International Journal of Electrical Engineering & Emerging Technology, Vol. 04, No. SI 01, Feb 2021, pp 33-36

Design and Implementation of RFID and GSM based Smart Prepaid Energy Meter

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[**Received on:** 31-01-2021 **Accepted on**: 08-02-2021 **Published on:** 18-02-2021]

***Abstract*— Pakistan is one of the most populated countries throughout the world which keeps more than 160 million electricity meter connections. For billing purpose, the data from these conventional meters is recorded physically on the monthly basis. This manual technique leads to various billing problems for consumers as well as electric companies because of inaccuracy and unreliability in measuring and recording the data. Besides, power theft is another common issue that results in loss of revenue. To handle these problems, the smart prepaid metering system with tariff indicator for automatic and superior billing systems is implemented in this paper using GSM and RFID technology. The proposed meter offers the accuracy and precision in measuring and recording the energy units. Moreover, it allows customers to check their electricity consumption at any time, so they can manage their finances easily in advance as well as it also prevents the theft of electricity.**

***Index Terms*— Smart Energy meter, Prepaid system, RFID Technology, Arduino, GSM Module.**

I. INTRODUCTION

THE demand for electricity is increasing day by day due to the population growth and industrial development. The power sector of Pakistan is confronting with consequential issues of lean revenue collection against energy supplied because of energy thefts and associated network losses. All the measures are taken regarding the improvement of revenue collection, but the desired results are still not achieved yet. It is proved that the most responsible part for this problem is the conventional meters [1]. The metering and billing systems of electricity consumption which are being used at present are discrete, erroneous, and time consuming. These methods involve long procedures, requires lot of manpower and has deficiency of scalability as well as reliability. Therefore, the number of efforts were made to make billing and metering systems automatic, portable and remote control [2-4].

Efficient energy management can be provided when there is an increased awareness among consumers about their consumption patterns and effective demands [5]. As a result, fast and correct readings can be obtained but still bill payments are conducted based on long old traditional billing processes. In such billing schemes errors get introduced at every stage such as errors with electromechanical meters, human errors while noting down the readings and errors while processing the paid bills and due bills [3]. There are certain cases where bill amount is paid but is shown as a due amount in next bill. Thus, there is no proper method of knowing consumer's maximum demand, usage details, line losses and the power theft characteristics [6].

With the rapid technological advancement in today's modern world everything is developing accordingly, and so energy metering systems are no exception to this phenomenon. This paper presents the designing and development of smart prepaid energy meter based on RFID and GSM technology which provides benefits to both suppliers and consumers in terms of facilities [4]. The prepaid metering equipment with both smart card and GSM technology allows power utility to save time and money by providing a new payment option for the customers. This system is capable of accepting number of units purchased by a customer, accurately calculating number of units being consumed by it, display the available energy from a pre-purchase of electricity and as soon as the amount exceeds the recharged value the system automatically disconnects the power supply system from the customer until the next recharge.

This meter has an additional service of providing message alerts as well as the advance electric units that a customer can request from a company in case of emergency. In the proposed work, the front end is customer friendly and can be easily handled with minimum computer knowledge. The insertion process of this system is quite an easy task which does not requires much hardware work. The implemented work can provide all required billing and metering services incorporated with high veracity.

II. SYSTEM DESIGN

The key components of smart meter include the hardware design of circuit board, interfacing with Arduino, recharging methods and Window based Application.

A. Design of Circuit Board

The hardware implementation of main circuit board of smart prepaid energy meter is presented in Fig. 1. Firstly, a power supply circuit is designed to energize the overall board. The 220V AC supply voltage is fed into the step-down transformer that converts it into 15V as shown in Fig. 2. Since, all electronic components being used operate at a 5V DC supply,

therefore a bridge rectifier is used that gives 12V output voltage which is then supplied to the 7805 Linear Voltage Regulator to finally get 5V DC.

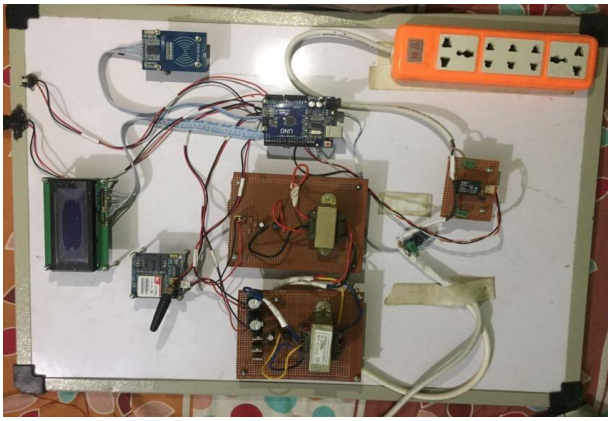

Fig. 1 Main circuit board

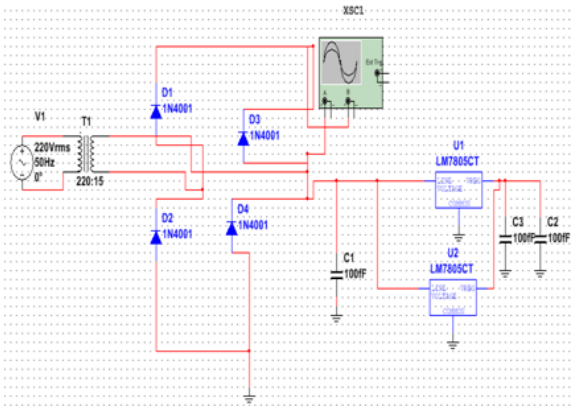

Fig. 2 Power supply circuit

The working of voltage sensor circuit can be analyzed through its connection diagram depicted in Fig 3. The step-down transformer in this circuit acts as a voltage transformer which supply 15V AC to the bridge circuit to convert it into 15V DC. Moreover, a voltage divider circuit is designed to measure the voltage using Arduino. Additionally, Zener diode is used for overvoltage protection

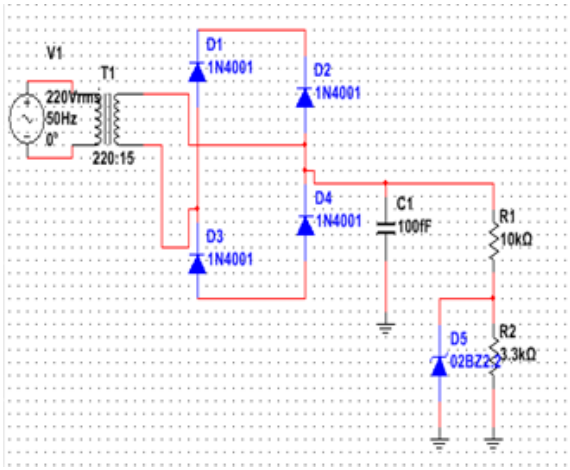

Fig. 3 Voltage sensor circuit

The simulation of disconnector circuit is shown in Fig. 4. It is responsible for establishing contact between consumer load and the utility supply. This circuit comprises of a latching relay and capacitor electrically associated with a linear Current sensor ACS712.

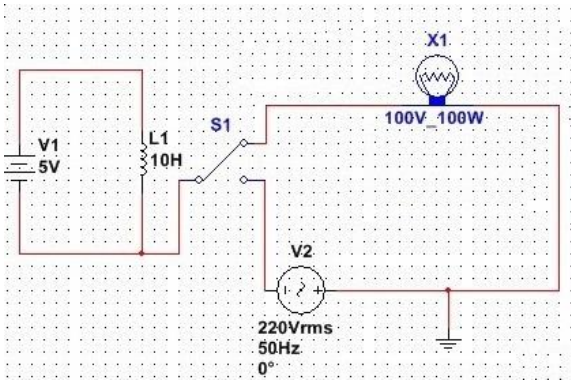

Fig. 4 Disconnector circuit

The balance present in meter system is determined through opening and closing of this latching relay. When the balance is available, the relay remains closed and the supply continues uninterruptedly for the consumer load. When the system runs out of credit, the relay will receive signals to open and disconnects load circuit from supply. Hence, even if voltage is received by the energy meter it will not reach the load because of open relay caused due to unavailability of balance.

B. Interfacing with Arduino

The communication between Arduino board and GSM module occurs as illustrated in Fig 5. GSM sim900 communicates with Arduino when it is activated through tracing the sim card.

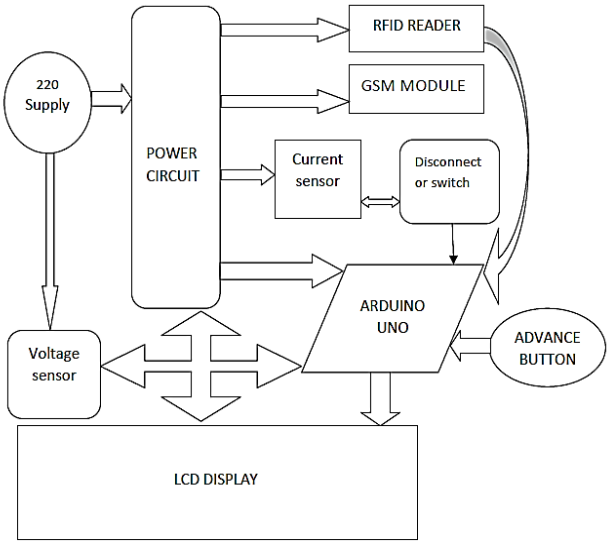

Fig. 5 Block diagram of smart prepaid energy meter

The communication between Arduino and RFID board is achieved using RFID reader and RFID tag both contains a coil inside them. When an RFID Tag is brought near to an RFID reader, it collects unique tag data. In this way, RFID is activated, and signal is sent to Arduino.

An LCD is interfaced with the Arduino to provide display feature to the consumer about their remaining balance, power consumption and the left units. The LCD also displays different types of signals like when the system is running on advance loan function.

C. *Recharging methods*

There are two main recharging methods introduced in this paper. The first method is recharging by loading credit into meter through smart card whereas the second method uses the GSM SIM card to load credit into the system.

Using the RFID smart card, the balance can be recharged into the system by bringing the card near to the RFID module. If the card contains balance, the relay will be actuated and ultimately load will get connected with the supply. Alternatively, the smart prepaid meter can also be recharged through mobile phone using GSM Technology. In order to top up meter with credit balance, the customer must go to the authorized retailer. There will be two GSM SIM sets one is installed at the retailer end as a service provider while the other is inserted at the customer end. The retailer will send customer's purchased credit to the server through SMS. On reception of messages, the meter mechanism adds the purchased amount in the current balance. As a response, a confirmation message will be received by the user on the display. In order to exclude interruptions in processing, only one number can be associated with a single meter.

Additionally, the proposed meter also has a provision for advance mode recharge. If the user due to any emergency could not able to recharge the meter, then the advance number of units can be requested one time. This amount will get subtracted from the purchased balance when the user will reload the meter again. Thus, this feature makes the meter more user-friendly as well as in interest of the utility company.

D. *Window based Application*

The window-based application is designed using Visual Studio to recharge the meter as shown in Fig. 6. It contains option for both types of recharge (i.e. either smart card or GSM Module). It can be operated by any type of computer, PCs, Laptops and is connected via the cable with the server so that the balance could get recharged into the meter.

Fig. 6 Window based Application

III. RESULTS AND DISCUSSION

The results are obtained on the hardware model of proposed smart energy meter. Each command execution is tested and verified through the LCD screen. Here, the following three working approaches are used:

A. *Actual unit-based working:*

First, the meter initializes the system as shown in Fig. 6. When units are loaded into the system either by the smart card or GSM SIM module, the meter will show the status on LCD indicating new units loaded and total available units as shown in Fig. 7

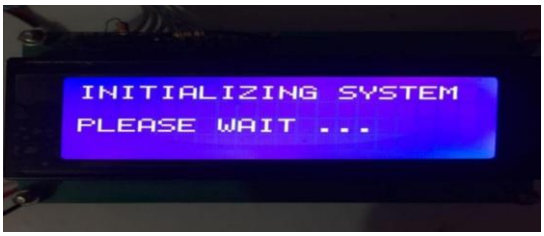

Fig. 7 System Initialization

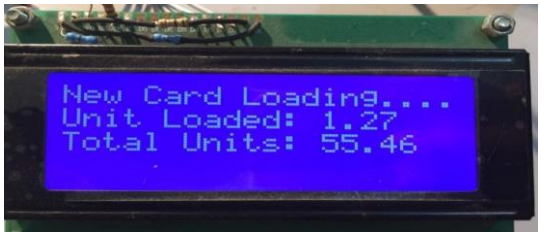

Fig. 8 Loading new card

In normal working of meter, the LCD Screen will display the real-time voltage, current, power and energy readings illustrated in Fig. 9. Moreover, it also indicates the number of units left so that customer recharge the meter on time. In case the same card is attempted to be used again then Fig. 10. shows the presented notification to the user.

Fig. 9 LCD displaying readings

Fig. 10. Notification when same card is used again

B. Time based working:

This working feature is included into the proposed work for the purpose of easy demonstration within the prescribed time. The meter will display the similar readings as for the number of units only difference is that the number of units have been replaced with the given amount of time for which it is desired to operate the meter as shown in Fig. 10 and 11.

Fig. 11 Recharging of balance on time mode

Fig. 12 Display on LCD during time mode consumption

C. Working of meter on Advance Mode:

As the user requests for the advance number of units, the meter will switch to the advance setting mode with the following indication on LCD Display as presented in Fig. 13. In case the advance has already been received or the balance is still present in the meter then the meter will display the warning as shown in Fig. 14.

Fig. 13 Advance Mode Request

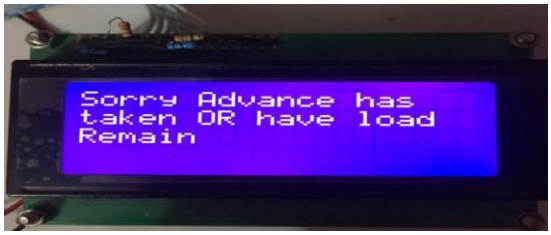

Fig. 14 LCD display when advance cannot be taken

Thus, it can be observed from the above observations that the proposed meter is completely inclined with the programming that is implemented in this paper. Furthermore, the meter is displaying useful indications such as measurement of voltage and current that will ensures the proper working of the meter systems. The meter is provided with some extra functions such as the displays showing in above results in order to enhance the meter working prospects.

IV. Conclusion

In this paper, a smart prepaid energy meter is presented with GSM and RFID technology that offer several advantages as compared to conventional energy meter. The proposed meter is simulated and implemented to verify its effectiveness under all working modes. The results show that the smart meter is advantageous for consumer as they can track their consumption status at any time and get benefit from many features like paying the bill without any delay. Moreover, the problem of power theft can be eliminated with this smart metering system, and it will also reduce the cost of reading units and making bills. The distribution and payment of bills will be performed more efficiently and fast which will surely raise the revenue collection.

As a perspective, the design of smart prepaid meter can be optimized to enhance its efficiency at high power ratings and reduce its size and cost. Moreover, anti-theft meter cases can be developed by using tamper detection sensors.

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