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Wireless Energy Monitoring System for Hydro-Turbine Laboratory

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ABSTRACT: Due to the increasing demand of the energy and limited availability of fossil fuels efficient use of energy has become the need of time today. Commercial and residential buildings are major consumers of the energy in most of the countries. Buildings also account for large amount of carbon dioxide emissions, involved in the phenomenon of global warming. In order to meet the future requirements of the electricity and for the protection of environment, energy efficient design and operation of buildings is must.

A state-of-art hydro-turbine R&D laboratory is proposed to be established at the Indian Institute of Technology Roorkee, India.An energy monitoring along with automation which will ensure the thermal comfort, visual comfort of laboratory occupants and testing needs of the laboratory with optimum energy utilization has been proposed for this laboratory. A proto type energy optimizer model has been designed for this purpose. The energy optimizer designed includes different systems like energy monitoring, environment monitoring, lighting and ventilation automation systems. The energy monitoring is done with the help of ZigBee based wireless energy meters. The development of this meter andZigBee based energy and indoor environment monitoring wireless network is described.

Energy monitoring and control software has been developedin Lab VIEW which continuously monitors the indoor environment and energy consumption of different equipment / systems of the laboratory through wireless sensor boards and energy meters respectively.

I. INTRODUCTION

The demand for energy is growing fast. Current energy production methods are notsustainable for both resource and environmental reasons.Commercial and residential buildings during its life cycle consume large amount natural resources, consume lot of energy and have a tremendous adverse impact on the environment in terms of 'greenhouse gas' emission, a factor behind global warming. Buildings are responsible for at least 30% to 40% of energy use in most countries [1]. A hydraulic-turbine test laboratory is being setup at the Indian Institute of Technology Roorkee. With a main objective of performance testing of hydraulic turbines , it is proposed to design the building of this laboratory with several green features and apply energy efficiency measures to make it energy -efficient as well as green laboratory.

Along with different energy efficiency measures and green features, an energy optimizer is proposed to be designed for the laboratory. The prototype of this energy optimizer is a wireless energy monitoring system and is discussed in this paper. An energy optimizer discussed in this paper is an arrangement that will optimize the energy consumption in hydro-turbine test laboratory, without compromising the comfort level of the occupant and the testing needs of the laboratory. Before discussing these energy efficiency measures and energy optimizer, a brief overview of the hydro-turbine laboratory given below.

II. HYDRO-TURBINE LABORATORY

The other objectives of proposed hydro-turbine laboratory along with the performance testing of the hydraulic–turbines are, human resource development, training, R&D and instrumentation and design for small hydroelectric power plants. The other activities include testing for research and site problem analysis, erection and commissioning checks, design verification, validation of design and operation and maintenance of power plants.

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The laboratory includes four main sections basement, test hall, office/meeting room and control room of the laboratory. Basement is the section at the level of 3.5 meter below the ground. Major energy consuming equipment like different types of pumps required during testing, water chilling plant and air handling unit (AHU) of earth air tunnel (EAT) will be installed in the basement. This section is not air conditioned. Test hall at 2meters above the ground level will accommodate the turbine test-rig components and different measuring equipment required during testing. An earth air tunnel system is proposed for the test hall to maintain the desired temperature during testing. Split air conditioner systems are proposed for control room and office/ meeting room sections of the laboratory.

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III. ENERGY SAVING THROUGH AUTOMATION

Automation can play key role in energy efficiency enhancement of the laboratory building. Different controls can be used for lighting system, water chilling plant and AHU of EAT to reduce the energy consumption.

Lighting system is one of the major energy consumers in the laboratory building. To ensure minimum wastage of lighting two different type of controls are proposed for the laboratory. First control is the timer based control, where timers will be used to switch on and off lighting circuits for predetermined times decided depending upon the working schedules of the laboratory sections [2].

In the second arrangementit is proposed to use occupancy based control to reduce the consumption of lighting in the unoccupied areas of laboratory. The occupancy sensors will be placed to operate the lights in the basement and the areas like toilets, meeting rooms, office section and common corridors [9]. Light intensity sensors are proposed to sense the daylight available in the different sections of the building and put on or off the lighting according to the availability of daylight [3].

The control proposed for water chilling plant is the temperature based control where on off control of the motors of the chilling plant will be implemented to control the water temperature in the test loop. A timer control is also recommended which will ensure that the chilling plant will put on just few minutes before the actual testing starts and will put it off as soon as testing is over. Similar to chilling plant a timer based control is proposed for AHU of EAT putting it on just before the testing starts and put it off as soon as the testing gets completed.

IV. ENERGY MONITORING MODEL

The basic building blocks of the energy optimizer are shown in figure 1. It consists of four different systems like, energy monitoring system, indoor environment monitoring system, lighting automation and ventilation automation system. Energy optimization software developed runs on the desktop workstation in the control room of the laboratory. The energy optimization software monitors the energy consumption of major equipment and systems in the laboratory through respective energy meters networked through wireless ZigBee network. The control decisions of the energy optimization software are sent to the respective systems through RS-485/MODBUS protocol. The control decisions are based on minimization of energy consumption for the desired level of temperature, light intensity and humidity. These parameters are monitored with the help of ZigBee based Crossbow wireless sensor boards MTS400. Apart from this occupancy based lighting and ventilation control is also implemented.

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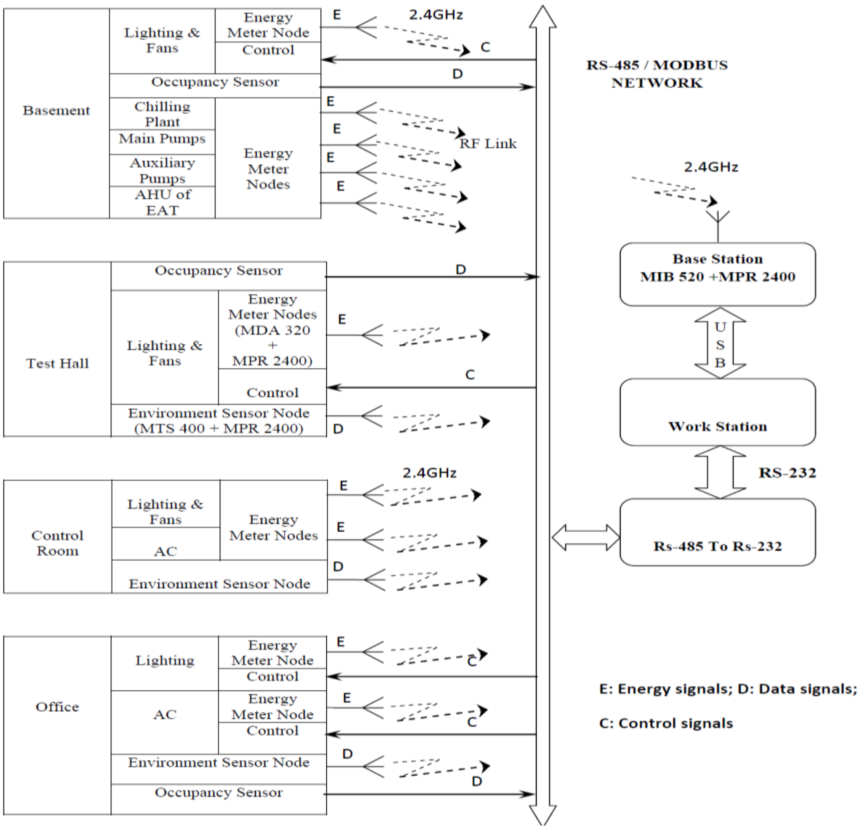

Figure 1: Energy Monitoring Model

V. WIRELESS ENERGY METER

Energy monitoring can play key role in the energy analysis by providing the energy consumption data of major individual equipment/systems in the laboratory. The first step in energy monitoring is to measure the energy at individual energy consuming nodes. Connect all these nodes at central data processing terminal with the help of network. It means the key element of this system is the energy meter. Conventional energy meters will not be suitable for this task as they do not have network ports.In this optimizer design to overcome this limitation, convectional energy meter isconverted in to network compatible energy meter. The block diagram of the wireless energy meter is shown in figure 2

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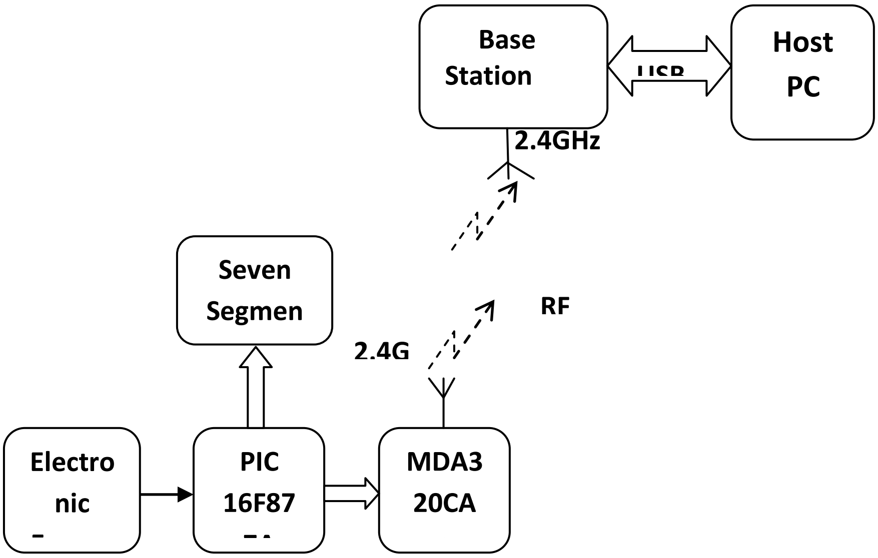

Figure2: Block diagram of wireless energy meter.

Energy meter is first interfaced with a PIC microcontroller 16F877A. It is a high performance RISC CPU with only 35 instructions and clock frequency of 20 MHz. It has 8K x 14 words of flash Program memory, 368 x 8 bytes RAM and 256 x 8 bytes of EEPROM Data Memory[4] .The energy read in the form of pulses from energy meter is stored as energy count in the EEPROM of microcontroller and the same is displayed on four digit seven segment displays interfaced with the microcontroller.

To make this energy meter network compatible, the Crossbow data acquisition card MDA320CA is interfaced with the PIC microcontroller.MDA320CA is a crossbow make data acquisition card, designed as a general measurement platform for the MICAz[5] . The data acquisition card reads the energy count available in the microcontroller. Crossbow Processor and radio platform MPR2400CA is programmed for reading the data from MDA320CA and transmit it in the form RF signal to the base station. The data acquisition card and the radio platform together form a node. The base station, the combination of crossbow USB interface board MIB520CB and MPR2400CA, interfaced with work station in the control room, receives this energy data.

The MIB520, a Crossbow interface board,provides USB connectivity to the MICA family of Motes for communication and in-system programming. It supplies power to the devices through USB bus. MIB520CB has a male connector while MIB520CA has female connector.The MIB520 has an on-board in-system processor (ISP)—an Atmega16L located at U14—to program the Motes. Code is downloaded to the ISP through the USB port. Next the ISP programs the code into the Mote.The MIB520CB offers two separate ports: one dedicated to in-system Mote programming and a second for data communication over USB.The MIB520CB has an on-board processor that programs Mote Processor Radio Boards. USB Bus power eliminates the need for an external power source [6]In this work, the MIB 520 is connected to PC through USB, which enabled the data streaming from MICAz (MPR2400) to be converted and made available for the monitoring software. This board also used for programming the radio processor module for the base station, sensor boards and data acquisition board.

LabVIEW(Laboratory Virtual Instrument Engineering Workbench) software is used for processing and displaying this data received from base station. The above developed wireless energy meters are used for monitoring the energy

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consumption of major equipment and systems of the laboratory. The schematic of the energy monitoring system is shown in figure 3Different equipment and systems whose energy is monitored in the different sections of the building are:
Basement: Lighting system, ventilation system, main pumps and auxiliary pumps; Test hall: Lighting system and Air-conditioner;Control room : Lighting system and Air-conditioner;Office/ Meeting room: Lighting and Air-conditioner

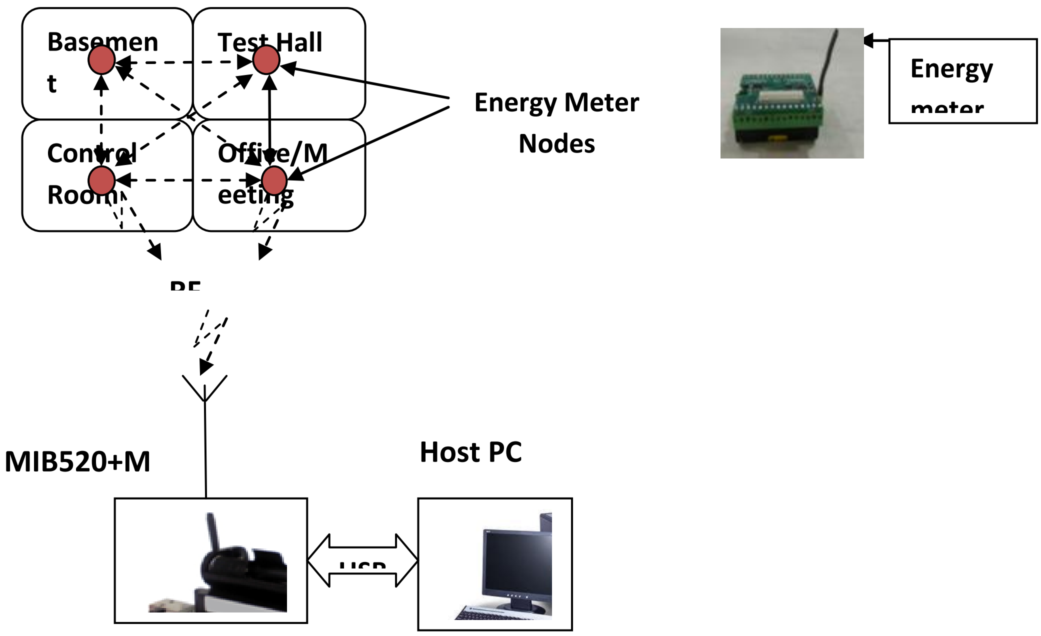

Figure: 3Energy Monitoring System

VI. ENVIRONMENT MONITORING SYSTEM

The aim of this system is to monitor the indoor environment parameters like temperature humidity and light intensity to ensure that values of these parameters are as per the comfort level of the occupant and testing needs of the laboratory.In order to monitor the indoor environmental parameters, crossbow sensor boards MTS400CA are used.The Crossbow MTS 400CA sensor boards utilize the latest generation of IC-based surface mount sensors [5]. These boards offer five basic environmental sensing parameters such as temperature, humidity, barometric pressure, ambient light and accelerometer.RadioProcessor MPR2400 and sensor board MTS400CA together form a sensor node. These nodes are placed at different sections of laboratory building like Test hall, Office/Meeting room and Control Room. Thesesensor nodes sense environmental parameters such as temperature, ambient light and relative humidity of the indoor environment of these sections and send these parameters to the base station (combination of Crossbow USB interface board MIB520and Mote Radio Processor MPR2400). The base station is interfaced with desktop workstation in the control room of the laboratory. Lab-VIEW GUIs developed, display this data on the screen of the workstation. Alerts are generated in case any parameter crosses the desired limit. The figure4 shows the scheme ofenvironment monitoring system

The light intensity data monitored through the wireless sensor nodes is used for lighting control of the respective sections. Thus according to the availability of the daylight artificial lighting is controlled resulting into energy saving, Temperature alerts generated can help the user in taking the appropriate action like set point adjustments of the of air-conditioning system and check the health status of the respective system/ equipment .

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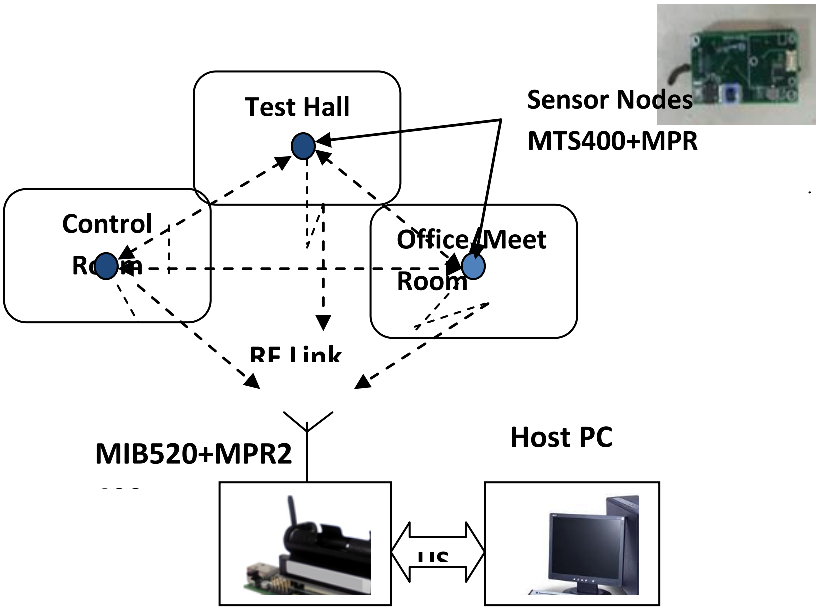

Figure: 4 Indoor environments Monitoring System

The output of humidity sensors indicates the relative humidity in the different sections of the building. Output of the sensor mounted in the Test hall is used to control the dehumidifier placed at the earth air tunnel outlet.

VII. LIGHTING MONITORING AND CONTROL

The lighting system is one of the major energy consumers inbuildings. As suggested in energy efficiency measures different controls if applied can reduce the energy consumption of the lighting system. The two important lighting controls implemented in this work are (a) Daylighting based control and (b) Occupancy based control.

(a) Day lighting Based Control

The day lighting control is implemented in this work with the help of day lighting sensors. The day light of different sections of the building like Test Hall and Office/Meeting rooms, is monitored with the help of crossbow sensor board MTS400CA. The light data received from wireless sensor is processed in the Host PC by the software written in LabVIEW. The sensed light output is compared with the desired light level (set point of visual comfort) and according to amount of day light available lighting system is controlled. In this work day lighting sensing is done with the help of wireless ZigBee based crossbow sensor boards. The control is implemented using wired RS-485/MODBUS protocol.

(b) Occupancy based Control.

Occupancy sensors are placed in these sections of the building. Occupancy sensor data is brought to the control room with the help of RS-485/ MODBUS. Control software written in LabVIEW processes this data and according to the status of the occupancy control signals are sent to put on the lights in the respective sections. If the space is not occupied, the lights will be on for a preset duration and will be off after the predetermined delay.. Apart from this, a main switch is provided in GUI to control the lighting system.

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VIII. VENTILATION AUTOMATION SYSTEM

It is proposed to design an Earth Air Tunnel (EAT) for Test hall. Hence there is no need of artificial heating during winter and artificial cooling in summer in the Test hall area. The EAT system will only need the Air Handling Unit and necessary ducting system for circulating the air from tunnel into the Test hall. The basement section is also not air conditioned. Split air conditioner systems will be usedfor control room and office/meeting room. Occupancy based control is used for the ventilation control in the basement and to control the air conditioner in the office/ meeting room. The software developed in LabViewhas also taken care of displaying the total energy consumption of all the equipment/systems under monitoring .Thus at a glance one can get the idea about the total energy consumption of all the systems of the laboratory . The GUI displaying the total energy is shown in figure 5

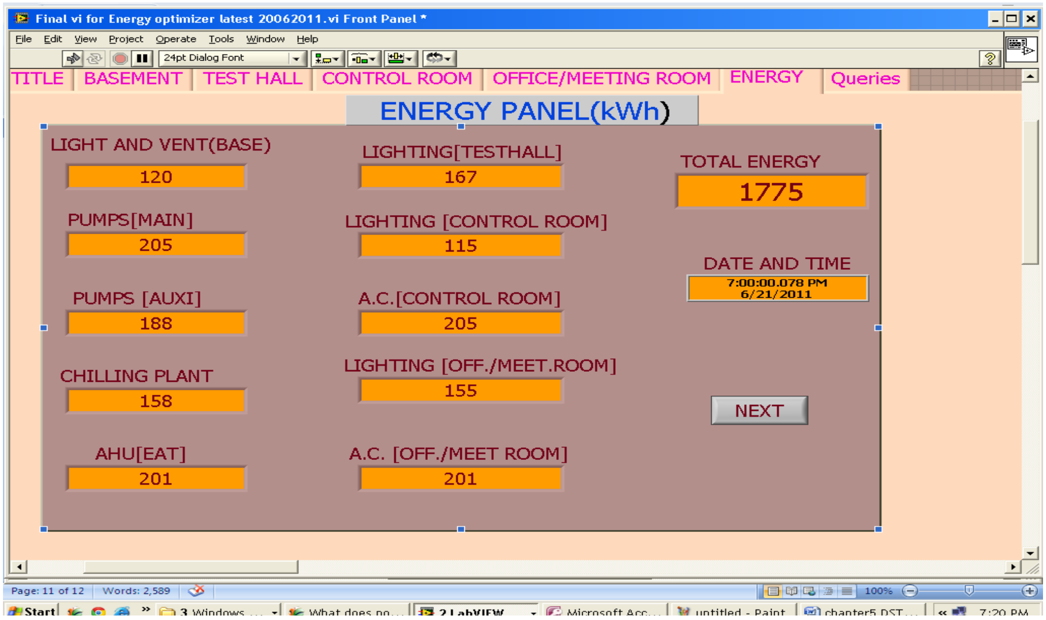

Figure 5LabVIEW GUI for Total energy display of the equipments and systems in laboratory

The control signal to actuate the lighting and ventilation are routed through RS-485/MODBUS protocol. The day light control is also implemented similar to the occupancy control. The status of these day light and occupancy sensor is shown in GUIs of individual section.

IX. CONCLUSIONS

There is huge scope for saving the energy consumption in buildings which are major energy consumers today. Different energy efficiency measures which can be applied to make the hydro-turbine laboratory more energy efficient has been critically discussed and suggested.An energy monitoring and control system developed in the work monitors the energy consumption of the major equipment and systems and indoor environment of different sections of the building and exercises different control to optimize the energy consumption for the desired comfort level of laboratory occupants and testing needs of the laboratory. To avoid Complexity and cost of cable wireless network is preferred for monitoring energy and environmental parameters. ZigBee protocol is used because of its ability to be configured in mesh network and offers ad hoc networking facility. To add the reliability in the control part of the optimizer RS-485/MODBUS

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protocol is used.LabVIEW GUIs are prepared for displaying real time energy consumption and status of environment parameters like temperature, light intensity and humidity.

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