Microcontroller and GSM Based Digital Prepaid Energy Meter

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Abstract: Energy meters in India have dominantly been electromechanical in nature but are gradually being replaced by more sophisticated and accurate digital and electronic meters. A high percentage of electricity revenue is lost to power theft, incorrect meter reading and billing, and reluctance of consumers towards paying electricity bills on time. Considerable amount of revenue losses can be reduced by using Prepaid Energy Meters. A prepaid energy meter enables power utilities to collect energy bills from the consumers prior to the usage of power by delivering only as much as what has been paid for. This paper suggests a prepaid energy meter behaving like a prepaid mobile phone. The meter contains a prepaid card analogous to mobile SIM card. The prepaid card communicates with the power utility using mobile communication infrastructure. Once the prepaid card is out of balance, the consumer load is disconnected from the utility supply by the contactor. The power utility can recharge the prepaid card remotely through mobile communication based on customer requests. A prior billing is bound to do away with the problems of unpaid bills and human error in meter readings, thereby ensuring justified revenue for the utility.

Keywords— Energy Meter; GSM; LCD; Relay control unit; load

I. INTRODUCTION

Electronic energy meter has got numerous advantages over the conventional electromechanical meter and due to this; many countries of the world have switched to electronic metering system.[1] The present system of energy billing in India is error prone and also time and labour consuming. In order to achieve revenue improvement, it is essential to measure the energy consumed accurately, render bills quickly and collect the amount promptly.[2] Errors get introduced at every stage of energy billing like errors with electro-mechanical meters, human errors while noting down the meter reading and error while processing the paid bills and the due bills. There are many cases where the bill is paid and then is shown as a due amount in the next bill. There is no proper way to know the consumer’s maximum demand, usage details, losses in the lines, and power theft. The remedy for this drawback is prepaid energy billing, which could be titled “Pay first and then use it”. Smart metering is such a complete end to end solution which minimizes the several errors.[3] There are clear results from many countries, where prepaid system has reduced the wastage by a large amount. Another advantage of the prepaid system is that the human errors made during reading meters and processing bills can be reduced to a large extent.

In this paper, the idea of pre-paid energy meter using ATME 89S52 controller have been introduced. In this paper, energy meters have not been replaced which is already installed at our houses, but a small modification on the already installed meters can change the existing meters into prepaid meters, so this meters are very cheaper. The use of GSM module provides a feature of pre-paid through SMS. One can recharge meter with the help of mobile through SMS, on the basis of recharge amount, ATME controller count the amount of energy consumed and display the remaining amount of energy on the LCD. If the amount falls below certain minimum amount, then it will be indicated by the controller through buzzer, so the user can recharge rapidly. If the power consumption exceeds the predefined limit then the user will be informed through SMS so that he can take the required action. The entire system is designed with the state-of-the-art digital and information technology.[4]

II. DESIGN OF THE SYSTEM

The energy metering system consists of Microcontroller, ADC, Voltage and Current controlling unit, GSM modem, Relay, Buzzer and Liquid Crystal Display (LCD).

Microcontroller calculates the energy consumed by the consumer utilizing the output of ADC through load section and programs loaded on the microcontroller.
- Voltage and Current controlling unit feeds the actual current and voltage of load connected to consumer side to the energy meter chip.
- GSM interfaces with the microcontroller unit in which the number of units recharged by the consumer are written.
- Relay mainly performs the opening and closing of a connection between energy meter and load through supply mains depending upon the number of units present at a moment.
- Liquid Crystal Display shows the energy consumption, number of unit recharged by the consumer, rest of the unit and maximum demand.

III. COMPONENTS AND WORKING OF THE SYSTEM

Energy Meter: The electronic energy meter is an important invention for Power Energy Measurement System, which is an effective measures for the electricity-stealing defence [5] The energy metering measure line voltage, current and

![Figure 2. Hardware Implementation](image-url)
calculates active, reactive apparent power, energy, power factor, and RMS voltage and current.[6] The electromechanical energy meter calculates the electrical energy (units) consumed by the load based on the mechanical energy of the disk or rotor. The electronic meter has this existing structure attached with a microcontroller programmed to perform specific calculations and present it in terms of electrical energy units consumed to a prepaid card.

Microcontroller: Microcontroller is a programmable device which mainly contains a microprocessor, memory and input-output ports and can be compared with the microcomputer. Microcontroller is a single chip computer. As microcontroller is a low cost programmable device, it is used in the automatic control application. Information such as power, energy and maximum demand are stored at the EEPROM of the Microcontroller. This system centres on AT89S52, single chip high-performance microcomputer used as the main control circuit for data processing.[7][8]. It has higher precision, higher reliability and better cost performance.[9] It fulfils the necessary requirements of the system and so there is no need to use higher versions of microcontroller. The features of this microcontroller are:

- Compatible with MCS-51® Products
- 8K Bytes of In-System Programmable (ISP) Flash Memory
- Endurance: 1000 Write/Erase Cycles
- 4.0V to 5.5V Operating Range
- Fully Static Operation: 0 Hz to 33 MHz
- Three-level Program Memory Lock
- 256 x 8-bit Internal RAM
- 32 Programmable I/O Lines
- Three 16-bit Timer/Counters
- Eight Interrupt Sources
- Full Duplex UART Serial Channel
- Low-power Idle and Power-down Modes
- Interrupt Recovery from Power-down Mode
- Watchdog Timer
- Dual Data Pointer
- Power-off Flag
- Fast Programming Time

- Flexible ISP Programming (Byte and Page Mode)

Relay Control Unit: The main relays are the protective elements which respond to any change in the actuating quantity, e.g. current, voltage, power etc.[10] The relays used are Solid State Relay (SSR) 240D45 (240VAC, 45A). One relay is only used to provide the coil current. When this relay will conduct then it energizes the rest of the relays and consequently the load current will flow through the four relays only which acts as one relay of rating 40A. When the number of units stored in the EEPROM reaches zero, the microcontroller initiates a pulse to the base of the transistor. Then the transistor will be switched on which initiates the operation of the relay and consequently the relay will be off. When the credit card is again recharged, the AT89S52 will send a pulse for which the relay establishes a connection between the load and the supply mains.

Display Unit: The liquid crystal display controller displays alphanumeric characters and symbols. It can be configured to drive a dot-matrix liquid crystal display under the control of microcontroller. In this paper, LCD is mainly used to display energy consumption of the load, the number of units recharged by the consumer, rest units, maximum demand of consumer.

Power Supply Unit: Every electronic circuit needs appropriate power supply for its operation. Basically Microcontrollers, Liquid crystal display and relays operate on ±5 volts supply. For this reason, we have used a ±5 volt power supply. We have taken into consideration the small energy consumed by the power supply itself that will be paid by the consumers.

GSM Module: The Global System for Mobile communications, GSM, is a pan-European Mobile communication system in the 900 MHz band which was first introduced in the early years of this decade.[11] It is used for the prepaid operation of the energy meter. The balance available for the user is send to his mobile phone via SMS through GSM modem. When the available balance reaches below threshold level, user receives a SMS through GSM modem. When there is overload in the meter, user receives a SMS by the modem. Here, we have used GSM modem 1122 developed by Sunrom technologies. This GSM modem is a highly flexible plug and play quad band GSM modem for direct and easy integration to RS232. Supports features like Voice, Data/Fax, SMS, GPRS and integrated TCP/IP stack.

ADC: It is used for the analog to digital conversion of the data received through load section. The output of the ADC is given to the Microcontroller which is programmed to give the required output. The ADC used in the project is ADC0808 which is a monolithic CMOS device with an 8-bit analog-to-digital converter, 8-channel multiplexer and microprocessor compatible control logic.
Figure 4. Flow chart of the Code

Figure 5. Matlab simulated model of prepaid energy meter
IV. MATLAB SIMULATION AND RESULTS

The output condition of electricity supply, opening and closing of local contactor and phase voltage magnitudes over the intended simulation time are depicted by the simulation model. The prepaid card is recharged as soon as its balance gets over when the consumer requests to the power utility. The variation in the electricity supply depending upon the prepaid card balance is as shown in Figure 6. (X-Axis – ON/OFF Status, Y-Axis-Simulation Time)

Figure 6. Output status of electricity supply based on prepaid card balance. (1 for supply existing; 0 for supply cut-off)

The variations during the opening and closing of contactor are shown in Figure 7 which are coordination with Figure 6. It shows that opening (status 0) and closing (status 1) of contactor is in synchronism with prepaid card recharge and discharge.

The individual phase voltage magnitudes shown in Figure 8, Figure 9 and Figure 10, appear in coordination with the prepaid card running out of balance and gaining a recharge respectively.

Figure 7. Working on contactor based on prepaid card balance (1 for supply existing, 0 for supply cut-off)

Figure 8. Variation in phase A voltage magnitude based on prepaid card balance

Figure 9. Variation in phase B voltage magnitude based on prepaid card balance

Figure 10. Variation in phase C voltage magnitude based on prepaid card balance

V. CONCLUSION

This paper has demonstrated a method for measuring the electrical energy consumption of an electrical load for two wire distribution systems with the proposed energy meter as an alternative to the conventional electromechanical meter. This microcontroller based energy meter prototype has been implemented to provide measurement up to 40A load current from a 230 V line to neutral voltage. The proposed energy meter is capable of measuring energy consumption for all loads conditions i.e. power factor and non-sinusoidal voltage and current waveforms. It does not possess any rotating parts that help in the prevention of meter tempering, which is an attractive feature for the utilities. The proposed energy meter includes a “no load threshold” feature that will eliminate any creeping effects in the meter. In addition, the process of reading the energy consumption is facilitated by the LCD display that is simpler than that for the analog meters which reduces human errors while noting down the meter reading. This energy meter has the potential to change the future of the energy billing system in India. The energy billing system may help the energy distribution companies to reduce costs and increase profits. Furthermore, it might improve metering and billing accuracy and efficiency, thereby contributing the energy in a sustainable way. The features like minimum balance detection and overload detection enhance the usability of this system.

REFERENCES


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