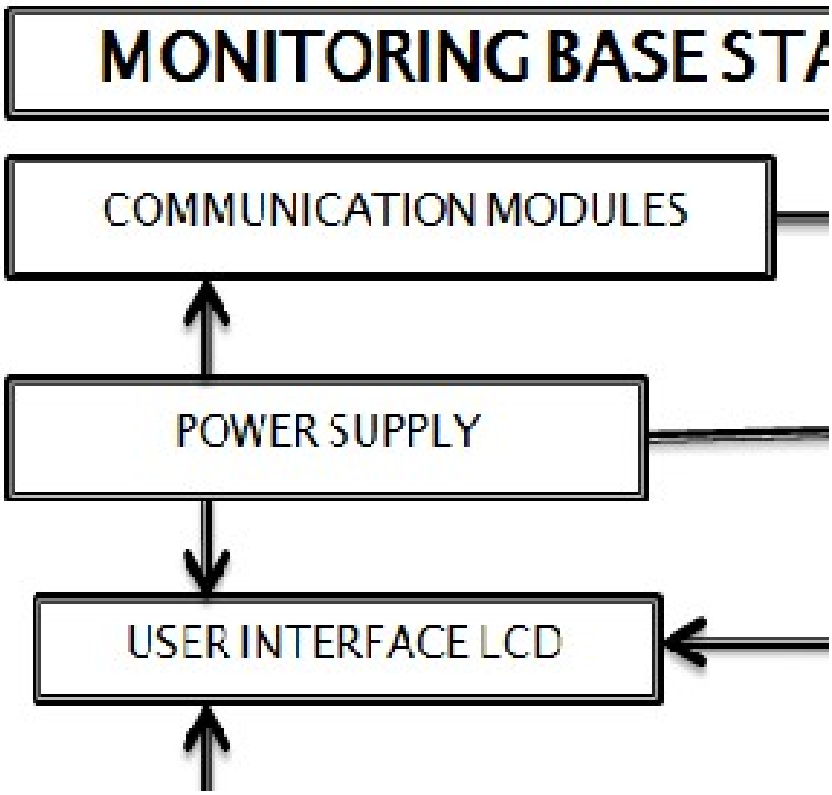

Fig 4.6 Proposed Block diagram of the Monitoring station

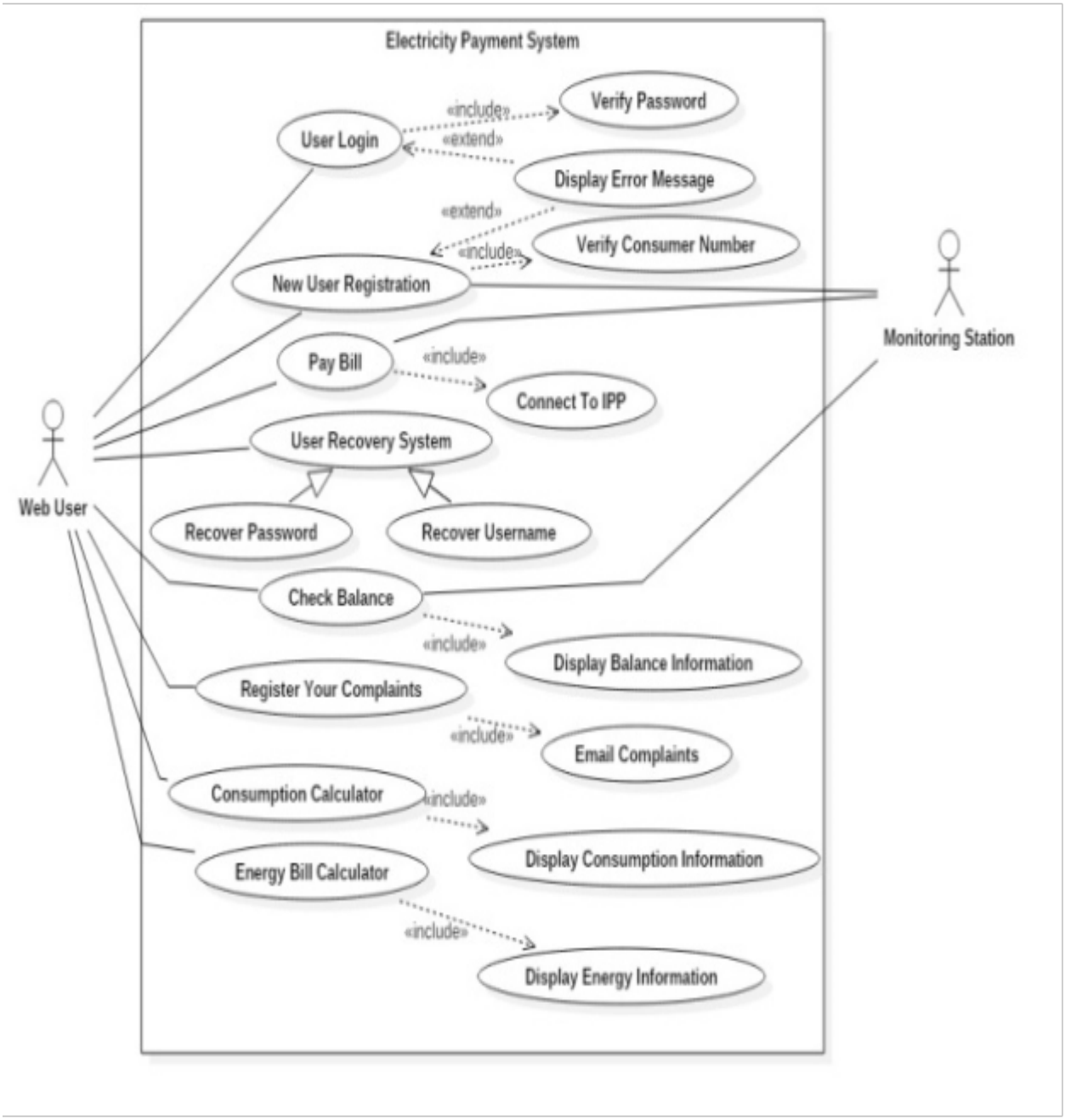

Figure 4.7 Proposed Use-Case diagram for the Web-Based System

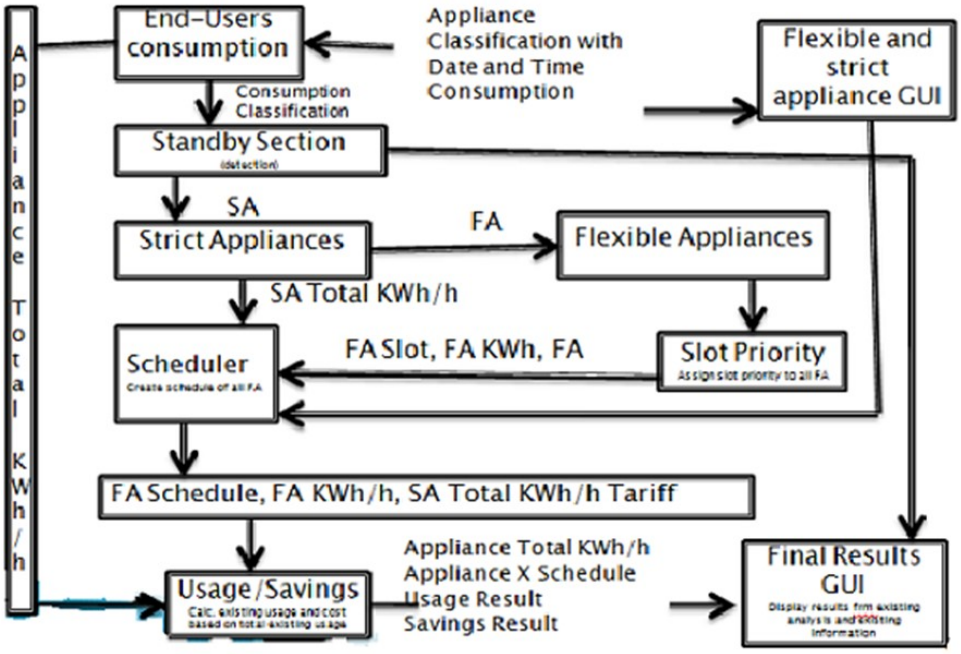

Figure 8: Proposed flow diagram of Home energy planner

3.4 Design consideration for the Home Energy Planner

The design of the home energy planner would be carried out by JAVA SCRIPT as shown in figure 4.8 each block is a JAVA component where the end-users consumption component reads consumption of data from Appliance Graphical Users interface (GUI), in the appliance GUI that is where end-user classified their appliances as flexible or Strict Appliance. Here Flexible appliances are those appliances consumers place on schedule like washing machine, dish washers while strict appliances are those appliances end-user does not want to be given schedule because they need to run all the time such as refrigerators, entertainment devices etc. whereas the slot priority is a component that would assign slot priority to flexible appliances based on highest KWh needed and the amount of hours needed to run one session of an appliance I ascending order which data would be received from the flexible appliance component thereafter final results of all would be display at Final result GUI.

As part of the design for the Home energy planner, the following stages is also proposed: Determine standby power consumption for all end-user appliances, Removing standby power consumption from existing data readings for all appliances, then add up total strict appliances power consumptions, Determine the power , time to run each appliance their respective usage per session for flexible appliances, assign slot priorities to flexible appliances on their average power consumption per session with respect to their loading condition, determine schedules for all flexible appliances and calculate estimated savings in KWh and Naira cost.

4.1 Data Presentation

It is expected that when power consumption falls below certain minimum amount, then a message will be sent to customer mobile phone and when they consumes more than allocated power, the system reset and regulate the power consumed and send message to wireless based monitoring station and some appliances will not be able to draw power and customers will need to shed some load to restore power. Shown in Figure 9 and 10 Monitoring customers meters (Meter status when balance is zeros and for low balance).

ENERGY MONITORING SYSTI		
HOME	ENTER RECHARGE AMOUNT	200
	ONE UNIT COST	5.00
REAL TIME	RUNNING COUNT	40
	TOTAL CONSUMPTION	40
SINGLE PHASE	BALANCE UNITS	0.00
	BALANCE AMOUNT	0.00
TRENDS	METER STATUS	

Figure 9: Monitoring customers meters (Meter status when balance is zeros)

ENERGY MONITORING SYSTI		
HOME	ENTER RECHARGE AMOUNT	200
	ONE UNIT COST	5.00
REAL TIME	RUNNING COUNT	31
	TOTAL CONSUMPTION	31
SINGLE PHASE	BALANCE UNITS	9.00
	BALANCE AMOUNT	45.00
TRENDS	METER STATUS	

Figure 10: Monitoring customers meters (Meter status when balance is Low)

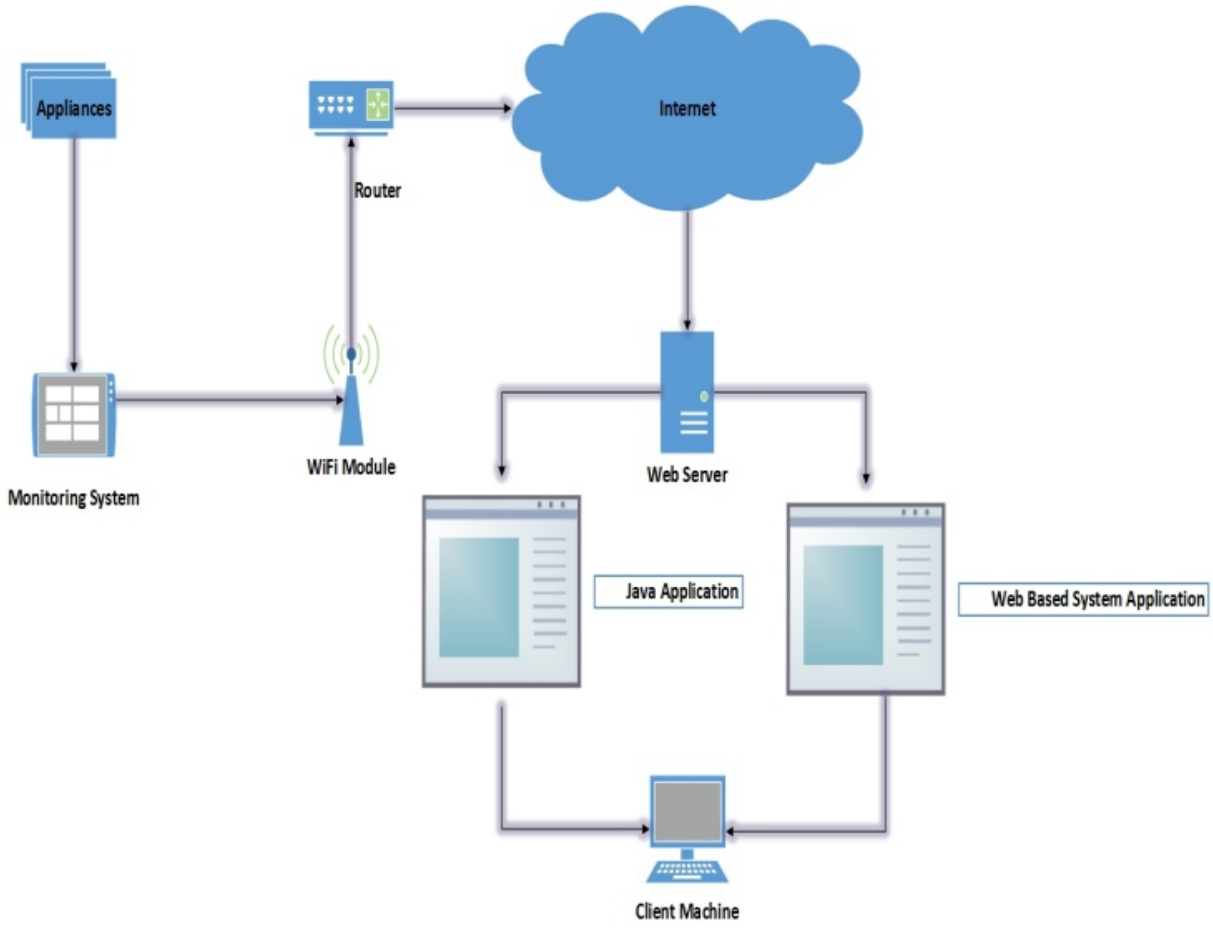

Figure 11: Expected setup of the Home Energy Planner

6. DISCUSSION OF FINDINGS

The expected outcome of this research is that it will enable end-users being able to manage their electricity consumption, determine the timing schedule of appliances either flexible or strict or both (see figure 11), with the automated metering system, Centralized wireless based monitoring system and tamper proof which also includes inbuilt fraud and fault detection, the utility company will be able to eliminate the possibility of electricity theft, non-payment of electricity bills and save huge amount of money for the distribution company.
The preliminary findings that may require further investigation are as follows:

i. Most wireless based system were not design with inbuilt fault detection and fraud detection same time.
ii. Most automated metering system was not incorporated with flexible home energy planner.
iii. It is very rare to find centralized monitoring system be used for even load shedding and load dependent.

7. CONCLUDING REMARKS

The proposed system when fully implemented it will solve the problem of power management and monitoring the energy usage in different prepaid meters of various customers.

The Live comparison of energy usage would be monitored on a centralized wireless based system. With the help of Home Energy planner, end-users will be able to determine the timing schedules to turn appliances on and off automatically and reduce waste. It will also help customers make payment easily with the help of web-based system.

The proposed system will eliminate the possibility of non-payment of electricity bills by customers, electricity theft and economically viable.

8. PROPOSED CONTRIBUTIONS TO KNOWLEDGE

1. Centralized wireless based metering monitoring system
2. Centralized automatic billing system
3. Load dependent and even Load shedding
4. Home energy planner.

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