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Designing and Developing Energy Information System for Academic Institutes

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Abstract: Energy Information Systems (EIS) are being promoted and implemented in the industry at a rapid pace. Industries are employing professional energy service providers to implement these systems to find the losses in the system and thereby reduce costs and improve efficiency. However, their usage in academic institutes is extremely limited today due to lack of awareness and financial limitations. The present research aims to describe a blueprint for developing energy information system in an academic institute. The study presents an innovative energy monitoring system used in Maharaja Agrasen College to measure and study the real time energy demand in various sub-domains of the college matched with time-table and occupancy levels. Using this systematic monitoring and precise matching of loads, energy consumption patterns of various sub units can be assessed and the wastage of electrical energy in each unit can be identified and minimized there by leading to energy efficiency in the academic institute. The technical details of the sensor network are also discussed. The innovative EIS comprises of energy meters capturing the instantaneous parameters (line current, phase voltage, frequency, power factor, active power, reactive power and apparent power) and cumulative parameters (active energy, apparent energy, active power and apparent power) connected to the server through USB to RS-485 converter module which contains the self-tuner ASIC which automatically tunes to the baud rate and data format for the RS-485 network. All such important real time parameters provide important information in order to frame policy decisions and undertake pro-active measures for better utilization of energy in academic institutes resulting in efficient management of energy and further reduction of their carbon footprints.

Key words: Energy Information System (EIS), modbus, energy efficiency, energy management, frequency, innovative

INTRODUCTION

India is a developing nation and the most important role in the development process is played by electricity. Energy is at the forefront of the global agenda and is central to the issues of development, security and environmental protection. India's energy consumption is estimated to grow by five percent every year whereas the conventional energy sources are getting depleted day by day. This gap between demand and supply has resulted in acute power shortage and extended power cuts across the country (EPRI., 2006).

As per the data available at the world economic forum, "India's energy consumption has doubled, since, the year 2000 and is expected to more than double by 2040 which will account for one-fourth of global increase in that same period. Per capita electricity consumption in the country is less than that of Africa's and one-tenth of America's levels. In fact, even though India is the third largest market in terms of gross electricity generation, it still has almost 250 million people without access to power. Rectifying this situation will be critical to ensure India's economy grows five-fold by 2040 and that policies such as make in India, Skilling India and Digital India are a success. Energy and electricity growth will therefore become crucial for powering the country's future" (Ministry of Power, 2016).

The continually increasing demand of energy from various sectors in a developing country like India is making it difficult to produce energy at the same rate. In order to reduce the difference between supply and demand of energy generating more electricity from already depleting resources by incurring mammoth finances does not seem a feasible proposition. Hence, in today's scenario, the daunting challenge is to use the energy efficiently to attain energy security as each bit of energy saved is equivalent to energy generated thereby reducing our negative impact on environment.

In the light of this, it becomes imperative that all the Government bodies, industrial sector and the academic institutes must respond this challenge of converging the difference between the demand and supply of the

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energy system by devising new strategies to address this crisis and undertaking innovative measures in energy saving technology and policies (Han *et al*., 2011; Lee *et al*., 2011).

In the industrial sectors, the role of Energy Management System (EMS) with facility monitoring and control systems is becoming very important resulting in real time control decision making (Kannan and Boie, 2003; Gordic *et al*., 2010; Zahiri *et al*., 2016; Chen *et al*., 2013).

In order to ensure a sustainable future, the academic institutes need to assume responsibility for their actions and commit themselves to encourage a participatory problem-solving process. The academic institutes can become a role model in this endeavor and promote energy usage optimization by sensitizing the students towards more committed vision to sustainability and devising innovative methods endorsing energy saving. The academic institutes can help increase awareness and galvanize academic fraternity including the students into action towards a concerted action to achieve the goal of improved energy efficiency (Ahmed and Iqbal, 2012).

MATERIALS AND METHODS

Design of energy information system

Proposed model: A small yet systematic step towards this goal was taken at Maharaja Agrasen College, a constituent college of University of Delhi by monitoring the energy used in order to use the available energy resources at the supply level efficiently. The method includes evaluation of energy consumption patterns of laboratories, cafeteria and hostel with the help of sub-meters specially deployed to check the energy consumed in real time. The data from the meters goes to servers where it is mapped with the student time-table and occupancy levels.

Design: Seven energy meters (Make: Crystal, Model: CCM-603P) were installed in different units of the college. These units included physics laboratory, electronics laboratory, computer laboratory, cafeteria, hostel mess and common room, hostel floor 1 and 2. Phase-wise instantaneous parameters (line current, phase voltage, frequency, power factor, active power, reactive power and apparent power) and cumulative parameters (active energy, apparent energy, active power and apparent power) can be measured by the selected energy meters. The technical specifications of these meters are given in Table 1.

Table 1: Technical specifications of energy meter

Variables	Values
Electrical parameters	
Power system	3-phase, 4-wire
Voltage	90-300 V_{ac} per phase
Maximum current	120 A
Accuracy parameters	
Accuracy class	1.0 as per IS: 13779-99
Voltage	±1.0% of full scale ±1 V
Current	±1.0% of full scale ±0.1 A
Active power	±1% of full scale
Reactive power	±1% of full scale
Apparent power	±1% of full scale
Power factor	±0.2°C
Energy	Class 1.0
Frequency	±0.0 4 Hz (47-53 Hz)
Communication module parameters	
Type	RS485
Protocol	Modbus-RTU
Baud rate	9600
Stop bit	1
Parity	None
Isolation	2.5 kV_{rms} at 50 Hz for 1 min

Modbus communication protocol: Modbus is an application layer messaging protocol that provides client/server communication between devices connected on different types of buses or networks. Modbus is a request/reply protocol and offers services specified by function codes (Ahmed and Iqbal, 2012). Modbus can be implemented using TCP/IP over ethernet as well as serial transmission bus like RS232, RS422, RS485, etc. The Modbus protocol defines a simple Protocol Data Unit (PDU) independent of the underlying communication layers. Thus the underline communication hardware of an industrial network can easily be upgraded without any changes in the software protocol. Modbus also allows a device to communicate with several Modbus nodes at once, even if they are connected with different interface types. This eliminates the need to use a different protocol for every connection.

The request protocol string contains slave device address, a function code defining the requested action, any data to be sent and an error-checking field. The request frame has 8 bytes. The details of the frame are given.

Modbus request frame protocol:

- Slave address
- Function code
- Start address (MSB)
- Start address (LSB)
- No. of registers (MSB)
- No. of registers (LSB)
- Error check (LSB)
- Error check (MSB)

Slave address: Slave address is the address of the device being addressed. It can have any value between 1 and 247. Slave address 0 is used as broadcast address.

Table 2: Common public function codes for modbus

Codes	Descriptions
01	Read coils (bit)
02	Read discrete inputs (bit)
03	Read holding registers (word)
04	Read input registers (word)
05	Write single coil (bit)
06	Write single register (word)
07	Read exception status
15	Write multiple coils (bit)
16	Write multiple registers (word)
17	Report slave ID

Table 3: Device address and modbus address

Registers	Device addresses	Modbus addresses
Coils	1-10000	(Device address) 1
Input register	10001-20000	(Device address) 10001
Holding register	40001-50000	(Device address) 40001

Function code: Function code is the one byte code which specifies the action to be performed by slave. Code can have any value between 1-255, however, values from 128-255 are reserved for exception responses. In the available function code range (1-127), function codes from 65-72 and from 100-110 are user-defined function codes whereas the rest are public function codes. Code 0 is invalid. Common public function codes used in modbus are shown in Table 2.

Start address: The 16 bit starting address of the data register is sent in big-endian format, i.e., MSB is sent first and then LSB. The relationship between the modbus address and device address for coils, input registers and holding registers is shown in Table 3.

Number of registers: This is the number of 16 bit registers (words) being requested in the command. The number of registers is also sent in big-endian format.

Error check: This field is the 16 bit Cyclical Redundancy Check (CRC) data. The LSB of the CRC word is sent first. The response to the read request.

Modbus response frame protocol:
- Slave address
- Function code
- Byte count
- Data (MSB)
- Data (LSB)
- Error check (LSB)
- Error check (MSB)

To read all the electrical parameters in one command request, following string of 8 bytes is sent according to Modbus request frame protocol (Table 2).

Example of Modbus request frame protocol:
- 01 H
- 04 H

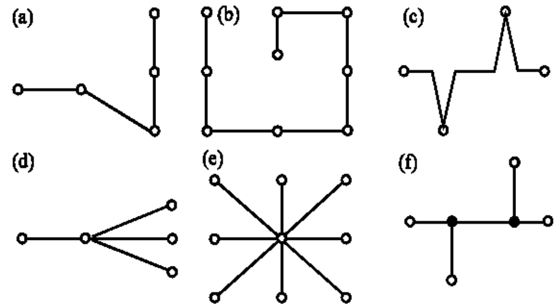

Fig. 1: a-f) RS-485 topologies

- 01 H
- 00 H
- 00 H
- 46 H
- CRC LSB
- CRC MSB

The energy meter responds by sending a string of 145 bytes.

Example of Modbus response frame protocol:
- 01 H
- 04 H
- 8 CH
- Data1, ..., data 140
- CRC LSB
- CRC MSB

The data 1-140 are the electrical parameter bytes as per the memory map of the energy meter used in the system. For example data 1 and 2 bytes are the MSB and LSB of phase 1 voltage respectively. Similarly data 41 and 42 byte represent the MSB and LSB of phase 1 current, respectively.

Different topologies may be used to physically connect different nodes/devices in the RS485 network. Some of the topologies are shown in Fig. 1a-c. Topologies offer superior transmission line performance as compared to those in Fig. 1d-f (Ministry of Power, 2016).

The energy meters were connected to the server through USB to RS-232/422/485 converter module (Make: ICP CON, Model: I-7561). I-7561 module contains self-tuner ASIC which automatically tunes to the baud rate and data format for the RS-485 network. This eliminates the need of direction pin for half-duplex data transmission.

RESULTS AND DISCUSSION

The energy information system was designed and implemented at Maharaja Agrasen College. The system faithfully captured the various electrical parameters in

Table 4: Instantaneous electrical parameters recorded by EIS

Data time	Mater addresses	Voltages	Current	PF	Frequency	kW	kVA	kVAR
19-01-2017 12:10:05	7	237	0.2	0.94	50.090	0.06	0.07	0.02
19-01-2017 12:10:04	6	237	0.2	0.76	50.110	0.05	0.06	0.04
19-01-2017 12:10:04	5	237	0.5	0.73	50.100	0.09	0.12	0.08
19-01-2017 12:10:03	4	233	4.7	1.00	50.110	1.28	1.28	0.00
19-01-2017 12:10:03	3	238	0.5	0.74	50.070	0.10	0.14	0.09
19-01-2017 12:10:01	2	234	4.6	1.00	50.090	1.23	1.23	0.00
19-01-2017 12:10:01	1	237	0.3	0.79	50.100	0.07	0.09	0.05

real time environment and simultaneously transmitted to the server using modbus protocol for real time monitoring, further analysis and archiving. A snapshot of the database file with captured parameters is shown in Table 4.

The EIS recorded the instantaneous parameters (line current, phase voltage, frequency, power factor, active power, reactive power and apparent power) and cumulative parameters (active energy, apparent energy, active power and apparent power) at regular intervals of 10 min. The custom designed PC Software monitored and logged the parameters in MS-access database.

The information about real-time energy parameters was matched with plug loads and the occupancy levels. The data obtained for laboratories was mapped with the energy load of respective laboratory time-table, so that, the actual energy use can be better managed. The data from cafeteria and hostel was compared with their standard usage hours and occupancy levels leading to a dynamic real time response to energy requirements.

CONCLUSION

The innovative energy information system implemented at Maharaja Agrasen College was used to measure and monitor the real time energy demand in various sub units of the college matched with respective time-table and occupancy levels. Using this systematic monitoring and precise matching of loads, energy consumption patterns of various sub-units were assessed. This system led to identify and minimise the wastage of electrical energy in each unit thereby leading to energy efficiency in the academic institute.

Information such as requirement of power factor correction device at various units was obtained which shall further improve the efficiency. The designed EIS can also be used to accurately estimate the wattage of power backup device required in various sub units.

The present EIS can be easily implemented in academic institutes with limited financial burden and minimum changes in the existing infrastructure. This system, on one hand enables the academic institutes to promote energy usage optimization and on the other hand helps increase energy awareness and stimulate academic fraternity to achieve the goal of improved energy efficiency there by reducing their carbon footprint.

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