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Building a Prototype Prepaid Electricity Metering System Based on RFID

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Abstract. The prepaid meter is important in making the consumer having sense about his/her energy consumption which is important in eliminating the difficulties facing the electrical utility employee in getting the reading of the conventional electromechanical meter and eliminating any error incurred in bills issuing. This paper is aimed at developing a prototype of a management system for a prepaid electrical power meter. The designed prepaid meter consists of an RFID reader, a microcontroller, a digital meter and a wireless gateway. The proposed prototype metering system consists of two parts: clients and server. An RFID reader is used to read the ID of the credit card and a PC connected to a hardware simulated circuit which is designed and implemented to simulate the operation of the digital meter. The server is located in the local substation which receives the card's ID from clients and sends ID's information back to the client after checking and/or updating the database.

Keywords: RFID, prepaid electricity meter.

1 Introduction

For a client to pay the electrical bill, he/she should install an energy meter which measures the amount of electrical energy consumed by the client. This meter needs to be calibrated and sealed so the client cannot mess with it. The meter has to be read from time to time and then the data collected will be processed and a bill will be issued. The bill will be sent to the client in order to pay it. The above mentioned process requires employers to collect data, issue bills and distribute them, collect money, facing cash money carrying risk and other troubles which might be encountered. All these problems can be overcome by using the new technology of the prepaid smart meters [1].

The traditional electricity meters are electromechanical meters, but the modern meters are digital meters and the prepaid meter is one of the categories of the digital meters. By using the prepaid meters, the customer has to make advance

payment before electricity can be consumed. When the prepaid credit value is exhausted the supply of electricity will be cut off by a relay.

Using prepaid meter will give the customers the sense about their energy consumption which in terms leads to the reduction in energy consumption. It will also help the utility provider to overcome the problem of not paying the bills by some consumers. Many other benefits are also apparent, such as the customer can recharge his/her account wirelessly and the prepaid meter's display will also show the current electricity rate. Since electricity rates vary throughout the day, the customer can cut down on consumption when the rate is high [2].

Intelligent metering (such as prepaid and other smart meters) is usually an inherent part of the Smart Grid. Smart Grid could be described as an upgraded electricity network to which two-way digital communication between supplier and consumer, intelligent metering and monitoring systems have been added [3,4].

2 What is RFID?

The roots of radio frequency identification (RFID) technology can be traced back to World War II. The Germans, Japanese, Americans and British were all using radar. The problem was there was no way to identify which planes belonged to the enemy and which were a country's own pilots returning from a mission. The Germans discovered that if pilots rolled their planes as they returned to base, it would change the radio signal reflected back. This crude method alerted the radar crew on the ground that these were German planes and not Allied aircraft. The British developed the first active identify friend or foe (IFF) system. They put a transmitter on each British plane. When it received signals from radar stations on the ground, it began broadcasting a signal back that identified the aircraft as friendly. RFID works on this same basic concept. A signal is sent to a transponder, which wakes up and either reflects back a signal (passive system) or broadcasts a signal (active system) [5].

RFID today is the popular wireless induction system. The RFID System consists of

- At least one RFID antenna for RFID reader,
- An RFID reader,
- RFID tags.

Each RFID tag in the system is given a unique ID. The RFID tag is composed of two essential elements: designed antenna and an RFID chip. Some RFID tags also equip memory. The antenna of the RFID tag is designed and used to absorb the electromagnetic wave for the power supply of the RFID tag and communicate with the RFID reader. In addition, according to the size and design of the antenna, the induction distance between RFID tag and RFID reader will be limited. Fig. 1 shows the procedure of the RFID system [6].

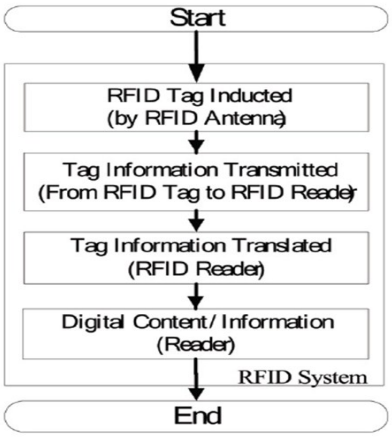


Fig. 1. Procedure of RFID System

If many tags are present, then they will all reply at the same time, which at the reader end is seen as a signal collision and an indication of multiple tags. The reader manages this problem by using an anti-collision algorithm designed to allow tags to be sorted and individually selected. Many different types of anti-collision algorithms are defined. The number of tags that can be identified depends on the frequency and protocol used [5].

3 What is Smart Grid?

There are many definitions of the Smart Grid and it means different things to different people. Greentech Media Company Research identifies Smart Grid as the convergence of three sectors – *Electric Power* which is the physical power layer, *Telecommunication Infrastructure* which is the communication and *control layer and Information Technology* which is the application and services layer. Expertise from all three layers is required for a complete end-to-end Smart Grid Infrastructure. Each layer has its own set of challenges that needs to be overcome [7].

Commercialization of electric power began early in the 20th century. At first, small utility companies provided power to local industrial plants and private communities. Some larger businesses even generated their own power. Seeking greater efficiency and distribution, utility companies pooled their resources, sharing transmission lines and quickly forming electrical networks called grids. With today's technology, the power grid can become a smart grid, capable of recording, analyzing and reacting to transmission data, allowing for more

efficient management of resources, and more cost-effective appliances for consumers [3,4].

In general, people have experienced the traditional credit-based system of electricity delivery, where the customer consumes electricity continuously, and makes periodical payments to the utility provider. The amount consumed is measured by an electricity meter. Representatives of the utility company periodically inspect the meter, and the customer is invoiced for the energy consumed. Depending on the terms of payment, customers have various periods of time to settle their accounts. Non-payment may result in customers being disconnected. The basic principle of the prepayment system is the reverse of the credit-metering system: customers decide how much energy they require before they consume it, and pay the relevant amount to the utility beforehand. The household is then credited with the purchased amount of electricity. After the prepaid amount of electricity is consumed, electricity is automatically disconnected unless the customer makes a further prepayment. Table 1 shows a comparison between credit-based system and the prepaid metering system [8].

Table 1 Credit-based versus prepaid metering system

Credit-based system	Prepaid metering system
Meter-reading is labour intensive; need for access to household	There is no need for meter reading in prepaid meter system
Loss of time and resources for clients and distributor due to connection and disconnection	Self-disconnection of prepaid metering system avoids such costs; lower level of customer complaints and communication around re-connection
Credit-based system business processes are very resource-intensive: invoicing, information processing, customer feedback, support, client monitoring, etc.	Self-administration of prepaid metering system cuts many of these costs; prepaid meter provides a basis for the development of innovative revenue management systems.
Low-income households have low levels of energy consumption but the same level of administration and maintenance costs	Once-off installation and maintenance costs are only major individual user costs

4 Prepaid Electricity System based on RFID

This project is divided into two parts: clients and server. The client consists of a digital meter based on a microcontroller and an RFID reader and the server consists of a PC with MySQL database server. The client installed in each house

and the server installed in local sub-station. The RFID reader is used to read the credit ID in meter charging, the ID is sent to the server to check the ID's information in the database and sends them back to the client where the microcontroller takes action based on that information. The microcontroller manages all the system work in the client. The ID and its information transmitted wirelessly between each client and the server through wireless gateway. For this case study, a personal computer is used to simulate the microcontroller.
Fig. 2 shows the block diagram of the proposed electricity prepaid metering system

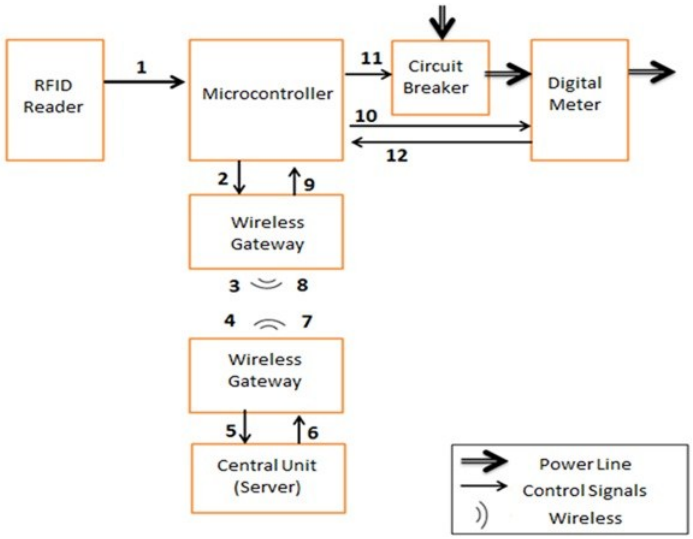


Fig. 2. System block diagram

The following steps explain the procedure of the system work:

1. The reader reads tag's ID and sends it to the microcontroller.
2. The microcontroller manages the ID and then sends it to the wireless gateway.
3. The wireless gateway sends the received information to the central unit.
4. The wireless gateway of central unit receives the information from the client's gateway.
5. The wireless gateway sends the information to the center unit.
6. The central unit checks the validity of the received card ID and if it is valid, it sends back the validity announcement and the credit of that card. If the card is not valid, it sends invalidity announcement.
7. The wireless gateway sends the information received from the center unit to the client.
8. The wireless gateway of the client receives the information from the center unit.

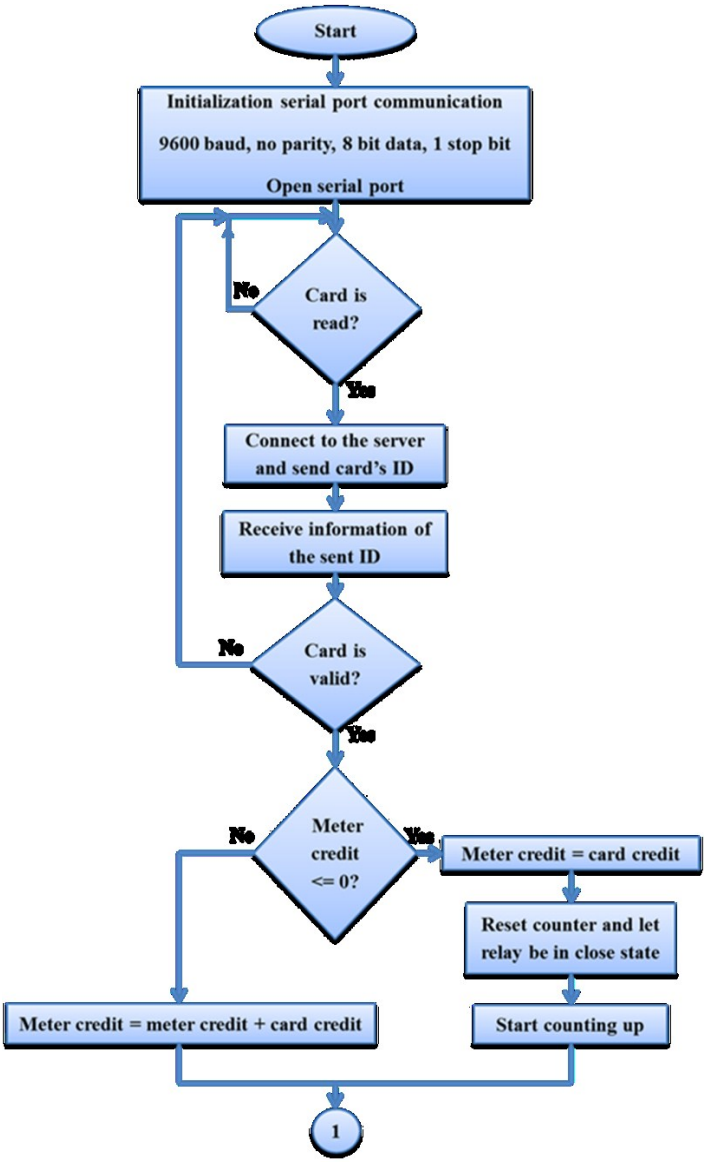
9. The wireless gateway sends the information received to the microcontroller. The microcontroller then checks the information. If it is not valid, it will neglect that information and return back to the wait state.
10. If it is valid, the microcontroller sends a signal to the digital meter to reset its counter.
11. Also, if the card is valid, the microcontroller sends a signal to the circuit breaker to be in close state (On).
12. The digital meter sends the reading of the power consumption to the microcontroller which multiplies it by the power unit cost and subtracts the result from the credit and checks the answer. Assuming linear relation, if there is extra credit, no operation is done. However, if there is no extra credit, then the microcontroller sends a signal to the circuit breaker to be in open state (Off).

5 System Software

The client PC program is written to do the following tasks:

- Opening the RS232 serial port and getting the ID of the card read by RFID reader.
- Connecting with the server and sending the ID.
- Receiving the ID information from the server. If it is valid then an action will be taken. If it is invalid, then an alternate action will be taken.
- Decrementing meter credit.
- Cutting the electricity power.

Fig 3 shows a flowchart for the procedure of the client program.


Start
Initialization serial port communication
9600 baud, no parity, 8 bit data, 1 stop bit
Open serial port
Card is read?
No
Yes
Connect to the server and send card's ID
Receive information of the sent ID
Card is valid?
No
Yes
Meter credit <= 0?
No
Yes
Meter credit = card credit
Reset counter and let relay be in close state
Start counting up
Meter credit = meter credit + card credit
1

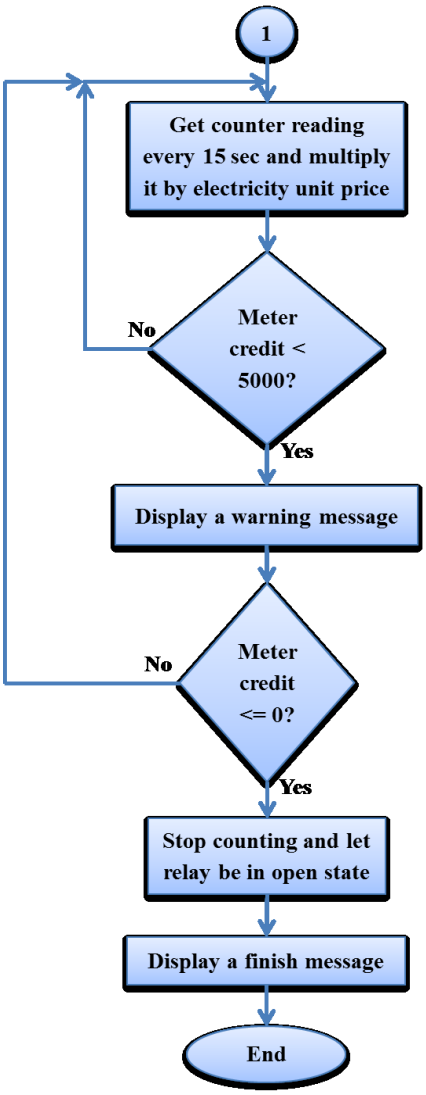


Fig. 3. Flowchart for procedure of client program

Server PC has server program and MySQL database server 5.1. Server program has a connection with the database server through MySQL Connector/Net 5.2. Server program uses TCP socket for remote connection with clients. Fig. 4 shows the flowchart for the server program steps.

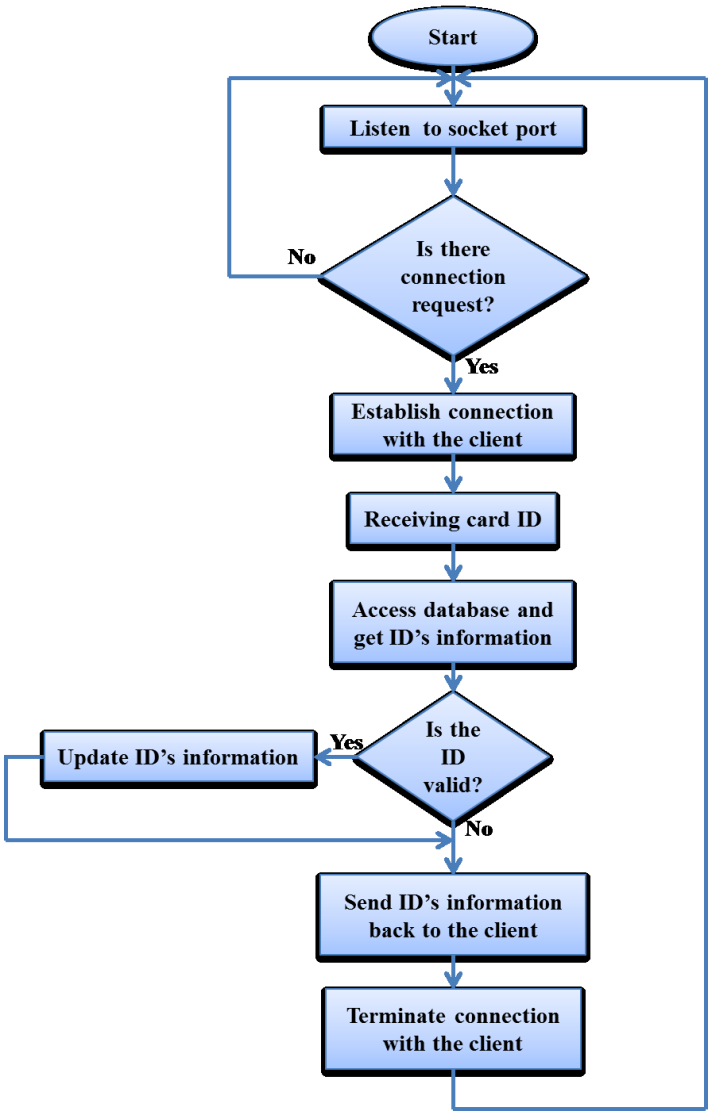


Fig. 4. Flowchart for the procedure of server program

6 System Implementation

It is assumed that each residential unit (home) has an installed electricity prepaid meter system and when the consumer recharges his/her meter credit, the meter will communicate with the remote server wirelessly. Fig. 5 shows the implemented system which is composed of the server part and the client part.

Fig. 5. The implemented system, client & server

6.1 The Server

The server part of the system is a PC. The server PC contains the server program and MySQL server 5.1. The server program manages the connections with the clients (one at a time) and checks and updates the database. Fig. 6 shows the server program (a: during listening for connection request, b: during connection with a client, c: during disconnection from client)

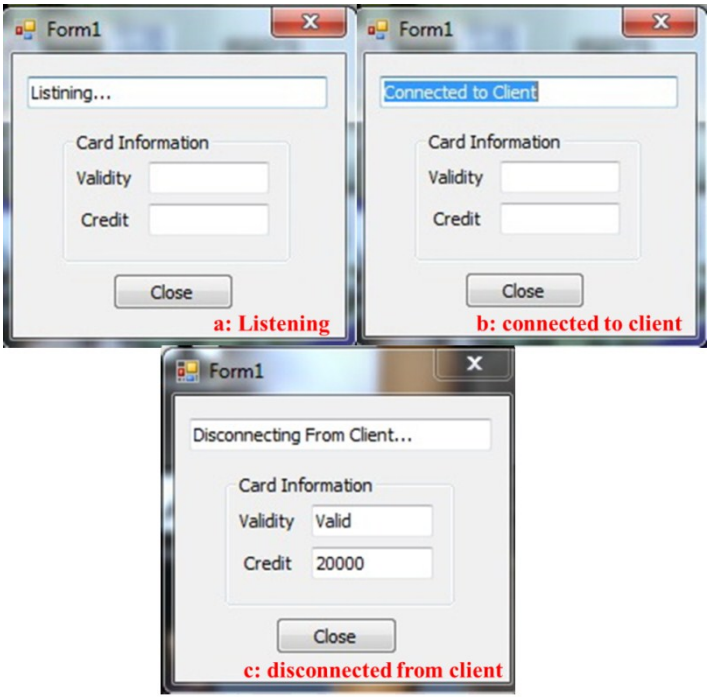


Fig. 6. Server program (a) listening, (b) connection, (c) disconnection

6.2 The Client

The client part of the system is composed of an RFID reader and the hardware designed circuit, which are both connected to the PC through a serial port and a parallel port respectively as well as number of RFID tags as shown in Fig. 7. The client PC contains the client program and it manages all steps conditions of the prepaid system from the recharging the credit to the finishing of the credit and cutting the power.

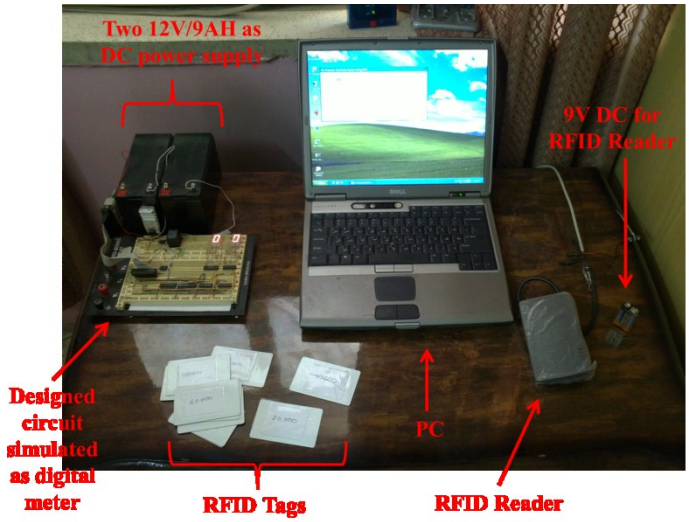


Fig. 7. Client part of the system

6.3 The Charging Procedure

When there is no credit in the meter (meter credit is equal or less than zero), then no electricity power passes to the home. In the designed circuit, there is a green LED which is used as indication for passing electricity to home or not. Before of credit charging, the green LED is off as shown in Fig. 8.

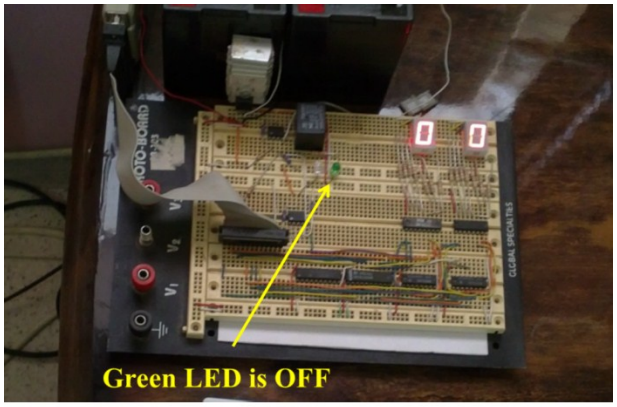


Fig. 8. Designed circuit before charging

Fig. 9 shows that a card (RFID tag) has been detected and it is valid according to the card information checked by the server. The credit is then stored and the green LED is ON which means that the relay is in close state and power is passing.

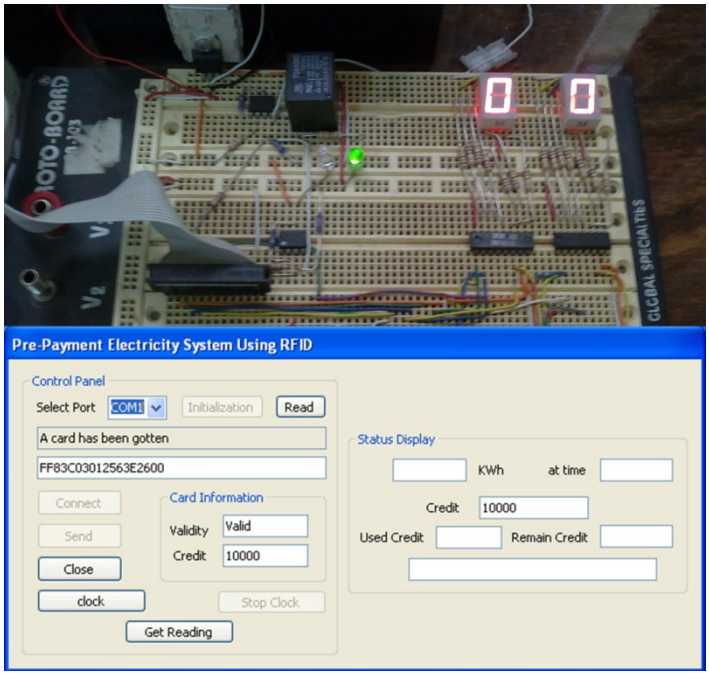


Fig. 9. The power is passing

At the server, the database consists of a table which has four fields: ID, validity, credit and usage_date. The ID's of the cards are written in the ID field. The validity field displays if the related ID is valid or not. If the validity is (1), then the ID is valid, while if the validity is (0), then the ID is invalid. The credit field displays the credit of that ID. The usage_date field contains defaulted invalid value (1111-11-11 11:11:11) and when the card is used, the time and the date of the recharging moment are entered. Fig. 10 shows the database before and after using a card.

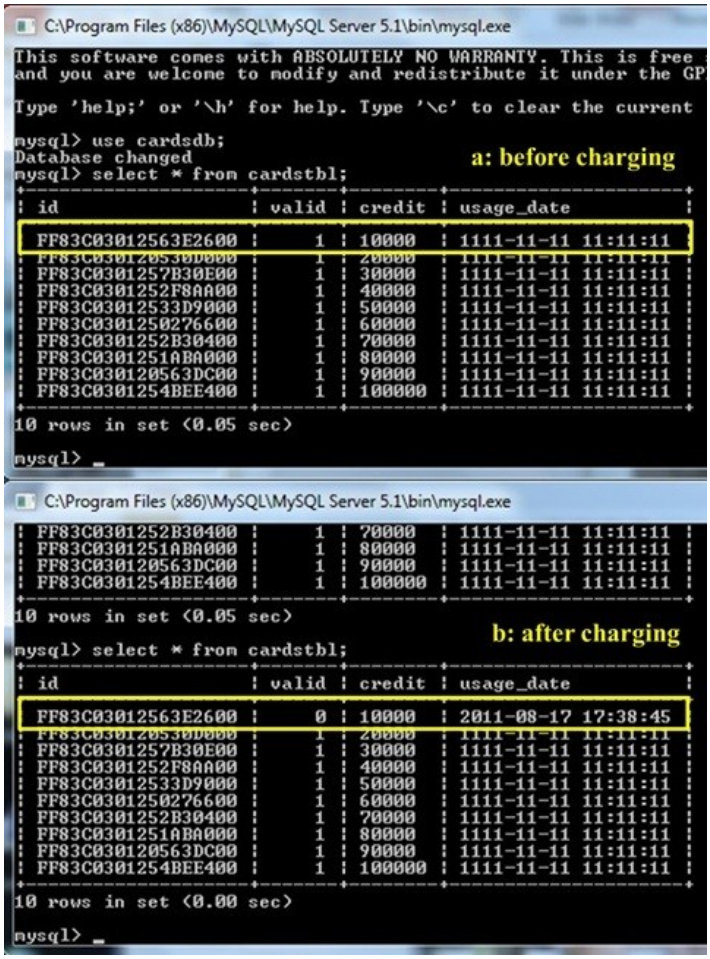


Fig. 10. Cards database (a: before charging, b: after charging)

After the meter credit is charged, counter reading will be read four times per minute and in each time, the reading will be multiplied by the electricity unit price and subtract the result from the meter credit. If the remaining meter credit is less than specific limit (5000 Iraqi dinar as an example in this work), then a warning message will appear so the consumer has enough time to buy credit. See Fig. 11.

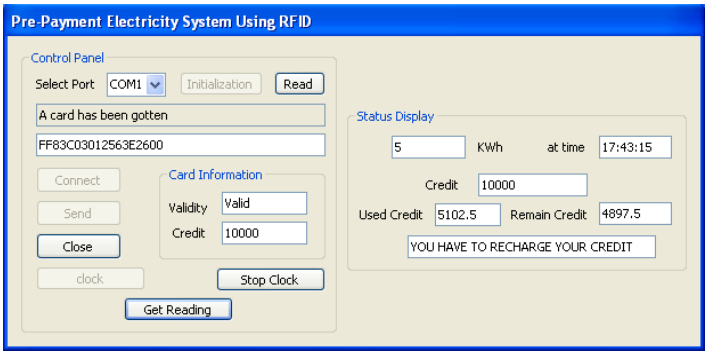


Fig. 11. The warning message

If the client doesn't charge the meter credit and the meter credit becomes less than zero, then the clock signal will be stopped, a signal sent to relay to switch to open state and finishing credit message will appear as shown in Fig. 12.

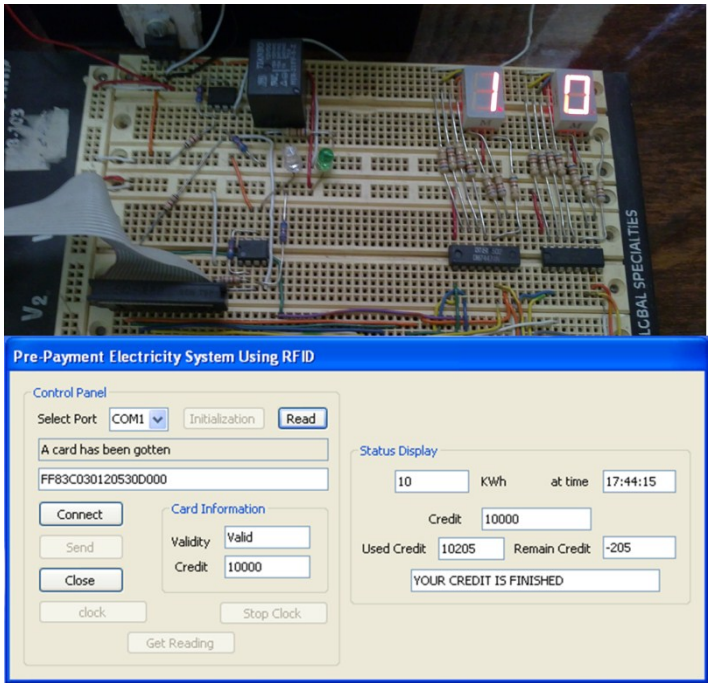


Fig. 12. The credit is zero

In case of using an invalid card, client program shows the invalidity in the card information part and a red LED card in the designed circuit is turned on for few seconds as shown in Fig. 13.

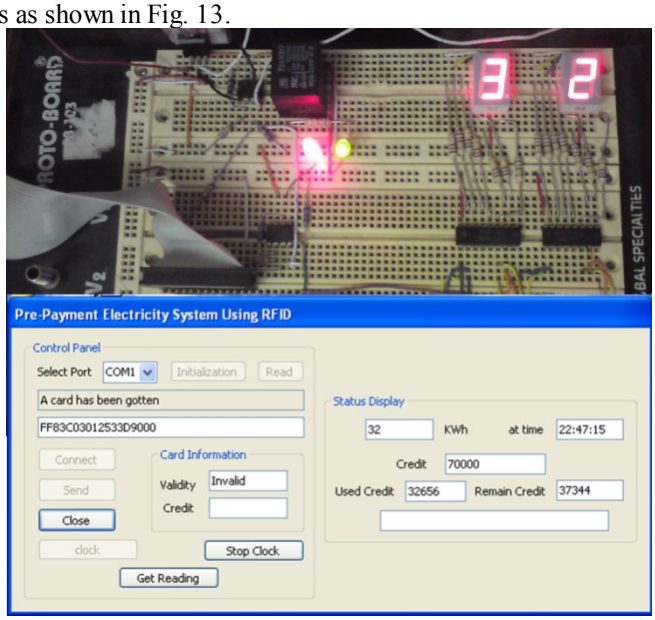


Fig. 13. Using invalid card

7 Conclusion

The importance of the electricity power leads the researchers to find new technologies to get a better utilization of electrical power and reduce the waste. One of these technologies is the prepaid metering system. There are many methods for recharging the credit and for communication with the server. The proposed prototype electricity prepaid metering system used RFID technology as recharging method. During the design of the prepaid metering system, a PC is used to connect with RFID reader instead of a microcontroller to manage all steps of the system. A microcontroller must be used and testing for functionality, efficiency and further effects must be done carefully before introducing the system in a real-life.

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