DESIGN AND DEVELOPMENT OF A PREPAID SMART CARD ENERGY METER

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ABSTRACT

This paper focuses on the design and development of a prepaid smart card energy meter. The electricity distribution companies are collecting their revenue from customers by billing system. The charges given to consumers became so high per unit. Customers used this opportunity to forge meter readings and also show reluctance towards paying their electricity bills on time. This brought about a high percentage of revenue lost to power theft and other illegal activities. The method employed the used of digital meter module that was interfaced with the microcontroller to count the total units purchased from the smart card and anytime the unit become zero, the microcontroller gives the signal to the relay to switch off the energy meter. The designed system facilitates energy management, and restricts the usage of electricity automatically, if the bill is not paid. The system also enabled the consumer to buy required amount of energy and provide information about their credit balance. A prepaid smart card energy meter has been developed and all the information obtained was found to be perfect, reliable, cost effective and easy maintenance. The test results obtained from the energy meter for the loads 40W, 60W, 100W, and 200W gave the following energy measurements: 0.2325kWH, 0.3522kWH, 0.5800kWH, and 1.1600kWH, respectively.

Keywords: *Prepaid Smart Card, Energy Meter, Billing System, Microcontroller.*

1. INTRODUCTION

Prepaid Energy Meter is a technique which is cost efficient and can reduce problems associated with billing systems and deployment of manpower for taking meter readings (Huramasroor *et al.,* 2010). Prepaid Energy Meter enables power utilities to collect electricity bills from the consumer prior to its consumption and it also attributed with prepaid recharging ability and information exchange with the utilities pertaining to customer's consumption details. The idea of Prepaid Metering is very important for the new research fields of micro-grid and smart Grid (Jain and Bagree, 2011).

Presently, the number of electricity consumers is increasing in great extent. It became hard to handle and maintain the power due to growing requirements. Maintenance of the power is an important task as the human operator goes to consumer's house and produces the bill as per the meter reading. The billing process takes much time if the consumers are not in the house while taking readings on energy consumption. It requires a lot of time and more labour to analyze energy consumption and generate the bill (Mejbaul *et al.,* 2011).

If the consumer did not pay the bill, the Foreman needs to go to their houses to disconnect the power supply. These consume time and difficult to handle and sometimes, the manual operator cannot find the unauthorized connections or malpractices carried out by the consumer to stop the meter reading. Some of the energy meters which had been implemented are prepaid but it needs smart card to recharge it.

In this paper, each consumer has to install digitally designed prepaid electricity meter along with smart card in their home, office or industry. Based on the electricity utilization, the credit will be deducted automatically from the smart card. When the credit goes below the threshold value, the meter gives warning icons and if credit reaches to zero the meter will automatically cut off the power supply.

The consumer has to go to the vending station with the smart card and money to pay for electricity. In the vending station, user can buy the credit to his/her smart card by paying the money. Then the consumer will insert the smart card to the meter and the meter will be recharged. In prepaid billing system, the consumer will be always conscious about the remaining credit and thus try to use electricity carefully and avoid misuse of electricity (Omijeh and Ighalo 2012).

Prepaid Meters can also make use of state of art technologies like WiMAX (Khan *et al*., 2010) owing to the idea of centralized accounting monitoring and charging. This system brings telecommunication to the core of its activities to support smarter grid application, such as Demand Response and Plug-in Electric Vehicles.

Prepaid System Architecture

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The prepaid meter will be installed in home, buildings or industries. For a specific region there will be a vending station called Cash Dispending Unit (CDU) from where the consumer will buy credit. The vending stations hold the regional user data base and billing software. The communication between the meter and the vending station is done by smart card (Mejbaul *et al.*, 2011). All vending stations are connected with a central server called the master station through the internet.

The overall architecture of the Prepaid Metering system is shown in Figure 1 and brief description of several components of the system is given in sections 2.1 – 2.2.

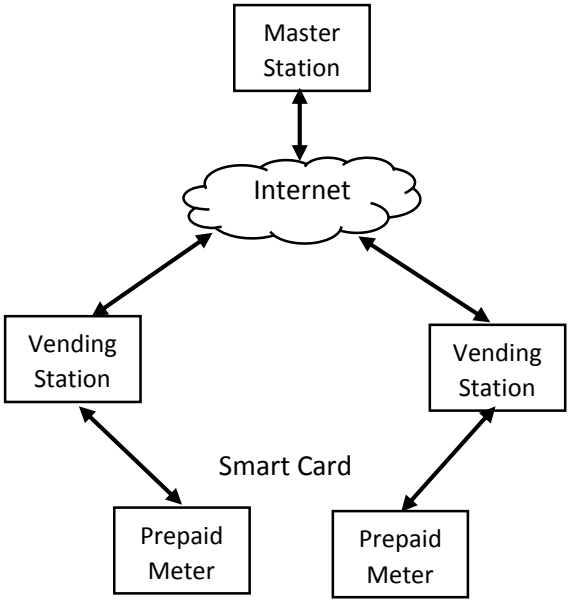

Figure 1: Architecture of the Prepaid Metering System

Master Station

Master Station holds the integrated database of all the vending stations, deletion of users account, creation, and edition are also done from the Master Station. In the master station, the values of the meter settings variables are given and users meter status report of any user can be generated (Ashiquzzaman and Nadia, 2012). As the master station holds the integrated database of all the vending stations, the overall analysis of the system can be done.

Vending Station

Vending Station is the office where the clients go to buy credits and holds the database of all local users. Every user of the prepaid meter has smartcard, which establishes the connectivity between the prepaid meter and the vending station (Sheelasobanarani *et al.*, 2014). The components of vending stations consist of the server PC, smartcard reader/writer and slip printers to print receipts.

When a client needs to buy credit, he/she goes to the local vending station with the smartcard and money. To keep the database of the vending station up-to-date, clients are advised to punch the smart card in the meter before coming to the vending station. When the card is punched, the meter's last status is copied to the smartcard.

In the vending station, the last status of the meter is read from the smartcard and save it in database. Then according to the client's demand, vending station writes the credit in the smartcard. When the user returns home and punch the smart card in the meter, credit is added with the remaining credit and the new meter settings are activated. Vending stations normally maintain relationship with master station through the internet (Homa and Abdul 2012).

1. MATERIALS AND METHOD

The Prepaid Smart Card system requires a combination of hardware and software for each implementation and application. The hardware comprised of digital energy meter, Liquid Crystal Display (LCD), AT89C51 Microcontroller, relay control unit, diodes, transistors, capacitors, integrated circuit, resistors, load, and power supply unit. The software components comprised of 4KB flash Programmable and Erasable Read Only Memory (PEROM), Assembly Language, 128 bytes of RAM, two 16- bit timers/counters, on- chip oscillator and clock circuitry.

The digital meter module was interfaced with the AT89C51 microcontroller through the optocoupler and the number of units consumed was counted with the help of the counted pulses generated from the optocoupler. The Light Emitting Diodes blinks when there was a unit consumed and this gave rays incident on optocoupler which drive the transistor connected to P3.2.

The microcontroller counted the number of units and simultaneously monitored the smart card reader. It also reads the total units purchased from the smart card and the unit value that had been reduced for every unit consumed. If the units in the smart card become zero, then the microcontroller gives the signal to the relay to switch off the total supply from the energy meter.

The P2.0 was connected to the relay through the transistor Q_1, and the 9th pin of microcontroller was connected to the reset pin and whenever the reset pin was pressed the assembly language in the microcontroller was executed. Therefore, the microcontroller got the data from the energy meter, the card reader and also controls the total power supply of the system. The circuit diagram of a prepaid smart card energy meter is shown in Figure 2.

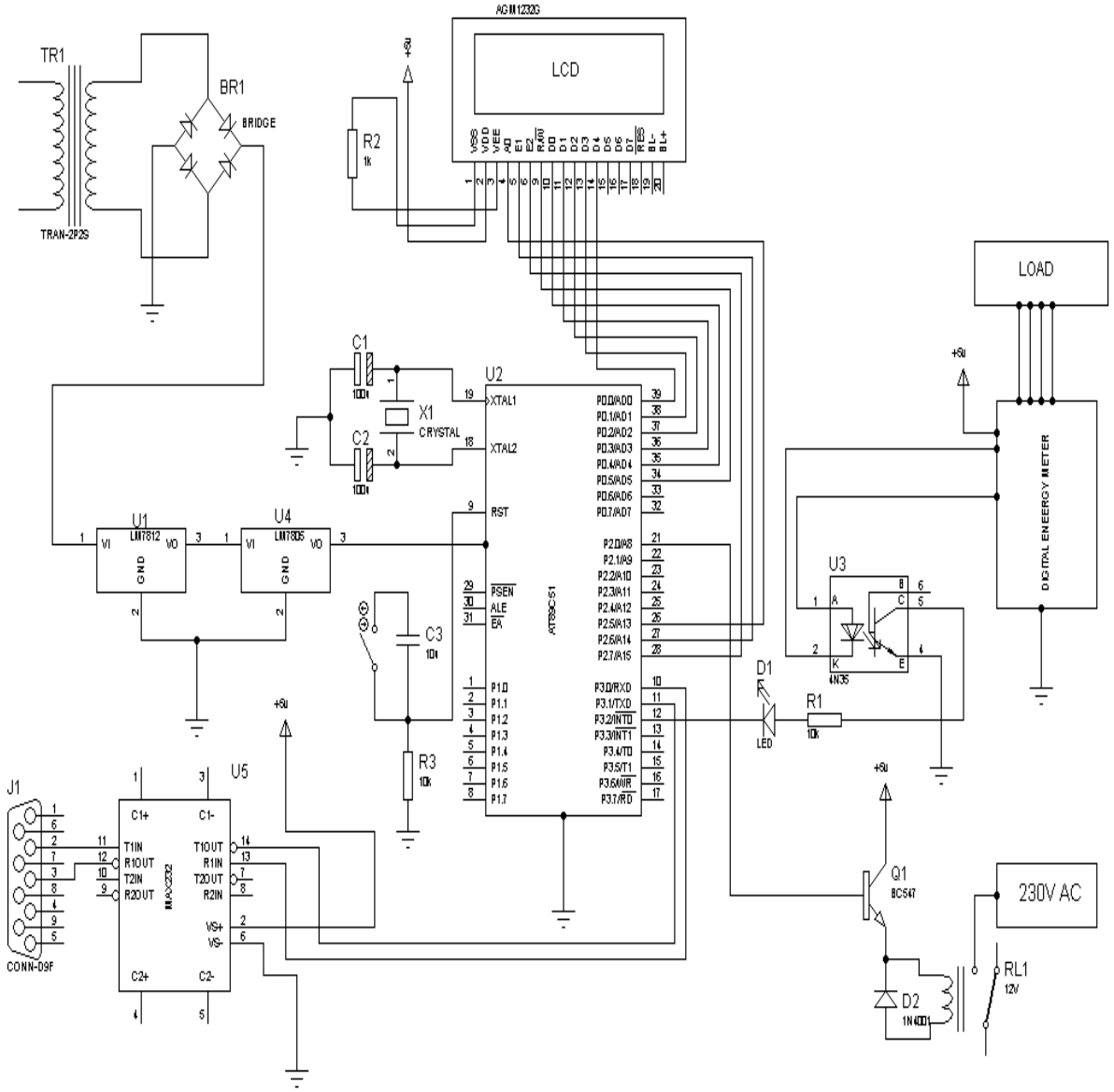

Figure 2: Circuit diagram of Prepaid Smart Card Energy Meter

In the circuit diagram, PIN P0.0-P0.7, P1.0-1.7, P2.0-P2.7, and P3.0-P3.7 serves as general input and LCD as analog output. In the 16pin LCD, first pin is grounded, second pin is connected to power supply and 3rd pin will be connected to variable pot to control the contrast of the LCD. LCD data lines are connected to port PO, the microcontroller pins P2.7, P2.6 and P2.5 are connected to the LCD control pins RS, R/W and EN, respectively. The ALE, PSEN, EA pins are left isolated.

Since the execution of the program of microcontroller requires clock pulses of frequency 12MHz which are generated by the crystal oscillator with grounding capacitance 33PF, therefore XTAL2 and XTAL1 pins of microcontroller are connected to the crystal oscillator.

The RX (P3.0) and TX (3.1) are connected to the 12 and 11 pins of MAX 232 serial communication through DB9 connector to interface the smart card reader module, from that smart card the data regarding the amount is fed to the microcontroller gets activated and starts to take the data from the optocoupler. The designed prepaid smart card energy meter is shown in Figure 3.

Figure 3: Designed and Implementation of Prepaid Smart Card Energy Meter

3.1 Software Development for Prepaid Smart Card Energy Meter

The system software was developed using assembly language and the flowchart showing the working process is shown in figure 4. In the flowchart, if the balance is insufficient, it will disconnect the load from the supply, but if the balance is sufficient it will connect the load to the supply.

The number of pulses is counted from the energy meter through the counter when the load consume power and the timer records the time. Then the energy is calculated and store in the microcontroller.

Also, if the smart card is valid, it will read, store, update the recharge information and display the updated information on the Liquid Crystal Display. Again, if the valid smart card is not inserted, the load again will be disconnected from the supply.

2. RESULTS AND DISCUSSION

Results

Table 1 shows the test results obtained for a period of 24 hours in the laboratory. These results are the load from each lamp, load measured by standard meter (kWH), load measured by prepaid energy meter (kWH), number of hours used for each load, deviation, error (%), and precision (%).

Table 1: Energy Measurement obtained from the designed Prepaid Energy Meter

S/NO	Lamp load(W)	Load Measured by Standard Meter (kWH)	Load Measured by Pre-Paid Meter (kWH)	Number of Hours	Deviation	Error (%)	Precision (%)
1	40	0.24	0.2325	6	0.0075	3.1	96.9
2	60	0.36	0.3522	6	0.0078	2.1	97.9
3	100	0.60	0.5800	6	0.0200	3.3	96.7
3	200	1.20	1.1600	6	0.0400	3.3	96.7
Mean	100	0.60	0.5811	6	0.1880	2.95	97.05

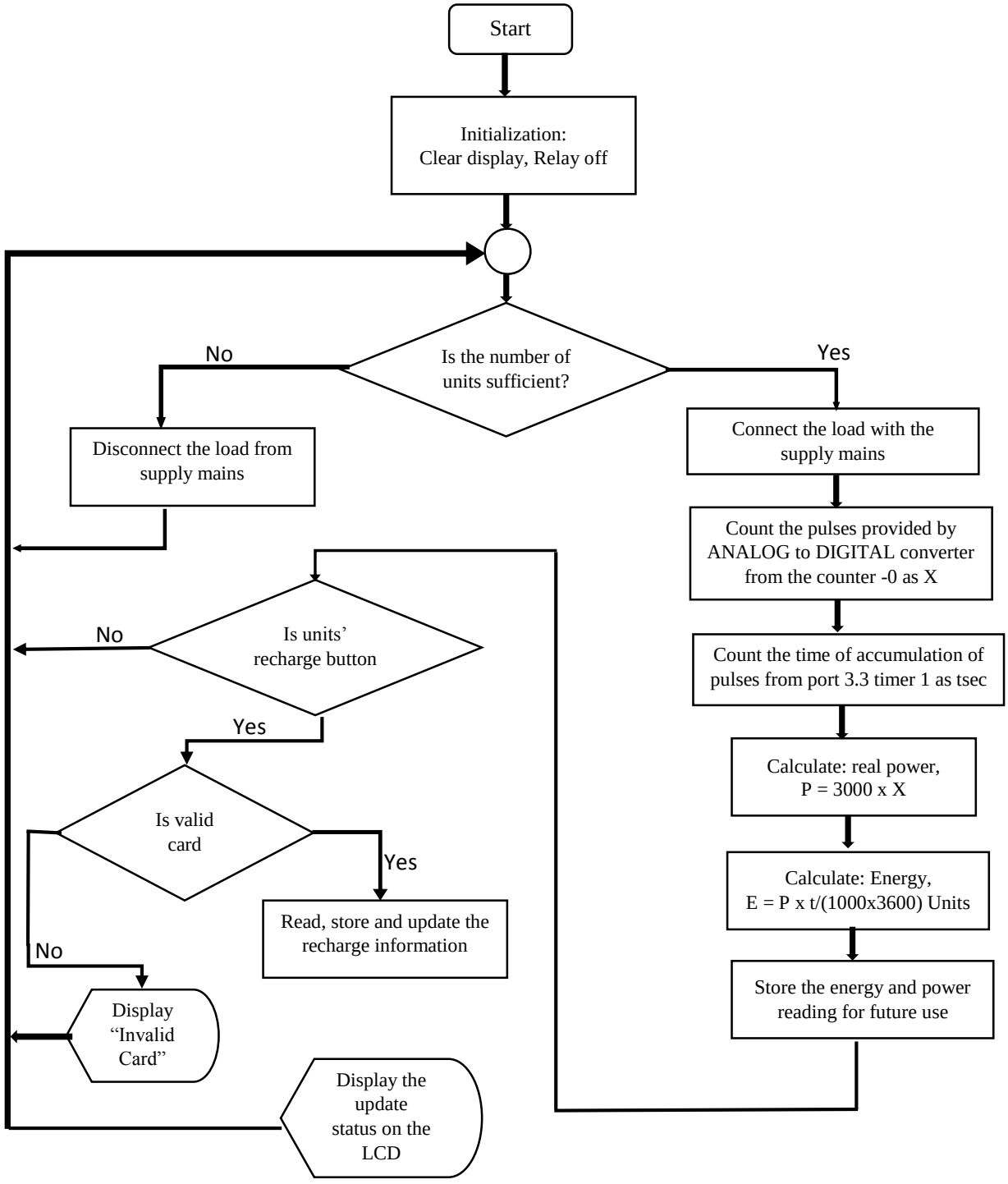

Figure 4: Flowchart of Prepaid Smart Card Energy Meter

Discussion

An electric bulb of 40W, 60W, 100W, and 200W rating was used as a load and it draws a current of up to 1.74A through the supply voltage of 230V.

When a certain amount of power was supplied to the load (W) and the power was maintained for a period of 6 hours for each load, the energy consumed was calculated and displayed on the Liquid Crystal Display.

The test was conducted over a period of 24 hours and measurements from each load were taken every 6 hours with the following results: 0.2325kWH for 40W, 0.3522kWH for 60W, 0.5800kWH for 100W, and 1.1600kWH for 200W, respectively.

The loads measured by prepaid energy meter (kWH) for 40W, 60W, 100W and 200W gave the percentage error of 3.1, 2.1, 3.3, 3.3 and 2.95 and precision in percentage to be 96.9, 97.9, 96.7, and 96.7, respectively.

From the results obtained, it was observed that the measured loads by prepaid energy meter gave a very high accuracy of 1.0. Also, the precision obtained from the experimental results was better than 97% and this value is compatible with the commercially available energy meter in the market.

3. CONCLUSION

In this paper, the prepaid smart card energy meter has been developed and tested successfully. The meter features include with alarming of remainder and storing data up to 12 years. This Prepaid energy meter system minimizes the human intervention in meter reading, bill calculations and bill delivery which ultimately reduces many defects like over running of the meter and over load than the currently existing post paid billing system.

The prepaid energy meter system is designed to continuously monitor the meter reading and to shut down the power supply remotely whenever the discharged unit becomes zero. It also provides efficient meter reading, avoid the billing error and reduce the maintenance cost. Smart Card energy meter will bring a solution of creating awareness on unnecessary wastage of power. The designed module will reduce the burden of energy by establishing the connection easily and no theft of power will take place.

REFERENCES

Ashiquzzaman, Md. and Nadia, A. (2012). Design and Implementation of Wireless Digital Energy Meter using Microcontroller, Global Journal of Researches in Engineering, Electrical and Electronics Engineering, Volume 12, Issue version 1.0.

Homa, K. O., and Abdul, R. (2012). Automated Wireless Meter Reading System for Monitoring and Controlling Power Consumption, International Journal of Recent Technology and Engineering (IJRTE) ISSN: 2277-3878, Volume-1, Issue-2.

Huramasroor, I., Syed, Rehan A., and Ahmed, H. (2010). Design and Implementation of low cost Electronic Prepaid Energy Meter, NED University of Engineering and Technology, Karachi, Pakistan.

Jain and Bagree (2011). A Prepaid meter using mobile communication, International *Journal of Engineering, Science and Technology,* Vol. 3, No.3, pp.160-166.

Khan, R. H., Aditi, T. F., Sreeram, V., and Lu, H. H. C. (2010). A Prepaid Smart Metering Scheme Based on WiMAX Prepaid Accounting Model. Smart Grid and Renewable Energy, Volume 1, Number 2, pp. 63-69.

Mejbaul, H., Kamal, H., and Mortuza, A. (2011). Microcontroller Based Single Phase Digital Prepaid Energy Meter for Improved Metering and Billing System. *International Journal of Power Electronics and Drive System*, (IJPEDS), Vol. 1, Number 2.

Omijeh, B. O., and Ighalo, G., (2012). Design of A Robust Prepaid Energy Metering and Billing System, JORIND 10 (3), December, ISSN 1596-8308. WW.transcampus.org. /journals.

Sheelasobanarani, K., Dinesh, R. S., and Karthick, R. (2014). A Prepaid Energy Meter for Efficient Power Management, *International Journal of Emerging Technology and Advanced Engineering*, Vol. 4, Issue 3. pp. 593-595.

Xiangyang, L., Genghe, L., Yan, Jie, and Yan, Ling U. (2011). The communication interface design of AT89C51 preparation robot based on Serial, International Conference on Electric Information and Control Engineering, Wuham., pp. 802-804.