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Design and Implementation of an Improved Apartment Prepaid Electricity Metering System in Uganda

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***Abstract*—** *In Uganda, Umeme Ltd is responsible for the billing and supply of electric power. Previously a postpaid metering system was used but there was a challenge when it came to recording of the readings because most premises were inaccessible due to different reasons. Umeme later introduced Yaka, a prepaid metering system where the customer is automatically turned off once the units paid for are fully used up. The charges involved in connecting and servicing Yaka to tenants are high and therefore the apartment managers resort to having single Yaka meter for several tenants however each tenant consumes different units which makes the available billing mechanism of contributing equal amount of money becomes unfair to tenants. This paper aims to design an improved pre-paid metering system for tenants which can be used in addition to the current Yaka System to solve the above-mentioned challenges. With this, several tenants can have a single Yaka meter but still be able to attain units that are proportional to their contribution of payments for Yaka units. This system also allows tenants to share and load units using the key pad and a phone.*

Keywords— Yaka, Tenants, Umeme, Meter, Pre-paid

1. INTRODUCTION

Before prepaid metering system (*Yaka*) in Uganda, post-paid meter system was used. In the post-paid meter system, the billing company (*Umeme* Ltd) would regularly send a representative to record the meter reading at the customer's premises. They would then manually subtract the new reading from the previous one to get the number of consumed units [1]. The amount of money to be paid for those units would be calculated and added to any previous unpaid amount. A detailed bill would then be issues to the customer. Many customers had fences surrounding their premises. *Umeme*'s representative had to seek permission to access such premises and at sometimes, they could fail to access the location of the meter. In fact, some customers would deliberately deny the representatives chance to read the meters [2]. In addition to the difficulties faced by the representatives, there was power theft through tampering with the meter. *Umeme* therefore introduced per-paid metering where the actual meter is installed on top of the electric pole and only a small device (Customer Interface Unit – CIU) is placed on the wall of the house. The pre-paid metering system, termed *Yaka* allows customer to pay for a certain number of units (through bank, mobile money or any other way). The customer is given a token which is then entered into the CIU. The system counts down the units the customer has paid for and once they are finished, the customer is automatically disconnected. Even with the *Yaka* system, some challenges are still not settled. For each meter, the customer pays a monthly service charge of around UGX.3, 360. In addition, connection to the grid costs the customer about UGX.750, 000.Ugandan urban settings usually have people (tenants) who rent small rooms or pairs of rooms. In fact, many people (sub-tenants) share the same room in arcades and shopping malls. For simplicity, such tenants and sub-tenants shall be called *tenants* hereof. Tenants who rent small rooms usually share the same *Yaka* meter. This is attributed to the high costs of connection and the high monthly service charges that would be incurred if every tenant had their own *Yaka* meter. Sub-meters are available on local market. These can be used to know how much each tenant has consumed and they are commonly used to tell how much each tenant should contribute [1]. However, the sub meters are analogous to the post-paid system and they cannot be used to implement the *Yaka* strategy of disconnecting the customer once the units he paid for are finished. There was need for a system that, could be connected after a *Yaka* meter shared by tenants, that could switch off individual tenants once the units those specific tenants paid for are consumed. A *Yaka* meter may be shared by 2 people (A and B), for example. If A contributes UGX.10,000 and B contributes UGX.20,000 and corresponds to about 30 units (kWh), it means that A should be allowed to use only 10 and B should be allowed to use 20 of the 30units. In this research, a system which is able to inform the manager/tenants about the total units bought and how much should be consumed by the tenant is designed and implemented, it works as though each tenant has his own *Yaka* meter but with only one connection fee and monthly service charge [2]. The system also has a screen that shows the instantaneous units left for every tenant. A keypad can be used by the manager (who knows the password) to load units for the other tenants. Alternatively, this can be done by SMS using the manager's Phone number. Once *Umeme* adopts this system, it will be a good replacement for the current *Yaka* system.

2. LITERATURE REVIEW

Yaka is a recent system developed by UMEME that works with prepaid billing. In some way this system enables people to monitor how much power they consume in a given period. [2]*Yaka* sub-meters are available on market. These can be used to know how much

each tenant has consumed and they are commonly used to tell how much each tenant should contribute but it's of disadvantage that landlords tend to overcharge the tenants.

Sub meters

Sub meters are devices used to measure electricity consumption, steam flow, natural gas flow etc. Historically, the allocation of energy costs was based on prorating the cost per square foot. The landlord would take the monthly utility bill and divide it up for each tenant based on their office size [1]. This is essentially why the process of sub metering came about. To prevent tenant rebellion, the property firms began installing sub meters for each office or tenant so that they could allocate the energy costs more efficiently and only bill the tenants for the energy they consumed. There are two types of sub meters that is the networked and non-networked sub meters [3].

Networked meters.

Networked meters are connected (wire or wireless) to a data collection device making them smarter and more easily managed.

Non- networked meters.

Non-networked (manual) meters are just as they sound, not connected to a data hub so they need to be read manually each month.

3. METHODOLOGY

The following block diagram describe how the system was designed; it describes how the components communicate among themselves.

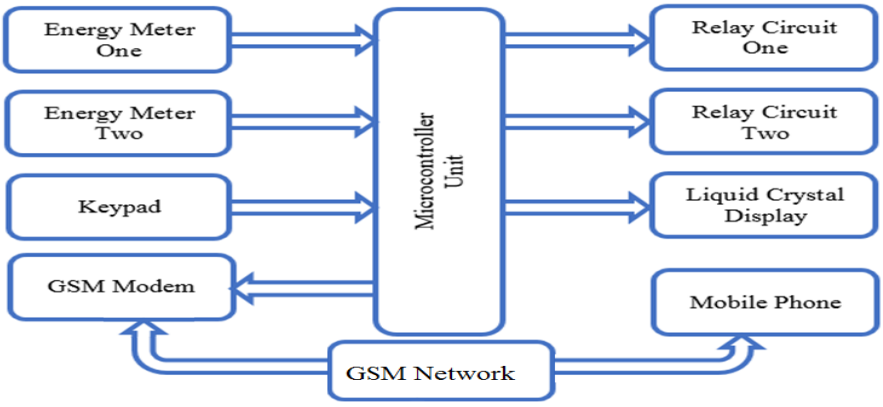


Fig. 1: *System Block Diagram*

The system is installed just after Umeme's meter which is the actual meter that shows the bought units. Once these units are finished, the whole system is automatically turned *off*. The above diagram therefore doesn't include Umeme's meter. It only shows the sections that are designed under this project. For each tenant, AC power passes through an energy meter and later through a relay switch circuit. Whereas the energy meter is powered by the same lines whose power it measures, the relay switch circuit requires a 5V DC power source. The role of this circuit is to switch the tenant *on* or *off*, depending on whether his units are still available or consumed fully. Besides the relay circuits, the microcontroller unit and the Liquid Crystal Display (LCD) also require a DC source therefore An AC to Dc converter was used. Since the keypad is just a network of switches, it does not really consume power but current flows through it from the microcontroller.

The microcontroller unit is the brain of the circuit and thus every component that executes some logic connects to it. It can read pulse from the energy meters as well as using the keypad to receive user inputs. It processes the inputs in reference to pre-saved instructions in order to determine which tenant should be *on* and who should be *off*. The microcontroller unit also commands the LCD on what to display and when.

Calculating Used Unit

Energy Meter outputs 1600 pulses per kWh of electric energy used. Call this constant K. The impulse is in form of a voltage pulse and a matching blink of an LED. When we need to determine the amount in kWh of energy call it units, U used in a given duration, we need to count how many pulses have been output by the meter in that duration [1]. Let the number of pulses be P.

$$A = U \,.\, K$$

$$\mathrm{U} = \frac{P}{K} = \frac{P}{1600}$$

For example, $\frac{32\ pulses}{1600\ pulse\ \ per\ kWh}$ = 0.02kWh

In the microcontroller program, the instantaneous number of pulses counted is called *P count[tenant]*, where *tenant* = 0 for the meter of tenant 0 or 1 for the meter of tenant 1. The used *units* then become *units* = $\frac{p\_count[tenant]}{1600}$ this can be deducted from the remaining units by mathematically adding their negative equivalent to the remaining units of that tenant.

```
for (int tenant = 0; tenant < NO_TENANTS; tenant++) {
  double units = ((double)p_count[tenant] / 1600.0); //1600pulse per kWh
  addUnits(tenant, -units);
}
```

Loading Units using Keypad (and LCD)

Once the manager presses D, the system asks for the password to confirm if the person who pressed D is the manager. If a wrong password is entered (or if one delays to enter the password, for about 15min), the system disregards the input and goes back to the normal mode from where it displays the units left [4]. If the person enters the right password, the systems show a menu. Menu item 1 is for *Loading units*, 2 is for *Sharing*/Transferring units from one tenant to another, 3 is for *Changing Password*, and 4 is for viewing or changing the managers *Phone Number*.

Once the user chooses 1 (load units), the systems ask for details of the receipt got after paying to *Umeme* and contributions of each member. Specifically, the systems ask for units received after paying to *Umeme*. These are received in the receipt/SMS the customer receives from *Umeme* after paying to them. For the scope of the current prototype, the number of units can have up to 4 digits before and up to 4 digits after a decimal point. These digital can however be less. The system then asks for amount paid by tenant 0 and later the amount paid by tenant 1 [5]. The amount should also have the same protocol of decimal points as it is with units. For example, if tenant 0 contributes Ugx.8,000 and tenant 1 contributes Ugx.5,000. The total amount becomes Ugx.13,000. The system does not ask for the 13,000 because it can calculate it from the 8,000 and the 5,000.

If the total units (*total units* in the program) bought are *Ut*, and tenant 0 contributed amount *A0* (*amount[0]*) and tenant 1 contributed amount *A1* (*amount[1]*), the system calculates tenant 0's units *U0* (*units[0]*) and tenant 1's units *U1* (*units[1]*) as shown below.

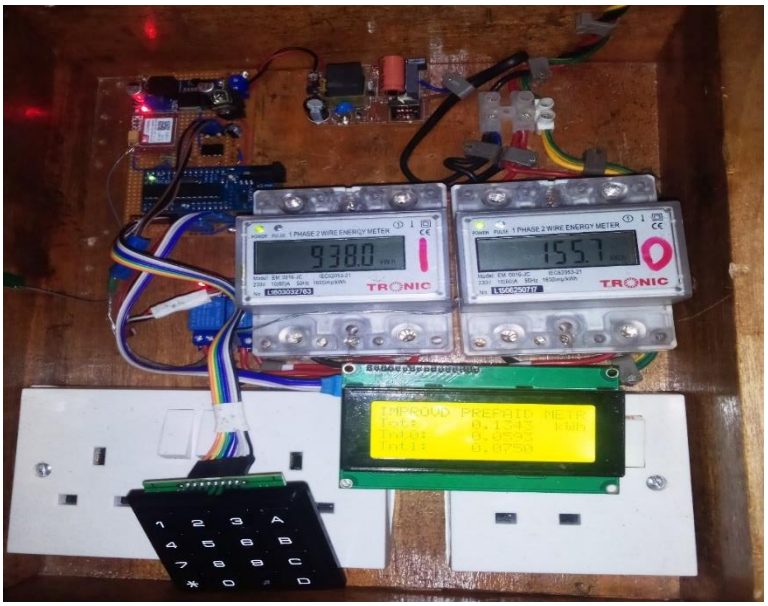
Total amount paid $At = A0 + A1$

$U0 = \frac{Ut}{At} . A0 = \frac{Ut}{(A0+A1)} . A0$ and $U1 = \frac{Ut}{At} . A1 = \frac{Ut}{(A0+A1)} . A1$

And in the program, it appears as *units [tenant] = (amount[tenant] * total units) / total amount;* where *tenant* is either 0 or 1 accordingly [4].

4. TEST AND RESULTS

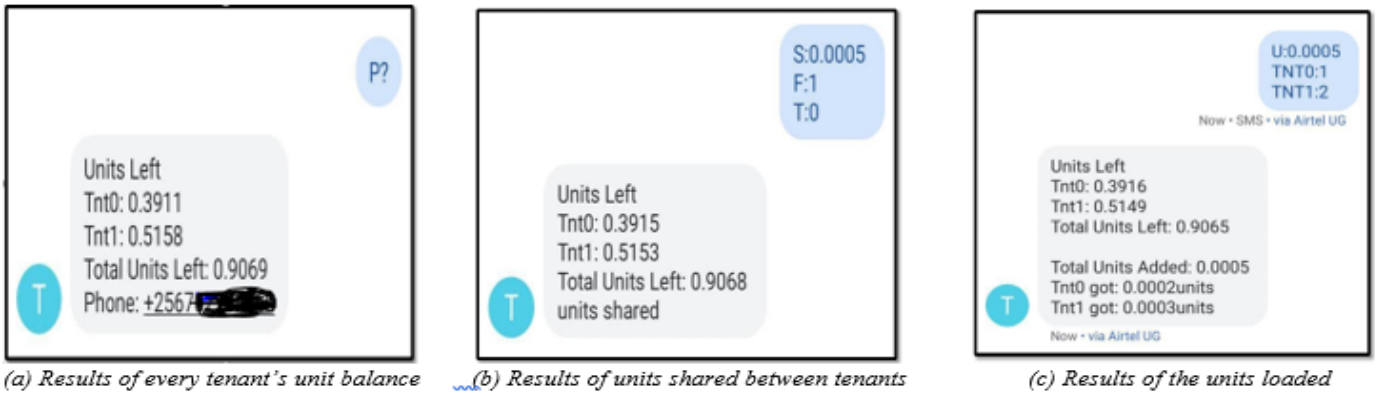
Considering the pre-stated objectives, the system was partitioned into sections that were designed and tested. Most of them had to have a connection with the microcontroller. The circuit was designed first by sketching a block diagram and later sketching an abstract circuit diagram for each of the blocks of the block diagram.



Picture 1: *Fully assembled System*

After assembling and connecting all the components, testing the system functionality was done, communication between components i.e., between the micro controller with LCD, Keypad, and GSM and Energy meter was established.

Experiment results



(a) Results of every tenant's unit balance *(b) Results of units shared between tenants* *(c) Results of the units loaded*

Picture 2: *Images of the phones screenshots showing result during system testing.*

Using the phone, the units of each tenant and the total units available at a particular time were checked. This was achieved by using the following steps:

- Insert a Simcard of any network in the modem which has either SMS bundles or Airtime.
- Type 'P?' in the SMS and send it to the number of the Simcard in the modem.
- The system will respond to you by SMS which will show the details as shown in **Picture 2(a)**

Tenant 0 (Tnt0) has 0.3911 units.
Tenant 1 (Tnt1) has 0.5158 units.
Total Units left at that time was 0.9069 units.

To get the result as shown in **Picture 2(b)** the following steps were followed.

- Type 'S': enter the number of units you want to share.
- Type 'F': the tenant you are transferring units from.
- Type 'T': the tenant you are sending the units to.
- Finally send the SMS to the sim card number in the modem.
- You will get a response from the system.

And finally, the result as shown in **Picture 2(c)** were achieved using the steps below.

- Type 'U' to enter the number of units you are loading
- Type 'TNT0'to enter amount of money contributed by tenant 0.
- Type 'TNT1'to enter amount of money contributed by tenant 1.
- Finally send the SMS to the sim card number in the modem.

You will get a response from the system

5.CONCLUSION

The project is basically designed to help building managers and tenants allocated electricity bills proportionally depending on what the tenants have contributed, hence giving both stakeholders a sense of satisfaction in their electric bill expenditure. This system will be helpful to Umeme Ltd if it's embraced because it offers clear means of monitoring the amount of electric consumed by its clients without having many third parts involved in the process of evaluation. For project demo concerns, the prototype was developed, test and proved to be working by integrating all the hardware components and software used. This Idea can be further implemented to develop a real product in the future.

6.REFERENCE

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