Abstract

Objective: This paper describes the use of virtual instrumentation tool - LabVIEW for web based demand side energy monitoring using GSM based wireless data acquisition. Method: The demand side energy monitoring is carried out by microcontroller based system on Time of Day basis. The demand side energy utilization tracked by the microcontroller based system is transmitted using GSM communication to remote metering infrastructure implemented on LabVIEW platform for real time monitoring. The demand side energy utilization information acquired by metering infrastructure can be accessed over the internet using server - client model based communication. The metering infrastructure is designed to provide SMS based customer service regarding monthly energy utilization. Findings: Demonstrates the use of virtual instrument for wireless and internet based automation of energy metering system for functions such as remote meter reading, meter data management, report generation and finally real time and historical trending are realized. Applications/Improvements: The LabVIEW based virtual instrument application can be improved to perform multipoint wireless communication.

Keywords: AMI, Data Acquisition, GSM Communication, LabVIEW, Microcontroller, VISA

1. Introduction

Smart Metering Infrastructure (AMI) can be referred to as a full measurement and data collection system that incorporates solid state meters at the customer site, two way communication GSM network for transfer of information between the customer (demand side) and the service provider, and data management system that presents the energy utilization information to the service provider or utility. The full measurement and data collection system comprises of electronic or digital hardware and software which performs interval data measurement and transmission of information over communication network. The transmitted information is collected by Meter Data Management System (MDMS) that manages data storage and analysis to provide information in useful form. The MDMS also performs issuance of peak load limit command or price signal to the energy demand side. SMI provides benefits in terms of system operation, customer Service and finance.

2. LabVIEW based SMI

The LabVIEW based SMI performs the monitoring of demand side energy utilization on TOD basis. The meter data management system implemented on LabVIEW platform facilitates easy access and analysis of energy meter data. The meter data management system also acts as consumer information system and billing system. The simplified block diagram of LabVIEW based SMI is shown in Figure 1. The energy utilization tracking system is designed to perform the electronic tracking of energy utilization on TOD basis. Time of Day (TOD) metering is a theory which helps the customers in getting an
economic incentive in consciously shifting a part of their overall electricity usage from the hours of peak demand to those of lean demand each day.

By shifting the major part of electricity usage to hours of lean demand, the demand for electric energy during peak hours can be reduced. This will in turn help in reducing the frequent power outages experienced by the customers. The electronically tracked demand side energy utilization is transferred to LabVIEW based meter data management system. The meter information acquired by LabVIEW based data management system is presented in graphical form. It also acts as a human machine interface to facilitate the selection of tariff per unit consumed during the different hours of demand and also to set the limit during the peak demand hours. The data management system is automated to perform tariff calculation and monthly bill report generation. The LabVIEW based system also facilitates the access of information through the internet.

3. Energy Tracking System

The energy tracking system is an 8051 microcontroller based system which is designed to read the output of the Application Specified Integrated Circuit (ASIC) controlling the solid state energy meters. The pulse train output of ASIC which is a measure of energy consumed in kWh is tracked on TOD basis\(^2\)-\(^3\). The ASIC is designed to make 800 to 3600 pulses per kWh. The pulse train output of ASIC in the solid state energy meter is considered as an external interrupt signal. Hence the demand side energy utilization is measured in terms of the number of falling edges of clock pulse train detected by the microcontroller. The design schematic of microcontroller based energy tracking system is shown Figure 2.

The electronic tracking of demand side energy utilization on TOD basis is carried out by the microcontroller with the help of serial real time clock chip - DS1307. For testing, the real time microcontroller based system tracks the demand side energy utilization for a time length of seven minutes and records hundred clock pulses as one unit of energy. A single time slot of seven minutes is further divided into smaller time slots of peak demand and lean demand. The smaller time slots can be also called as tariff slots. In a single time slot, the first three minutes is taken as period of lean demand. The period of lean demand is represented as NC\(_a\). The fourth minute is taken as a period of first peak demand. The period of first peak demand is represented as X\(_{Ca}\). The fifth minute is again a period of lean demand. The sixth minute is taken as the period of second peak demand. The period of second peak demand is represented as X\(_{Cb}\). Finally the seventh minute is again a period of lean demand. At the end of seventh minute of single time slot the energy tracked by the microcontroller based system is transmitted using GSM communication to LabVIEW based meter data management system. The LCD interface allows the real time monitoring of energy consumed during differ-
ent time slots. The prototype of microcontroller based energy tracking system is shown in Figure 3.

The energy meter data is transmitted over the GSM communication network using SIM 900-RS232 GSM modem. The data comprises of meter ID, the number of units consumed during the different hours of demand. The modem performs serial communication with the microcontroller for the data to be transmitted over the communication network. The transmitted information consists of twenty six characters in the following format - &MIwwwwNCayyyyXChzzz$. The energy meter identification number is a four digit number denoted as wwww. The energy consumed during the period of lean demand is a three digit number denoted as xxx. The energy consumed during the period of first peak demand and second peak demand is a three digit number denoted as yyy and zzz respectively. The energy meter information transmitted in encrypted form will be decrypted by the LabVIEW based meter data management system. A set of sample data tracked by the system during the test run is shown in Table 1.

### 4. Meter Data Management

#### 4.1 LabVIEW based System

The energy meter data management system is designed using the virtual instrumentation software - LabVIEW developed by National Instruments. LabVIEW (short for Laboratory Virtual Instrument Engineering Workbench) is a system design platform and development environment for a visual programming language. Common applications of this virtual instrumentation software are data acquisition, instrument control and industrial automation. The meter data management system runs two LabVIEW applications. The first application known as VI for wireless data acquisition is designed to perform the functions such as automated wireless data acquisition to enable the graphical analysis of energy utilization during the periods of peak demand and lean demand, registration of consumer details for the generation of monthly bill statement, selection of tariff during the periods of lean demand and peak demand, automated customer service for monthly bill statement, selection of energy consumption limits during the two periods of peak demand, retrieval of energy utilization history from the database using the bill reference number, operator or user registration for internet based remote monitoring and control. The second application performs all the functions of first application except the wireless data acquisition of electronically tracked meter information and also the user and consumer registration. The second LabVIEW application known as VI for internet based access is configured for internet based monitoring and control using web publishing tool. The communication between the two VI applications of LabVIEW based meter data management system is shown in Figure 4.

Table 1. Test Run Data

| Data Set | NCa | XCa | XCb |
|----------|-----|-----|-----|
| 1        | 38  | 02  | 02  |
| 2        | 34  | 02  | 02  |
| 3        | 40  | 02  | 02  |
| 4        | 31  | 2   | 1   |
| 5        | 30  | 2   | 1   |

Encrypted Data

&MI2323NCa038XCa002XCb002$

&MI2323NCa034XCa002XCb002$

&MI2323NCa040XCa002XCb002$

&MI2323NCa031XCa002XCb001$

&MI2323NCa030XCa002XCb001$

Figure 3. Test model of Energy Tracking System.
The information in both LabVIEW applications is shared between each other with the help of global VI. A VI defined with global variables is referred to as global VI.

The graphical user interface shown in Figure 5 performs wireless acquisition of energy meter data using the different NI-VISA function. NI - VISA stands for National Instrument - Virtual Instrument Software Architecture. The encrypted meter data received by the LabVIEW based system is decrypted for the meter ID, the energy consumed during the peak hours and lean hours using the scan from string function in LabVIEW. The block diagram of VI for wireless data acquisition is shown in Figure 6.

The LabVIEW based GUI shown in Figure 7 is designed for web based monitoring and control which is configured and enabled using NI web server and web publish tool.

This enables the monitoring and control of demand side energy utilization using web page. The application is designed in such a way that only registered operator/user can perform web based monitoring and control. The web based monitoring and control is using Client - Server model based communication. In this communication, the LabVIEW based system running the two VI applications shown in Figure 4 will act as the server. The VI application referred to as internet based access is published as a web page using web publishing tool in LabVIEW. This enables the access of the VI by the client via the internet. When the client requests the server for the control of VI, the server will transfer the control of VI. Once the con-

![Figure 4. Developed LabVIEW Application.](image)

![Figure 6. Block diagram of VI for wireless data acquisition.](image)

![Figure 5. LabVIEW based GUI for wireless data acquisition.](image)

![Figure 7. LabVIEW based GUI for internet based access.](image)
control of VI is transferred, the VI referred to as wireless data acquisition running on server will display the logged in operator details on client system. The block diagram of VI for internet based access is shown in Figure 8.

In client - server model based communication, at a time only the server or one of the multiple clients will have the control of the VI. The request for the control of VI made by the client named VIPC19 to the server named VIPC20 is shown in Figure 9.

The request for the control of VI will be queued in server and the control is transferred to the client after time out. The control of VI transferred to the client is shown in Figure 10.

4.2 GSM Communication in LabVIEW

The LabVIEW based meter data management system is designed to perform GSM communication to acquire the energy meter data transmitted by the energy tracking system on the consumer side. It is also designed to transmit the energy utilization limit during the hours of peak demand and lean demand to the energy tracking system set by the LabVIEW based meter data management system and also to perform monthly SMS billing. The acquisition of energy meter data is referred to as GSM read operation. The monthly SMS billing and transmission of energy utilization can be referred to as GSM write operation. The LabVIEW application performs serial communication with the GSM modem using RS-232 serial interface standard. The GSM read and write operation is initiated using different AT commands send by the LabVIEW application to the GSM modem. For GSM read and write operation, three AT commands has to be send by the LabVIEW application to the GSM modem. For each AT command, the modem will send back a result code. Hence the transfer of AT command from LabVIEW application to modem involves serial read and write operation implemented using NI - VISA function. The block diagram of VI application for GSM read operation is shown in Figure 11.
4. Conclusion

This paper demonstrates the use of virtual instrumentation as a powerful productive automation tool which is customised to interact with real time data using various communication networks for designing a supervisory control and data acquisition system for energy metering infrastructure.

5. References

1. Prashanth BUV. Design and Implementation of wireless energy meter system for monitoring the single phase supply. International Journal of Computer Application. 2012; 41(2):26-9.
2. Jiang X, Dawson-Haggerty S, Taneja J, Dutta P, Culler D. Creating Greener Homes with IP-Based Wireless AC Energy Monitors. USA: Sixth ACM conference on Embedded network sensor systems, SenSys’08. 2008; p. 355-56.
3. Jansson PM, Tisa J, Kim W. Instrument and Measurement Technology Education - A Case Study: In expensive Student - Designed Power Monitoring Instrument for Campus Submetering. IEEE Transaction on Instrumentation and Measurement. 2007; 56(5):1744-52.
4. John M, Joseph A. Implementation of Automated Demand Side Energy Monitoring on TOD Basis Using LabVIEW. Vellore, India: 2014 International Conference on Advances in Electrical Engineering (ICAEE’14). 2014; p. 1-4.
5. Rahnema M. Overview of GSM system and protocol architecture. IEEE Communication Magazine. 1993; 31(4):92-100.
6. Wells LK, Travis J. New Jersey, Prentice Hall: LabVIEW for Everyone. 2001.
7. Schierbam KD, Cherradi M, Bouchtaoui M. Computer Control of surface science experiments with LabVIEW. International Journal of Computer Applications. 2010; 3(4):1-8.
8. Bitter R, Mohiuddin T, Nawrocki M. USA, CRC Press: LabVIEW Advanced Programming Technique. 2001.
9. Karthik T, Rajkumar K. Efficient Power Management and Data Intensive Computer Systems in Computer Networks. Indian Journal of Science and Technology. 2015; 8(12):1-7.