

Design and development of RFID based Multi-User Smart Energy Distribution System at Sunyani Technical University, Ghana

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Abstract: In Ghana families living in large and compound houses desire to have separate energy meters from other occupants. This is because individuals cannot monitor and control the energy consumption of other tenants and results in misunderstanding in energy bill sharing, overcrowding of energy meters on the wall of a building and likelihood of fire outbreak. It is therefore expedient to have a very accurate, efficient and peaceful means of delivering electrical energy to multiple users within a household with just a single energy meter and this has necessitated the introduction of Smart Multi-user Energy Distribution Meter (SEDS). In this paper microcontroller based smart electrical distribution switch that has the capability of allocating independent energy units to several users in a household is proposed. Experiment was done by assigning Energy units of 4kWh, 8kWh and 6kWh to three logging points on the SEDS device representing three different users. A load of 100W was connected representing the consumption of individual user. The results indicate that the rate of consumption is dependent on the total load connected. The SEDS device has different switches allocated to each user which monitor the consumption rate of the user and automatically isolate a user when power gets exhausted which serve the same purpose as several users having different energy meters. However, individual consumption can be monitored and controlled by the user.

Keywords: Multi- user meter, single meter, household, energy distribution.

1. Introduction

Ghanaian communities live in large family houses, hence there is the need for each family or individual to have a separate energy meter to measure and monitor the energy consumption. Utility service providers in Ghana over the years have challenges when it comes to efficient monitoring and controlling the consumption of electrical energy by individual consumers, which is usually achieved through metering. Poor billing system, Faulty meters, Illegal connections and difficulty in matching the demand for separate meters with population growth account for these shortcomings [1].

Various individual premises like homes, hostels and other institutions may have more than one user which may result in numerous problems in billing and monitoring of the energy consumption, difficulty in monitoring energy usage of other users, cost of providing extra energy meters and hazard/threat to environmental beauty. When the demand for separate meters' increases, it will necessitate multiple energy meters in a single house to serve the occupants. Figure 1 illustrates a typical case in Sunyani Technical University (STU), Ghana where several meters are clustered on a wall of a building causing threat to environmental beauty and likelihood of fire outbreak. The high demand for separate meters gives rise to an increasing burden on the electricity service providers i.e. (in the form of unplanned expenditure, labor, turnaround time stress etc.), the ever-growing demand of energy users and stakeholder expectations.

These and other factors enumerated have called for the introduction of SEDS that requires only one meter but may have multiple output connection to the occupants of the house. The electrical energy purchased would be slotted into the system and be stored on the erasable programmable read only memory (EPROM) of a microcontroller which monitors each user's energy base on their consumption rate. The SEDS may have different switches allocated to each user. The system will automatically disconnect or reconnect the user connected to a particular line as and when energy is purchased or exhausted. SEDS are devices that act as a user interface between the utility-controlled intelligent meters as well as the home automation domain network. SEDS are besides responsible for the data transmission and management between the intelligent meters, power utility companies and the energy consumption by the customer.

SEDS is operating as a Data concentrated unit (DCU) that manages the data input from the occupant in the

house. Each network connected to an apartment will be managed and monitored by the DCU through a console-based application written on the microcontroller[2]. It coordinates the activities between the users and the meter.



Fig. 1 Multiple Meters on Busia Hall Wall, STU

In recent times, the cost of RFID tool kits have drastically been reduced, thanks to the diverse applications of RFID technology in many fields of endeavours such as smart homes, surveillance systems, transportation systems, animal identification systems, tracking systems and many more. The relatively low cost of RFID components is a great opportunity for the potential researchers to take advantage of the impressive RFID technology [3]. RFID technology has no physical contact, hence wireless technology. RFID technology depends on the radio waves for automatic remote identification of different objects under study. RFID systems can be categorized based on the operating regions. For example the operating range of 0 to 1 cm is ideal for close coupling, 0 to 1m is meant for remote coupling, and above 1m is used for long range systems. [4]. RFID technology has a small portable device called tag which is responsible for transmission of data and the reader also reads the data and processes it to suite the requirements of the application under consideration. The RFID tags can be either active or passive. The passive tag uses RF signals of the said RFID reader to operate and it has no power source.

2.Literature Review

2.1.Advent of Energy Meter Technology

The technological advancement of this era of human life has made way for much automation to be implemented in our everyday life. With the help of information technology and electronic theories, a lot has been achieved in the electrical engineering field to supplement human activities. A lot of situations have arisen since the introduction of electrical energy generation and distribution towards its purchase and usage. The utility company is always concerned with efficiency, reliability and security. The primary difficulty to efficient energy management are losses but can sometimes be minimized with effective system supervision by a technical team. Losses occur when any used energy goes unbilled, or unaccounted for[5]. In the electrical field, there are many parameters that contribute to non-technical losses such as illegal connections, faulty electric meters, inconsistency in meter readings, wrongful estimation of bills, flat rate connections, meter tampering of meters etc. These Non-Technical Losses (NTL) in totality account for a reasonable amount of hundreds of kilo Volts Amperes of power. [6]. Among all the non-technical losses, billing inefficiency as a result of metering inaccuracies are dominant. The main reason for this issue of non-technical loss is the inability for the power utility service provider to keep a close watch at the customers' activities remotely and to effectively monitor and control their activities at the side of the consumer and take action. To effectively deal with this problem, the Volta River Authority/NEDCo has developed a number of strategies, among these strategies are: the introduction of prepaid meters with tokens, prepaid meters with IC cards, load limiters, credit meters and currently pole mounted split phase prepaid meters. This evolution is aimed at monitoring and controlling the meters from a remote end of the consumer.

In electrical distribution system, the technological development is gradual. The goal of this study is to develop a technology that is capable of reading and monitoring electricity consumption at any point in time [7].

2.2.Energy Meter Automation

Energy meter automation system is the application of hardware, software or combination of both technologies with associated electrical technologies to achieve a partial or fully monitoring and control purpose [8]. This ranges from simple methods like induction-based energy meter design, prepaid energy meter design, to fully automated complex systems with high artificial intelligence like telemetering and pre-paid energy meter monitoring system with amplified sound for industries. Electrical energy is one of the most flexible and efficient forms of energy which is easy to be controlled and converted to other forms of energy for a specific intended purpose. The introduction of the microcontroller in electronic design system has proved economical and simple in

many fields of engineering. As a result of the above positive effect, the electrical engineering field has benefited a great deal of flexibility by the introduction of this chip [9]. The energy meter has undergone many transformations in its construction technology including the billing system and alert signaling system. A brief analysis is therefore made to review into a few of ideas on this area of study.

The single phase energy meter with remote monitoring capability via short message service (SMS) was designed and implemented by [10] the energy meter was a microcontroller (ADE7755) chip together with other discrete elements. The GSM module called Neoway M590 was the main communication device for the SMS. The device was tested and implemented on a locally made single of Dip trace software. The simulation of the design was done by proteus software,the 8051 tool kit and a serial port monitor.The results presented indicated that,the system was capable of producing both instantaneous and average real time power expended remotely.

3.Methods and procedures

The solution design is represented in the form of a block diagram. As shown in figure 2, the design is subdivided into basic blocks: power supply unit, RFID unit, microcontroller unit, relay/switch and LCD display unit.

The microcontroller chip was used to design this work. PIC18F452 Microcontroller was chosen because of its interesting features like Erasable Programmable Read-Only Memory (EEPROM), analogue comparators, timers, serial peripheral interface (SPI), universal asynchronous receiver/transmitter (UART) and channels 10 bit analogue to digital converter (ADC). The RFID tag was used to load the units (credit) into the microcontroller. The microcontroller then stores the information of instantaneous energy, tariff, current, unit credited, units remaining, load and all the relevant information and updated in the microcontroller. The energy consumption of the customer is calculated by the microcontroller and the units used are automatically deducted from the initial units uploaded. The current transformer (CT) in the system is to measure the current drawn by the loads. Here all the connected loads have the same voltage at different current levels. Two potential transformers (PT) are involved for two different DC levels: namely 5volts to power the microcontroller and 12 volts for the relay to function. The relays are integrated into the system to control the ON/OFF of the loads connected if the available balance of the prepaid reaches zero. Simulated circuit diagram showing the proposed system is indicated in Figure 3.

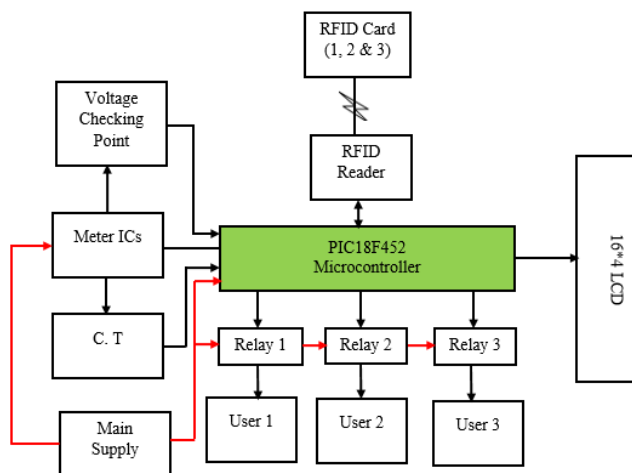


Fig. 2 Block diagram of SEDS System

The implementation of a smart multi user energy distribution system was based on the algorithm shown in figure 4. The aim of this design is to allow multiple customers (users) to be hooked onto the single household energy meter but the customers' energy consumption is independent on each other. The system functions in the manner that, a minimum threshold of 2 units of credit is set for each customer's meter and when the balance of the credit gets to this level an alarm will sound in every 45 seconds reminding that particular customer that his/her credit is low until the credits finally get to zero. If a customer fails to load credit onto his/her meter, power to that user will be disconnected by the relays.

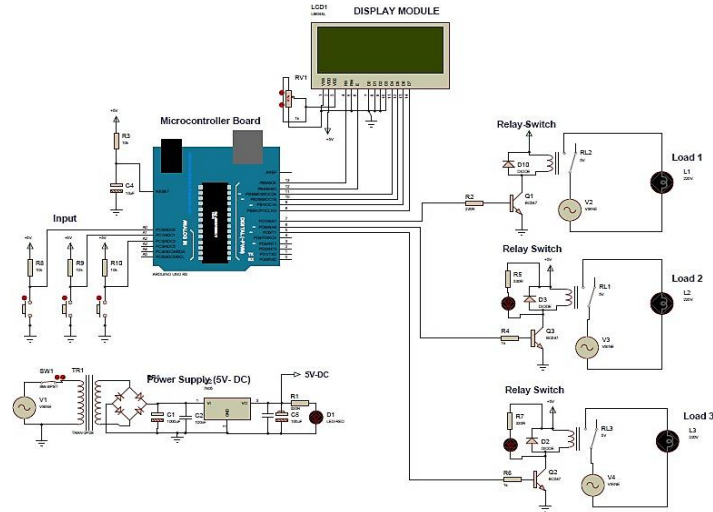


Fig. 3 Schematic diagram of Multi-user SEDS

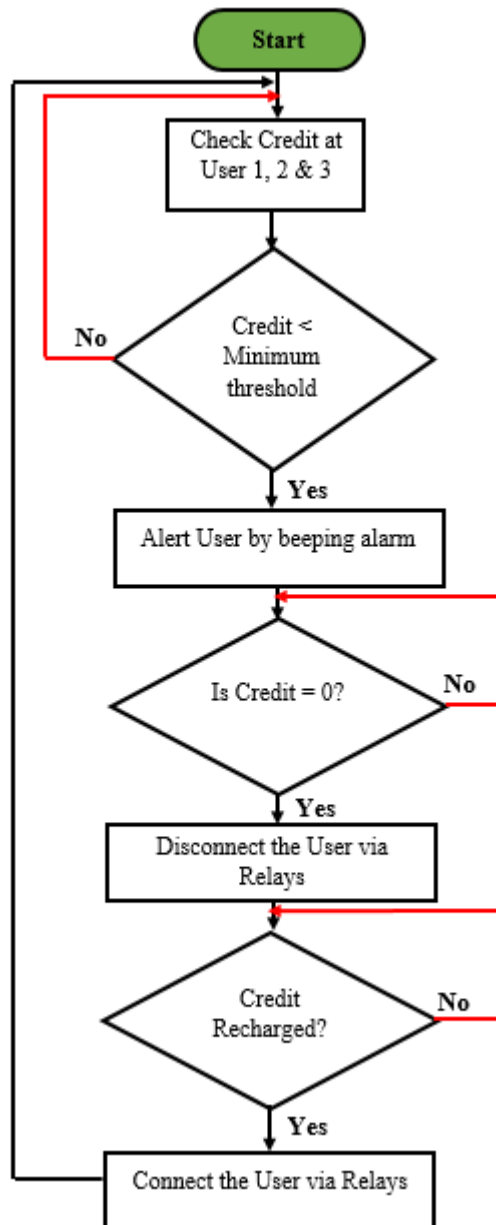


Fig. 4 Process Flow of the proposed SEDS device

3.1.SEDS Construction

This section focuses on the design and construction of multi-user smart electrical distribution switch system.

Smartmeter ICADE7816 is used to measure the units consumed.ADE7816 is a high accuracy multichannel metering IC that allows the energy to be measured on up to six current channels.It provides a variety of energy measurements including active and reactive energy, along with current and voltage rms readings. A variety of power quality features, including no load, reverse power, and angle measurement, are also provided. Figure 5 shows smart meter IC.

The microcontroller is connected to the energy meter through an interface device known as opto-isolator. Optocoupler IC was incorporated for counting the number of units and send signal to micro controller to load, count and deduct energy units based on the user's total connected load. Figure 6 illustrates optocoupler circuit arrangement.

The RC522 RFID with the MFRC522 IC is ideal for this work, since it is design to create a frequency of 13.56 MHz. This frequency is used to communicate with the RFID tags (ISO1443A). The operating voltage is between 2.5 volts to 3.3 Volts. Since the logic pins are 5 volts, it is possible to connect the logic pins to the Arduino/5volts logic microcontroller making it most favourable for this design without employing logic level converter. The RFID technology is wireless, between the tag and reader .To send information to the tag ,a written code is done by the RFID controller or programmer. The reader accepts only valid information from the tag either tag 1, 2, 3 etc and reject error information. Fig 8 presents the RFID reader module. Figure 9 shows the complete construction of smart energy distribution switch system.



Fig. 5 smart meter IC

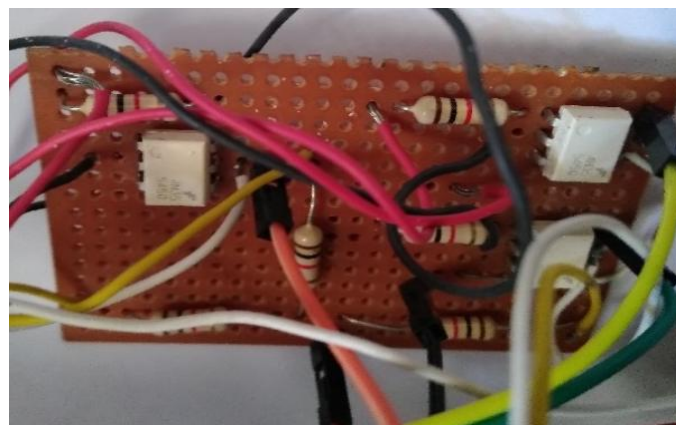


Fig. 6 Optocoupler Circuit

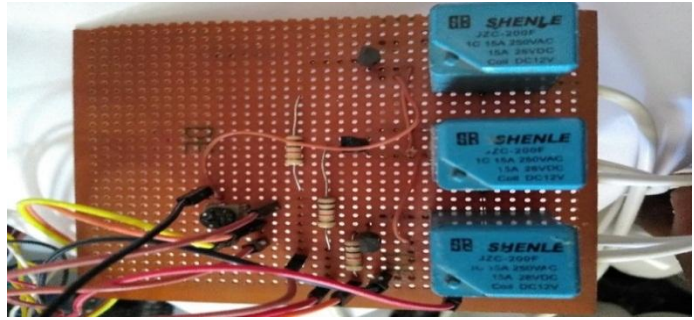


Fig. 7 Internal Arrangement of Relays

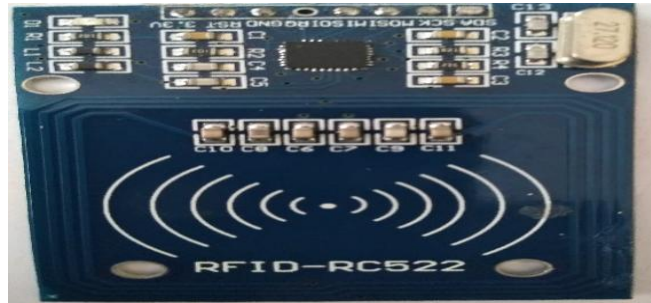


Fig.8 Smart Card RFID Reader



Fig. 9 Smart Energy Distribution box

4.Results and discussion

Figure 10 shows the state of the system when all the three users has no energy units loaded on the SEDS device. At this point all the loads stay disconnected from power supply. These relays will stay opened until the RFID smart card is inserted into the meter. Three different RFID card representing the energy meter cards are slotted to load credit of 4kWh, 8kWh and 6kWh for user 1, User 2 and user 3 respectively with the same load of 100 W connected to each user, as shown in Figure 11. Figure 12 also shows how the loaded energy is being used up with time. The observation clearly shows that individual consumption is based on the user’s total load connected and that the energy units got drained according how the users manage and use energy.

The table 1 shows the various consumption rate with respect to connected loads for the three users.

It continues to deduct until the credit reach zero and the user 1 relay is cut, when user 2 credits also finish the user 2 relay also is cut until credit is loaded again and user 3 credit finishes user 3 relay also is cut until credit is loaded again.

Table I Rate of consumption with respect to energy purchased and load connected

S/No	Users	Credits in(KWh)	Load In(W)	Time (hours)	Actual Time(hours)
1	L1	4	100	40	39.5
2	L2	8	100	80	78.9
3	L3	6	100	60	57.6



Fig. 10 SEDS Displaying no energy units input



Fig. 11 User 1, 2 and 3 loaded with Energy Units

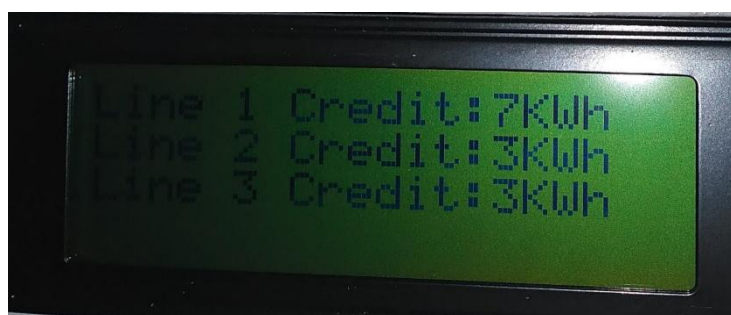


Fig. 12 Consumption of energy by the Individual Users

5. Conclusions

The test was successful as shown in the table 1. Three different users were able to use a single meter without interruptions and interference from other circuits. The system isolates the user as soon as the user's credit is completely used up. After series of test and observation, it was observed that there were some minimal errors in the operation of the microcontroller circuitry and the whole layout. This error can be described as technical error from the circuit design. The error was estimated around 1.0% of the normal reading which was considered as a threshold added to the readings obtained. However, SEDS has demonstrated robustness, high level of intelligence and accuracy to get a fully functional embedded system for monitoring the status of electrical energy usage for multiple users in households and communicate the information to the user with minimal error. Hence, capable of replacing the clustered meters at Busia Hall, Sunyani Technical University, Ghana.

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