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Global System for Mobile (GSM) Communication Based Smart-Prepaid Energy Meter Monitoring System

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ABSTRACT

The increase in the consumption of electricity both domestically and industrially has necessitated monitoring to understand energy consumption patterns and reduce wastages. Also, with the wide capabilities of mobile technology, data and report can easily be exchanged. With the help of GSM-Module and an Arduino microcontroller, this study presents a prepaid energy meter monitoring system that enables real time remote utility-consumer monitoring of domestic energy usage. This system also curbs the present challenges with meter tampering and guides the consumer to be energy conscious. This system is recommended for policy considerations by utility companies since the deployment of this system can potentially improve operational efficiencies.

Keywords: *GSM, meters, microcontroller*

INTRODUCTION

In the new global economy, electricity generation and consumption has become a central issue. Electricity consumption boosts economic growth, global networking, and productivity. For example, warmth and cold housing result to health risks and being able to afford to keep house temperature moderate is highly imperative. As claimed by O'Sullivan *et al.* (2011), in New Zealand from 1980 to 2011 an average estimate of 1900 excess winter deaths occurs each year. A primary concern of electricity production and usage includes its service delivery reliability and accurate allocation of energy costs based on real consumption; which is equally important to both consumers and service providers. System losses thus, technical or non-technical (Han and Xiao 2017) result to huge economic damages. According to Chou and Yutami (2014), non-technical losses by power utility companies total 20 billion dollars annually globally. Most importantly, Depuru et al. (2011) emphasizes apart from increasing installed generation capacity in addressing technical losses, controlling the electricity theft and regularizing existing consumers' electricity consumptions could be helpful with regards to load management to meet increasing demands.

Recently, researchers have shown an increased interest in electricity consumption payment methods i.e. postpaid and prepaid (Oseni 2015; Arawomo 2017) to address electricity consumption behaviors amongst end users. Recent evidence suggests that, prepaid meters can improve customers' welfare by making them more conscious of their energy usage and reducing energy cost (Oseni 2015). Du *et al.* (2017) show how consumers who receive timely feedback from prepaid meter usage tend to have lower electricity consumption rate. Furthermore, Chou and Yutami (2014) mentions the consideration of smart meters as a means not only to allowing consumers remotely control their energy usage; also, presents a promising technology for conserving limited energy resources. The aggregate of smart and prepaid meters

present quite an optimal solution to non-technical losses, billing problems as well as end user consumption behavior towards power conservation (Franek et al 2013). Despite its efficacy, smart prepaid meters suffer from several major drawbacks including how customers receive alerts before their prepaid units gets exhausted. Some smart prepaid meters alert customers using cloud-based technology which is Internet Protocol dependent (Pau *et al*. 2017; Aziz *et al.* 2013), sound alarms and blinking LEDs. Although the cloud-based smart meter outage management systems presents remote power consumption monitoring, in the event of no internet access its benefit is limited. This paper contest the claim that, smart meters should be able to send consumption information remotely anytime and anywhere. The main purpose of this study is to design and implement a GSM based smart-prepaid energy meter monitoring system.

The whole organization of the study takes the method of six sections, comprising this introductory section. The next section (II) focuses on review of relevant literature in relation to the subject matter. Section III outlines the research methodology. Section IV presents the findings. Section V discusses the findings and section VI concludes the paper.

LITERATURE REVEIW

According to Ebole *et al*. (2016)[3], an "Energy Meter is a device that measures the amount of electrical energy used up by a residence, business, or an electrically powered device". In 1954, Gunn showed the various types of electric meters including Integrated Single Phase meters, Integrated Three Phase meters and the Split Single Phase meter. In the past, meters commonly used were electromechanical (postpaid meters) devices which gave poor accuracy, theft issues and lack of configurability (Arun and Naidu, 2012). Postpaid meters operate by counting the revolutions of a non-magnetic, but electrically conductive metal disk. The speed of rotation is proportional to the power passing through the meter and the number of revolutions is thus proportional to the energy consumed (Markose *et al*., 2016); which is used to generate consumers' bills manually. Thus, personnel from the utility providers visit homes to check the amount of electricity consumed by customers and the billing is done according to what is being recorded. Previous research has indicated some pitfalls with regards to the manual billing system and its associated energy fraud.

Electric Meter Billing System

The manual billing system of postpaid meters poses problems such as: (1) mishandling of billing sheet by customers, (2) meter reading frauds (3) bad weather conditions may affect the billing process (4) tediousness and time wasting billing tasks (Mareena 2013). Although many cash offices and pay points, banks, third parties and revenue collectors are common now, it is not enough. The delivery of bills to wrong people, lateness in delivering bills, inconvenience of travelling long distances to make payment also poses unforeseen challenges [7]. According to Kayaga *et al*. (2004)[5], Bill payment and collection efficiency which supports proper utility provision are generally poor. This are mostly due to irregular bill delivery, dissatisfaction among consumers, occurrence of overcharging and undercharging due to billing errors and inefficiencies in the billing system. On the contrary, several studies have shown an improvement in revenues by utility organizations through proper billing. For example, a review in Rwanda done by Mwaura (2012)[9] about electricity prepayment billing system shows that revenue rose from US$ 261,000 in 1996 to US$ 22.9m in 2008. Also, revenue collection is on time and has increased. Furthermore, the smart prepaid meters have been identified as major contributing

factors positively addressing the challenges as posed by postpaid meter usage.

Electricity Energy Consumption Fraud

Electrical energy consumption fraud is a long term problem costing power generation companies to make huge revenue losses and threatening the main power supply security and reliability. According to (Kalaivani *et al*. 2014)[4], in India, every year, the electricity companies fare the line losses at an average 20-30 percent causing the ministry to lose more than RS.125 billion. Some strategies deployed by fraudster to interfere with electric energy meter include; (1) physical bypass: This method is the most common and easiest. The disconnection can be done inside or outside the meter where cables from the meter are disconnected and re-routed directly to the load [8]; (2) mechanical interference: That is when the movement of the disk becomes slow, the fewer number of units is recorded by the meter. The aim of this strategy is to reduce the speed of the disk so that electricity is billed at a very slow rate [8]; and (3) instrumentation control (cyber-attack): Fraudsters that are knowledgeable in computer and IP networking systems have found smart and intelligent ways of tampering with meters with the aim of stealing energy. They can reprogram the prepaid meter using software to alter billing and energy registers of the meter [8]. Also some cyber-attacks could be lunched via meters having infrared connectivity attachments. According to Rastogi et al., (2016)[11], these are the various types of cyber-attacks: (1) COA (Ciphertext Only Attack): The attacker tries to deduce decryption key from the ciphertext; (2) KPA (Known Plaintext Attack): The attacker obtains pairs of plaintext and ciphertext by reading the meter; (3) CPA (Chosen Plaintext Attack): The attacker can choose the plaintext and the corresponding ciphertext; and (4) CCA (Chosen Ciphertext Attack): Since a message authentication code is generated for each encrypted meter reading, the attacker cannot forge a valid ciphertext for an arbitrary value, though, he/she can launch this outbreak for public-key cryptosystems.

METHODOLOGY

Hardware

Arduino microcontroller

The Arduino Uno microcontroller is a microcontroller based on the ATmega328 (datasheet). “Uno” means “One” in Italian and is the newest in a series of USB Arduino Boards. [2].

Part Name	Specification
Microcontroller	ATmega328
Operating Voltage	5V
Supply Voltage (recommended)	7-12V
Maximum Supply voltage (not recommended)	20V
Digital I/O Pins	14(of which 6 deliver PWM output)
Analog Input Pins	6
DC Current per I/O Pin	40mA
DC Current for 3.3V Pin	50mA
Flash Memory	32KB (ATmega328) of which 0.5KB is used by bootloader
SRAM	2KB (ATmega328)
EEPROM	1KB (ATmega328)
Clock Speed	16MHz

(Source: Daulatkar et al., 2017[2])

Features of the Arduino Board and Their Specifications

Energy meter

An energy meter operates by continuously measuring the voltage and current or wattage. The product of which gives the instantaneous electrical power which is then integrated against time to give energy used.

LCD

This interface displays vital information to users. In this project, a 16×2 LCD was used. 16×2 means it has two rows which can display 16 Characters per line. As compared to LEDs, LCDs are preferred as display devices because of its low power consumption, flexibility in display content and compact structure appropriate for embedding in the hardware unit. They work on the principle of change in orientation of the liquid crystals due to incident light.

Relay

A relay is the connecting link between the consumer load and utility supply. Depending on the units available on the meter, the relay cuts or restores power. Its stays closed when it restores uninterrupted supply of power to the load and it opens and disconnects the load from power supply or cuts power when the user runs out of units. Current and voltage value generated and fed to the microcontroller for calculations are also done from the relay since it also consumes some amount of energy. [10]

GSM module

The SIM300 is a Tri-band GSM/GPRS solution in a compact plug-in module. It delivers GSM/GPRS 900/1800/1900MHz performance for voice, SMS, Data and Fax in a small form factor with low power consumption. These features make it ideal for virtually unlimited applications and handheld devices [2]. Some other features are a Tri-band GSM/GPRS module with a size of 40x33x2.9mm; Customized MMI and Keypad/LCD support; has an embedded Powerful TCP/IP protocol stack.

SYSTEM ARCHITECTURE

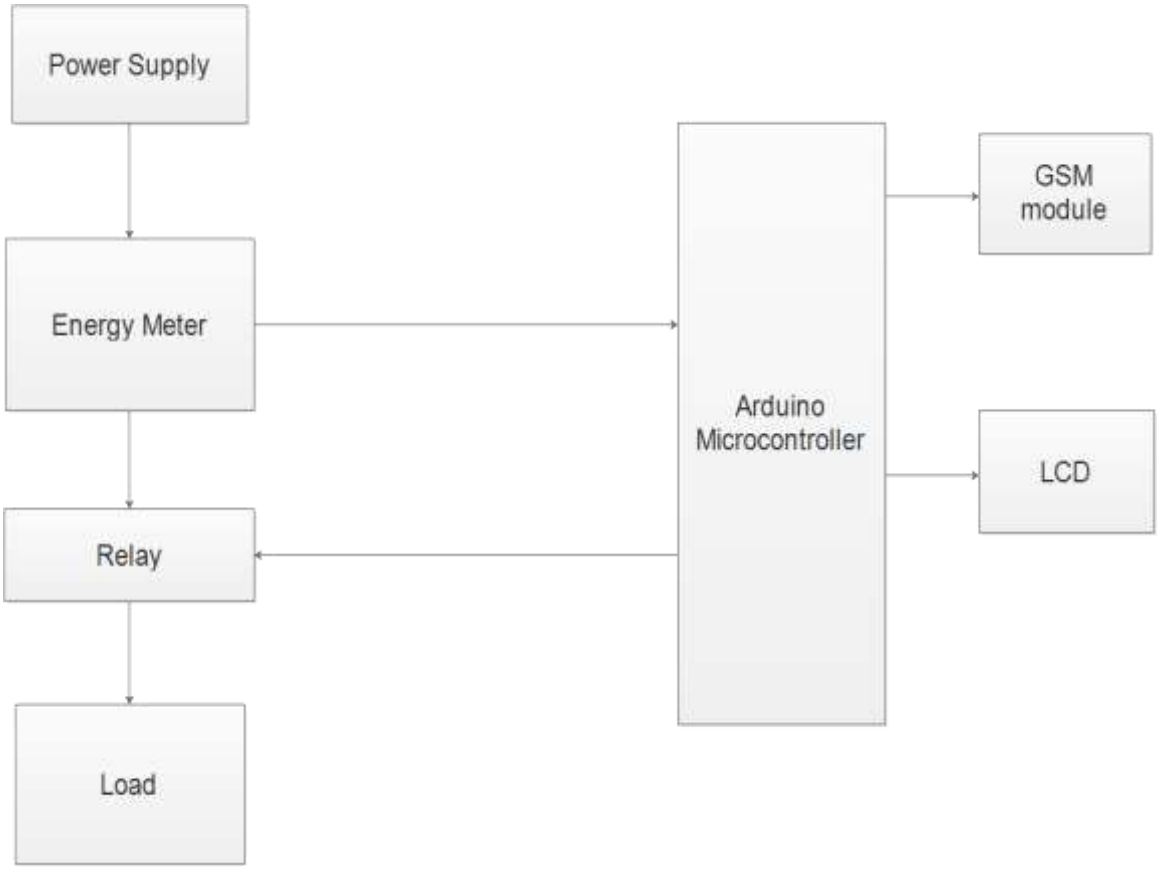

Fig.1: *Block Diagram.*

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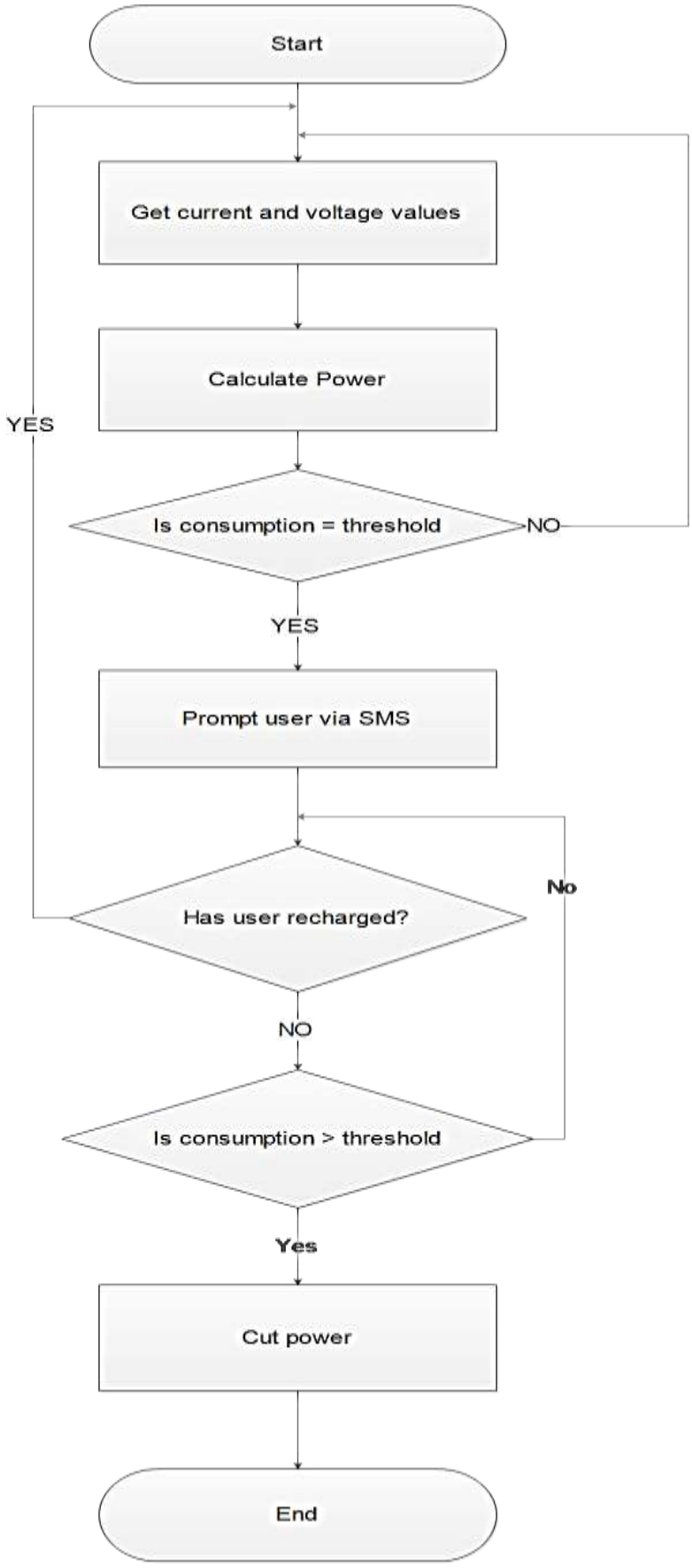

***Fig.2**: Flowchart.*

Implementation

The system is based on serial data transmission using SMS over GSM Network in order to facilitate communication between the Customer and the energy meter. Energy consumption is audited by using a current transformer (CT), connected in series to the load and the current is measured by implementing Analog to Digital Conversion (ADC). The ATmega328 microcontroller on the Arduino Uno board makes all relevant calculations pertaining to the billing of electricity usage and real time instantaneous power and current is displayed on the LCD. A button stuck to the microcontroller triggers a message to the Utility Company for the case of Mechanical Interference.

Fig.3: *Interfacing of the Hardware.*

Fig.4: *Working Condition.*

FINDINGS

As the two lightbulbs consumes energy, the serial monitor of the Arduino IDE sketch records and displays the instantaneous power and current readings measured in watts and amperes respectively. This is shown in the figure below.

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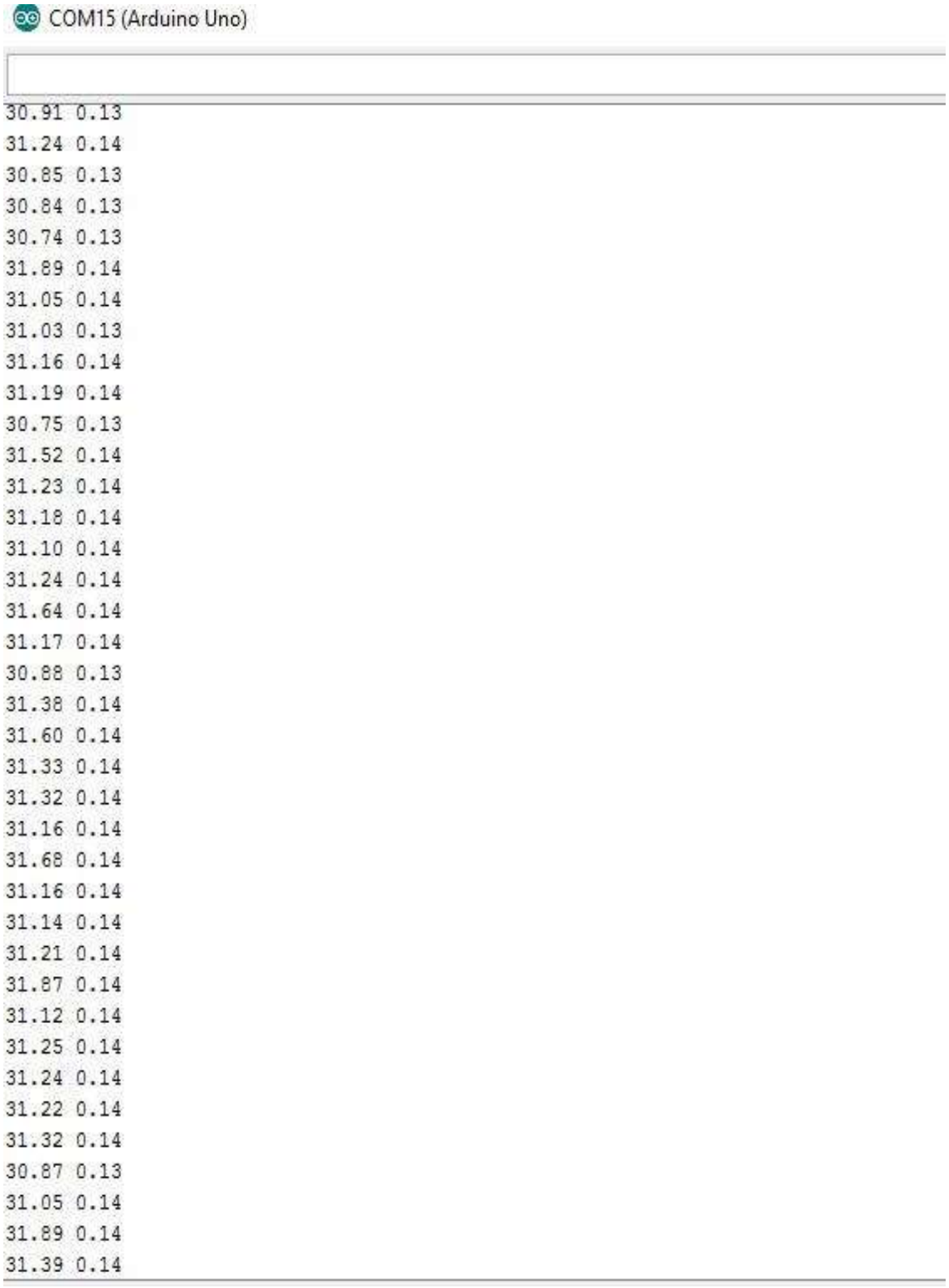

Fig.5: *Display in Serial Monitor.*

A message is sent to the Customer via the GSM module when the threshold is reached to prompt him/her to recharge. If the Customer is able to recharge, the new balance is added to the previous balance the cycle begins again, otherwise if the Customer is unable to recharge and the units is less than the threshold, a signal is sent to the relay to cut power.

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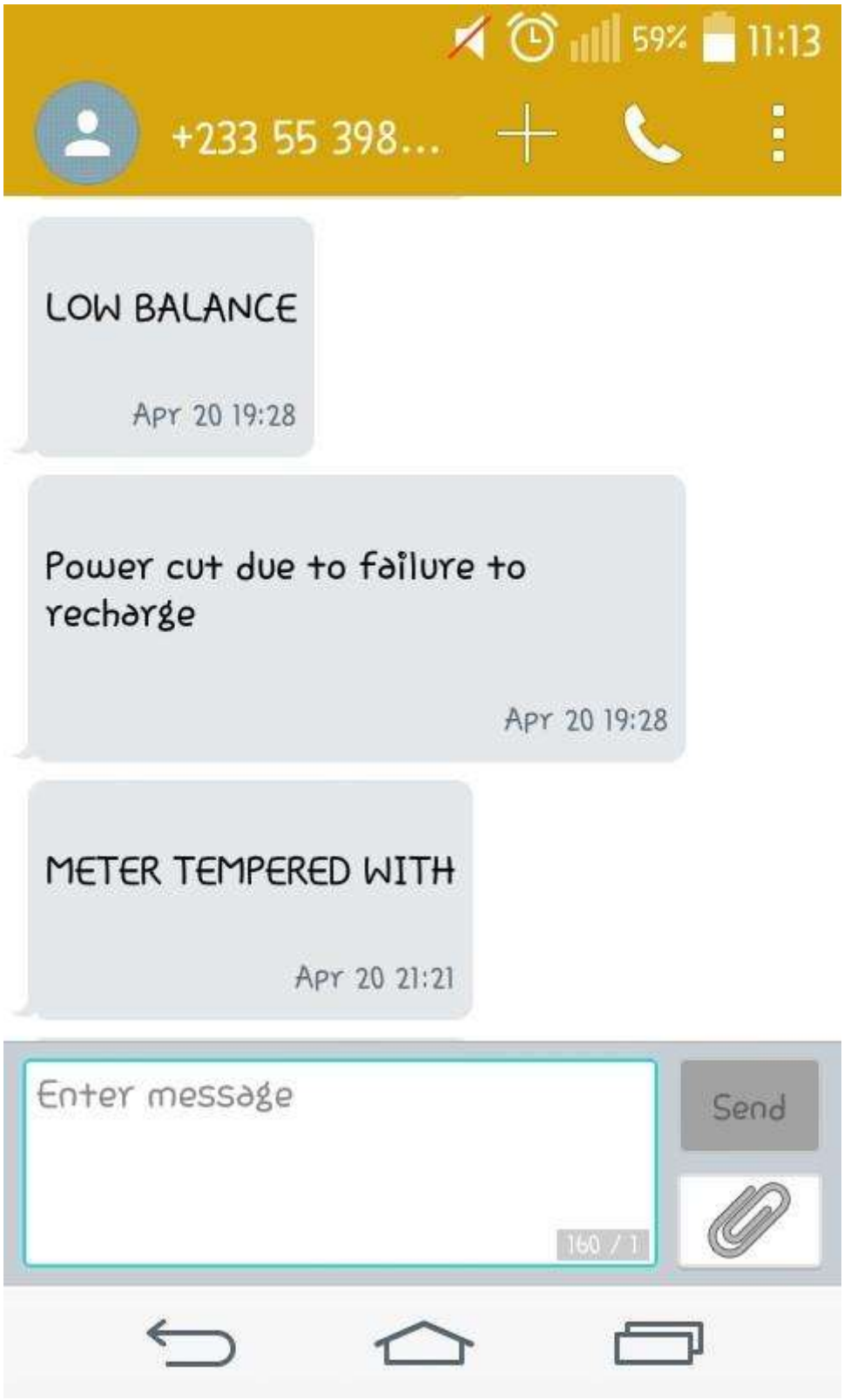

Fig.6: *Messages sent to the Mobile Phone by GSM.*

On the other hand, when the Customer or someone tries to tamper with the meter through mechanical interference, the utility providers are notified by an SMS alert through the GSM module. In this project, the same GSM was used for sending

messages to the user and to the utility providers. Also, for display purposes, the Customer represents the Utility Provider.

DISCUSSION

A smart system like this can help manage energy usage and also curb the mechanical interference technique of stealing power. This system is user friendly and cost effective. Developments such as these provide a great means of monitoring electricity usage as well as electricity theft

CONCLUSION

In this project, a GSM based prepaid monitoring system has been designed and implemented. A model of the system has also been developed to help prepaid energy users remotely monitor their energy usage. This project is economically good because the utilization of energy will be keenly monitored and users will prepare their budgets on energy usage since an awareness will be created via the GSM module. Monitoring of power consumption by the utility provider will also help in selecting areas to suitably control energy usage and in load shedding issues. A mechanism of prompting utility providers when meters are tampered with has also been achieved. These positive results will help in conserving energy and the crime of stealing power may be brought to an end.

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