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Low Cost GSM based Smart Energy Meter Design: Capable of Demand Side Management and Data Logging

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Abstract: In this paper, design and fabrication of a low-cost multifunction smart energy meter, is proposed for domestic electricity consumers. The proposed design of smart energy meter has been first implemented in software environment and then a prototype model has been developed, which communicates the consumed energy data through GSM network. In addition to this, time of use (TOU) metering, data Logging and the Demand Side Management (DSM) during peak hours techniques are utilized in proposed design which will help utility companies to make electricity metering system more efficient. The meter tampering detection feature is also added to handle power theft challenges.

Keywords: Smart Energy Meter (SEM), GSM Network, Demand Side Management (DSM), Data Logging

I. INTRODUCTION

Smart metering is possible because of continuous efforts and advancements in the electricity metering methods [1]. Electronic Energy meters, reduced but did not completely eliminate the need to visit the customer for meter reading. Therefore, an automatic meter reading technique was introduced in [2-3]. AMR system provides real time energy consumption of the consumers and quick response service [4].

Smart energy meter proposed in [5] may be used either in pre-paid mode or in post-paid mode. In [6], new design scheme is proposed keeping in view, the energy efficiency and convenience for the user. A smart metering approach using Arduino with ZigBee as communication media to central PC server and GSM for communication between utility and user is proposed in [7]. A low cost smart metering system is proposed using power line communication for billing and controlling purposes [8]. A smart energy meter is proposed with GPRS communication technology along with the development of In-home display using LabVIEW software [9]. An advanced metering and billing system is proposed utilizing an existing digital energy meter and incorporating GSM modem with Arduino microcontroller [10]. A smart metering system is proposed using an existing electronic or digital energy meter with SMS sending capabilities using GSM network for remote metering and billing purposes [11,12,16]. An automatic billing system is proposed through GSM energy meter based on MCP3905A metering IC and PIC16F877A microcontroller [13]. An ARM microcontroller-based AMR system has been designed to send readings to utility company on special request [14]. An overview of smart metering; its evolution, advantages and challenges are discussed in [15]. A ZigBee communication-based AMR system is proposed for billing and controlling purposes [17-19]. In [20], different electricity theft techniques have been specified and a GSM based prepaid meter has been proposed. In [21], an automatic meter reading technique has been implemented with the help of Radio Frequency (RF) module. In [22] the major drawbacks of traditional metering system have been discussed.

In this paper, a low cost multi-function Smart Energy Meter (SEM) is proposed using components as described in section II. The proposed SEM sends all the measuring parameters including peak and off-peak energy consumed through GSM network, implementing the time of use tariff, DSM to limit the maximum demand and meter tampering alert.

II. DESIGN OF PROPOSED SMART ENERGY METER

A. Software and Hardware Implementation:

The major components of proposed SEM are:

- Arduino Mega 2560
- GSM Module 900A
- Non-Invasive Split Core Current Transformer
- LCD (20×4)
- Real Time Clock (RTC, DS3231)

The Fig.1 shows the schematic diagram of SEM simulated in Proteus 7.0 software.

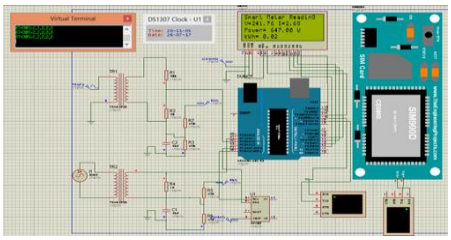

Fig. 1. Schematic diagram of proposed Smart Energy Meter

It can be seen in schematic diagram simulation that the incoming power supply is connected to a potential transformer. A DC offset is applied to the output of potential transformer to make it compatible with the Arduino analog input voltage range. The microcontroller performs the analog to digital conversion and calculates the root mean square voltage. Similarly, the analog to digital converter performs the same operation as done in voltage measurement and the root mean square value of current is measured.

The relative time difference between the voltage waveform and current waveform is found by taking the voltage waveform as the reference and the amount of the angle or time by which the current waveform lags provides the power factor information by detecting the zero crossing of the voltage and current waveforms.

The proposed SEM measures peak and off- peak energy separately with the help of Real Time Clock. The Smart Energy Meter also saves peak and off-peak energy measurements in EEPROM. If power to the Arduino gets cut off, the measurements are kept stored in EEPROM. A GSM network has been preferred in proposed SEM for communication purposes [23-24].

B. Proposed Algorithm:

- Start and get the stored values from EEPROM.
- Measure the values of current and Voltage.
- Check whether the load is switched ON, if yes then start noting the time.
- Measure the power of load.
- Check whether the time of use lies in Peak hours or Off- Peak hours.
- Measure the Peak hours or Off- Peak hours energy consumption respectively.
- Store the Energy values in EEPROM.
- Data Logging in SD Card.
- Send the SMS to Utility company through GSM network.
- Display the results on LCD.
- Check for Maximum Demand limit during Peak hours, if exceeds then shed the load.
- Check for Meter Tampering, if yes then store the information in SD card and generate an alert.

III. EXPERIMENTAL RESULTS AND DISCUSSION

A. Test under RL Load:

The verification of results has been ensured by using an analog Power Factor Meter and proposed SEM for different RL load as shown in Table 1. The Fig. 2 show the results on SEM LCD when RL load was connected.

TABLE 1. THE COMPARISON TABLE FOR RL LAOD

Sr. No.	Observations		
	Resistive and Inductive Load Current	***Smart Energy Meter's Power Factor***	***Power Factor Meter***
(i)	1.62A	0.96	0.95
(ii)	2.86A	0.86	0.86
(iii)	3.66A	0.75	0.76
(iv)	4.19A	0.66	0.67

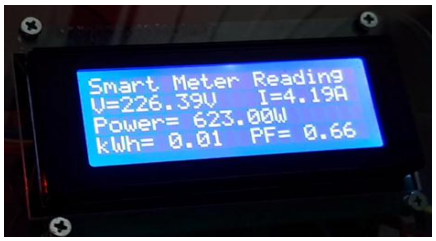

Fig.2.Power Factor value is 0.66 at 4.19A Load Current

B. Time of Use Metering:

The proposed SEM displays ToU as shown in Fig. 3, and this feature encourages consumer to shift from peak to off peak-hours.

Fig.3. ToU on SEM LCD

C. Demand Side Management:

SEM would help utilities to limit the maximum demand. If load exceeds the predefined threshold value during peak hours, it sheds the load as can be seen in Fig.4. SEM waits for consumer to reduce the load and switches the load on as shown in Fig.5. If the load remains unchanged then it again sheds, until load is reduced.

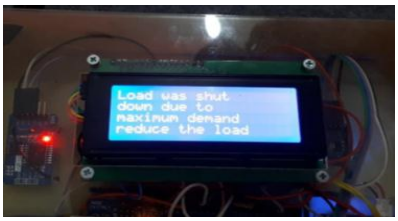

Fig.4. Message on LCD after Switching Off the Load

Fig.5. Message on LCD before Switching ON the Load

D. Meter Tampering Detection:

To eliminate the illegal use of electricity, a lever switch has been placed inside proposed SEM. When someone opens the SEM casing, the lever switch will get disconnected, Arduino will detect the change in the state of the lever switch, it will store the time and date of meter tampering in SD card, also generate an alert message as shown in Fig. 6.

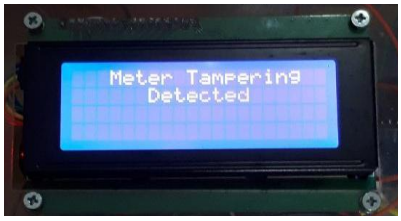

Fig.6. Message on LCD after detecting Meter Tampering

E. Data Logging:

An SD Card has been used to store the real-time loading and as well as meter tampering information. The data is first stored in the digital card before transmitting it to the utility company through GSM, if the SMS are not received by the utility company, then the utility company can still access that particular reading through this digital data storage card as shown in Fig.7.

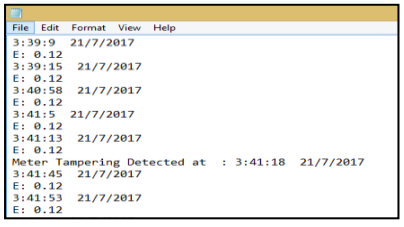

Fig.7 Data Logging in SD Card

F. SMS Result:

The Fig. 8 displays the messages that have been sent by the proposed SEM and are received by the utility company.

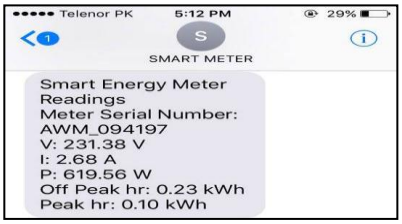

Fig.8. SMS sent by Smart Energy Meter

IV. COST DESCRIPTION

Table 2 gives the cost breakdown of proposed SEM as of January 2018.

Table 2. COST BREAKDOWN OF PROPOSED SMART ENERGY METER

Components	***Price ($)***
Arduino ATmega 2560	7
GSM Sim 900A	18
RTC DS3231	1
Current and Potential Transformer	10
LCD (20×4)	5
Relay, Lever Switch and SD Card	3
Total Cost	44

V. CONCLUSION

This research paper describes in detail the designing and development of smart energy meter. It accurately measures the consumed peak and off-peak hours real-time energy, transmits it to utility company's control centre and plays a significant role in saving energy during peak hours. The application of time of use (ToU) metering will allow utility company to implement multiple tariffs. In addition to this, the meter tamper alert and data logging features provide utility a greater control over energy theft issues.

VI. ACKNOWLEDGMENT

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