Wireless IoT based Metering System for Energy Efficient Smart Cites

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Abstract—**The emerging of IoT concept recently in our lives, has offered the chance to establish energy efficient smart devices, systems and cities. Due to the urging need for conserving energy, this paper proposes an IoT based energy efficient wireless smart metering system design. It competes with the existing meters as being a low cost completely integrated metering system. It offers an easily operated Android application for users as well as a Website and database for the electricity supplier company. The proposed system design has an accuracy level of 97% and it is about 25% lower cost than its peer in the global market. The proposed design reduced the power consumption by 16%.**

Keywords—**metering system; prepaid; IOT; energy efficiency; smart cities.**

I. INTRODUCTION

The drastic increase in urbanization over the past few years requires sustainable, efficient, and smart solutions for transportation, governance, environment, quality of life, and so on. Since the evolution of IOT concept in the early 2000s, the Internet of Things offers many sophisticated and ubiquitous applications for smart cities. It is the ability of devices, networks and sensors to communicate with each other, with and without any human interaction [1]. Internet of things (IoT) basic simplified workflow can be described as follows: object sensing, identification and communication of object specific information, trigger an action and lastly, the smart device or system provides its service [2]. The energy demand of IoT applications is increased, while IoT devices continue to grow in both numbers and requirements. Therefore, new smart city must have the ability to efficiently utilize energy and handle the associated challenges [3].

The conventional electromechanical energy meters have a great contribution in dissipation of energy. Mainly because they are post-paid meters, customers cannot keep track of their energy consumption, except on a monthly basis. However, Smart meters when programmed with home appliances can be used to control the electricity consumption. Moreover, Smart meters are less error prone [4]. Smart Meters are electronic measurement devices used by utilities to communicate information for billing customers and operating their electric systems [5]. It is simply consisting of a metering unit and a communication interface between the metering unit and the utility. The communication interface module is connected to the microcontroller to transmit and receive information between the utility and the metering unit installed in the house [6].

This paper presents the design and implementation of a full integrated smart energy efficient metering system. The design provides a low power consumption smart metering system. The proposed design is implemented at two ends, one on the consumer end for IoT operation and other on the service provider end for managing customers' data through an implemented Website and customized database. Android application is also designed to have a more easily operated system at the customer end. Shown in Figure 1 is the overall system block units, from the main supply in the house to the back end, electricity supplier, managing unit.

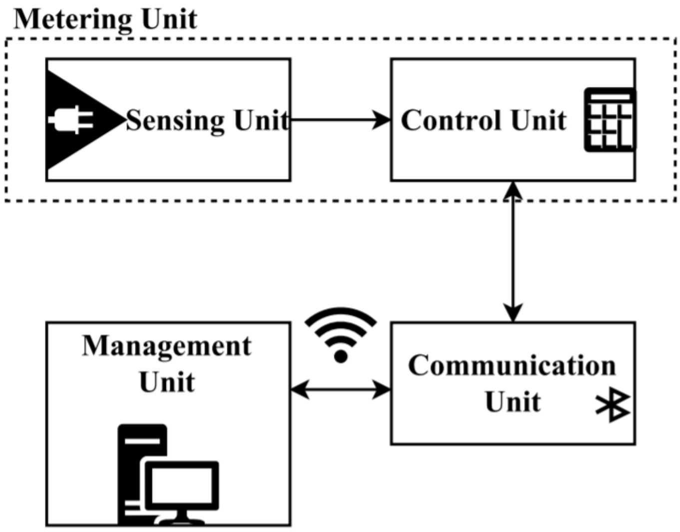

Figure 1 Proposed Metering System Block Diagram

The paper is organized as follows: section II gives a detailed explanation for the sensing unit, control unit communication unit and the managing unit block, illustrated in Figure 1. In section III, the calibration procedure and system implementation results are discussed. Finally, the conclusion is given in section IV.

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II. PROPOSED METERING SYSTEM DESIGN

The proposed IoT based metering system is designed to contribute in establishing energy efficient smart cities. Its main aim is to minimize the rapid increase in average electricity consumption issue. Additionally, it provides a more convenient solution to problems faced from using the existing meters, such as the manual readings' errors from the analog electromechanical meter. The conventional electromechanically post-paid metering system, where the consumer is charged on a monthly basis, provides no sense of the energy used until the end of the month. However, it guarantees that customers will always have electricity supplies, except during blackouts [7].

On the other hand, Prepaid meters offer many advantages both to the utility provider and the consumers. To the utility provider, this reduces many issues tremendously arising from meter readers such as delays, wrong and infrequent meter reading resulting in bulk amount of billing that consumers would need to pay and further consequent in not paying, disputes and so forth [8]. Additionally, prepayment metering system, encourages users to control their energy consumption, in order to avoid cut off, due to zero credit [9]. Thus, the proposed metering system uses the prepayment metering as an attempt for building energy efficient new cities. Figure 2 shows the complete proposed system design with the components and building components for each unit block, which will be further discussed in the this and the following sections.

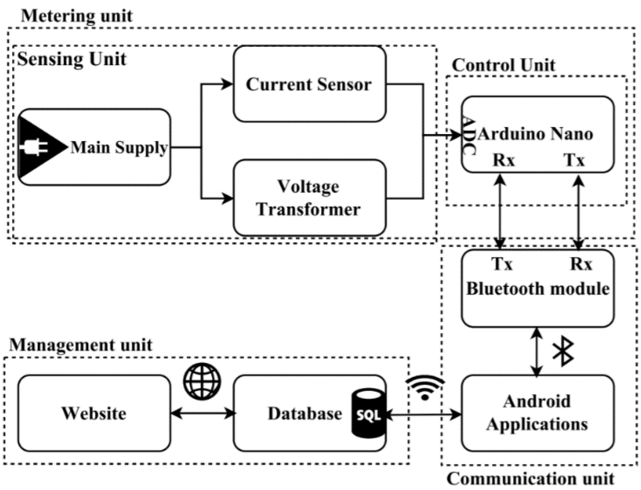

Figure 2 Overall System block Diagram

A. SENSING UNIT

The sensing unit comprises of the voltage transformer and the current sensor that are connected to the main supply. The voltage transformer used was a 240v to 6v step down transformer. Whereas, the current sensor was a SCT-013-000 non-intrusive sensor, clipped over a single wire either live or neutral, to sense the passing current [10]. This sensor's output is voltage, so, to get current reading, a burden resistor is connected to the two terminals of the sensor. The reading of both components are transferred to the next unit for processing.

B. CONTROL UNIT

The control unit consists mainly of the micro-controller, which is ATmega328 based Arduino Nano. Data received from the sensing unit are passed as an input to the built-in analog to digital converter (ADC) in the microcontroller. Afterwards, the data is processed then used units in kilowatt hour and remaining balance and units.

These calculations were performed as follows: first calibration values for the current and voltage are calculated as shown in equations (1) and (2), where 0.707 value is used to convert the measured value to RMS value, 1024 is the maximum reading of Arduino input pins, 36 is the value of the burden resistance used with the current sensor and 240 is the maximum voltage that can be read by the meter. Current value read from the supply is calculated using a loop which takes 200 samples from the micro controller analog pins connected to the sensor and finds the maximum and minimum values [11]. Then the current is calculated as shown in equation (3). On the other hand, voltage is calculated by taking the reading of the analog pin of the microcontroller connected to the transformer as shown in equation (4), using software function analogRead(). Figure 3 represents the voltage and current waveforms passed to the meter.

CalibrationI = 0.707/(1024*36)…………....(1)

CalibrationV = (0.707*240)/1024…………(2)

Current=(maxI-minI) * CalibrationI……....(3)

Voltage=analogRead(A1) *CalibrationV.....(4)

Afterwards, the control unit issues warnings for the user when either 20% or 10% is left in the balance. At zero balance, 24-hours allowance time is given to user, as a chance to recharge before electricity is cutoff. The calculated values are then passed to the communication unit.

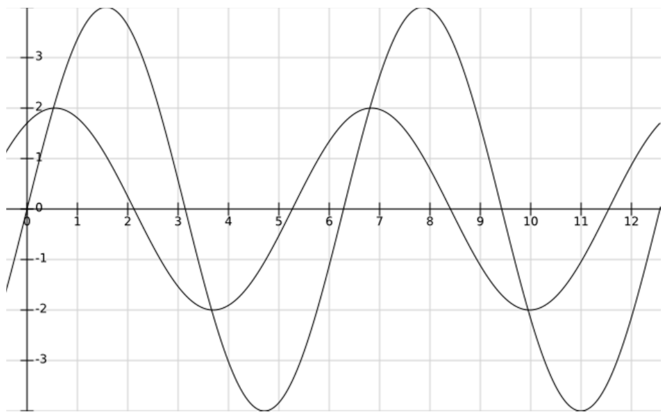

Figure 3 Output Voltage and Current Waveform

III. COMMUNICATION UNIT

This unit's main functionality is to establish the communication between the control unit and the Android application. It is composed of the Bluetooth module, HC-05, and the Android application. The module is connected to the control unit, in the metering system, serially. The Bluetooth pins, Tx and Rx, are connected to two digital pins in the Arduino Nano.

The implemented Android application was implemented using MIT App Inventor 2 Software. Its main functionality is to establish communication between the control unit and the managing unit. Additionally, it enables the user to track his/her usage at any time and view metering data on the Android application. The reason behind integrating an android application with the prepaid smart energy meter system is that it will make it easier for customers to monitor their energy consumption even if they are not near the meter display screen.

IV. MANAGEMENT UNIT

The management unit consists of the database of the users' information and the implemented website. The database was created using XAMPP MYSQL database, used to store different billing data of each customer such as first name, last name, mobile number, meter ID, balance, remaining balance used units and remaining units. The website was designed using NetBeans IDE software, HTML and Java servlet.

This unit's functionality is allowing the utility to have control over the customers' billing data and to have a record of this data to track the electricity consumption. The website enables the utility to add new customer, delete, update or view an existing customer's record. It can be accessed by the users as a meter and mobile application user guide.

The management unit receives data from the communication unit which was processed by the control unit. This data is received and stored in the database. The database is then accessed by the utility through the website to manage the customers' data.

V. CALIBRATION AND IMPLEMENTATION RESULTS

Before designing the final PCB layout, a prototype PCB was designed, to check for any instability or errors in the circuit, such as components or connection error. The meter's calibration was done by turning on two refrigerators for five hours and the reading of the already installed meter was taken, the difference between the initial and final readings was 0.5kWh. At the same time, the reading from the implemented circuit design was recorded, the reading differed by 0.01 kWh, the meter read a value of 0.51kWh, when clipped over a single current wire of the two refrigerators connected through the same plug. Figure 4 shows the final system with all components connected together.

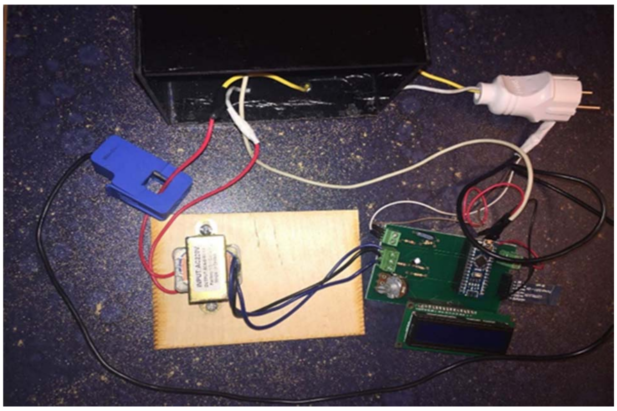

Figure 4 Final Proposed System

Figure 5 illustrates the final system working mechanism. The system operation starts by taking inputs from the current and voltage transformer. Then these inputs are passed to the analog to digital converter of the microcontroller unit where the billing data are calculated. Then a check is done on the billing data. the first check is whether the balance reached 10% or 20%. if the balance reached these low percentages warnings are issued. The second check is whether the balance is finished which if true the electricity is cut off and then the data is transmitted through Bluetooth to the android application then to the database which is managed through the website by the utility.

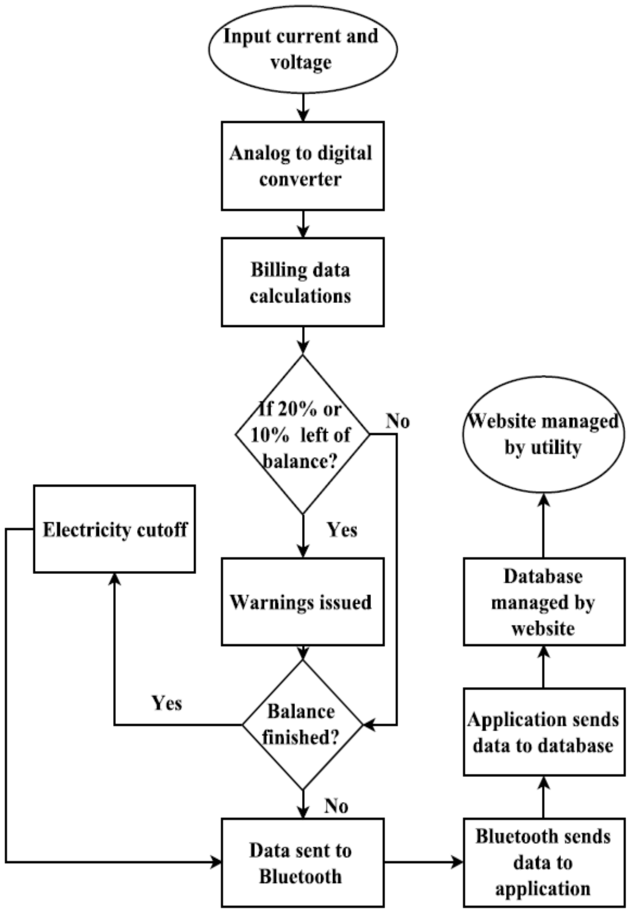

Figure 5 Proposed System Flowchart

The readings were recorded 30 times and the average was calculated. The average recorded value showed that the meter readings were recorded, for 30 times, on different devices, such as, vacuum cleaner and washing machine, as they consume large power in short time. The values were compared by the device power label as well as the already installed meter reading. Results showed that the proposed meter has an accuracy percentage of 97%. However, it is most accurate for measuring current values greater than 3A.

The proposed design's cost is about 25% lower than its peer in the global market, due to the use of a low cost communication module, a small area PCB as well as a relatively low cost microcontroller module. The proposed design also consumes about 16% less power than the existing meter due to the small area of the design as well as the existence of low power modes in most of the components used.

A comparison between the proposed metering system, the existing system as well as a research paper published in in India [12], was conducted and summarized in Table 1. It shows that the proposed design competes in cost, back end interface as well as the Android application. It also, displays more data on the LCD screen as well as the application. However, the research paper has two payment modes, postpaid and prepaid modes.

Table 1: Comparison between proposed meter and other meters

Feature	**Proposed Design**	**Existing meter in Egypt**	**Research paper Design - 2016**
Communication Type	Bluetooth	Smart Card	Zigbee
Payment Method	Prepaid	Prepaid	Prepaid and Postpaid
Data Displayed On LCD Screen	-Remaining Credit -used units - Cost of units Used -left units	-Remaining Balance -Used units - Remaining Days before balance reaches zero.	-Payment Mode -Power Consumption -Bill
User Friendly Interface	-LCD Screen -Android Application	LCD Screen	-LCD Screen -SMS in Power Theft
Allowance Period	- 24 Hours	- 24 Hours	-Electricity cuts off when balance is -20
Controlling Energy Consumption	Android Application offers conservation plans	No controlling methods	No controlling methods
Back-end interface	Website and database	No interface	Zigbee Receiver
Cost	Low Cost – about 42 Euros	High cost About 100 Euros	High cost- 2 payment modes

VI. CONCLUSTION

The advancement on technology and the need of electricity in every aspect of life has made the electrical power irreplaceable. Taking advantage of IOT smart meters has developed and took various shapes and types. Consequently, the design of a low cost, low power and user friendly smart meter which helps in the conservation of energy can be of great importance.

The proposed smart meter design helps the users to track their energy consumption from LCD display and Android application. The users' data are saved and sent to the users' database through the mobile application, where the database is always updated by each meter's data then it can be edited by the utility website. The system has a 97% accuracy level compared with the existing conventional electromechanical meter. It is also 25% lower cost than its competing smart meter in the global market. The implemented Android application offers a consumption plans as well as online payment. The proposed design meter minimized the power consumption by 16% compared with the global market design.

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