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Lab-View Based Energy Optimizer for Hydro-Turbine Test Laboratory

Arun M. Dongardive

Assistant Professor, GCOE Jalgaon, India

ABSTRACT: A state-of-art hydro-turbine R&D laboratory is proposed to be established at the Indian Institute of Technology Roorkee, India. Efficient use of energy has become the need of time today due to the increasing demand of the energy and limited availability of fossil fuels. It is aimed to make the design and operation of laboratory building with such a features and measures which will make it energy efficient with minimum impact on the environment.
An energy optimizer software for the prototype is developed in Lab-View which not only monitor the energy consumption of the laboratory but also exercise control to optimize the energy consumption. The energy monitoring is done with the help of ZigBee based wireless energy meters and control is exercised through wired RS-485/MODBUS protocol. Details of the different systems of this energy optimizer are discussed in this paper.

KEYWORDS*:* Lab-View, ZigBee, wireless

I. INTRODUCTION

Present energy production methods are notsustainable for both resource and environmental reasons and the demand of the energy is growing fast. 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. Energy optimization can be one of the most significant factors in addressing the energy challenge. 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 developed 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.
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.There will be number of tangible and intangible benefits of this energy optimization and efficiency measures for the laboratory building. Tangible benefit will be reduced operating cost due to lot of energy saving. Intangible benefits will be the reduced impact on environment, enhanced occupant health, comforts, and improved productivity

II. ENERGY EFFICIENT GREEN DESIGN OF LABORATORY BUILDING

It is proposed to use several green building features to reduce electrical energy consumption in the laboratory building and also reduce its environmental impact. Along with this energy efficiency is proposed to be enhanced with the help of energy efficient equipment and advanced automation techniques. In order to suggest energy efficient green building model for the laboratory building energy simulation of the building model has been performed with design builder. All these measures and simulation are discussed in brief in the following sections.

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a.Energy Saving Through Green Building Measures

In order to make the laboratory building energy efficient and eco-friendly several green building measures are proposed. These measures include Passive solar design, passive daylighting, earth air tunnel system and use of different green materials and renewable energy sources.

Passive solar design is the combination of building features which can reduce or even eliminate the need of artificial heating and cooling. In this design takes into account the solar geometry and local climate [1] . The orientation of the laboratory building can be done such that maximum sunlight will be entering into the building during winter reducing the hating load and sun light will be blocked during summer reducing the cooling load.

Passive daylighting a concept of building design in which maximum daylight is allowed into the building with the help of windows or other day lighting features ,reducing the need of artificial lighting during daytime[3]. Some daylighting features which can be prefferd for laboratory building are, windows, skylights ,light shelf and light tubes.

In order to reduce or even eliminate the need of artificial cooling in summer and heating in winter, an eart air tunnel(EAT) system is proposed to be designed for the labopratory building.The daily and annual temperature fluctuations decrease with increasing depth of the earth and at about 4m below the ground, the temperature remains constant [5]. This fact is used in the EAT system. Air is forced through the pipes buried at about 4-m or more below the ground. The air will take away the heat from the earth during winter and will release the heat into the earth during summer. The AHU of this system will be similar to conventional heating ventilation and air conditioning (HVAC) system except heating and cooling coils will not be there. Thus energy required for heating and cooling can be reduced due to EAT.

Another green building measure proposed for laboratory building in order to make maximum utilization of renewable energy. A solar water heating system will be useful during winter season is proposed for office section of the building and solar lighting for the open spaces. Green materials offers different benefits to the building occupants like,reduced maintenance or replacement costs over the life of the building, maximum energy conservation, occupants health will be improved and alsogreater design flexibility will be offered [7].In order to reduce the impact of the laboratory building and its construction on the environment differentgreen materials will be used to the maximum possible extent. The different materials proposed to be used in a laboratory building can be fly-ash blocks, fly-ash cement, recycledaluminum, recycled steel, recycled tiles and nontoxic paints.

b. Energy Saving Through Energy Efficient Equipment

Energy efficiency of the building may be affected by the inefficient equipment used in the laboratory. These equipments will consume not only the extra energy but also can generate more heat increasing load on the cooling system. Therefore selection of equipments and their locations will be decided such that they will have reduced energy consumption and will not affect the load on cooling system.

Major energy consuming equipment in the laboratory are pumps, water chilling plant and AHU. All these equipment will be located in the basement which is not air conditioned. The sizing of the pumps will be decided as per the requirements of the laboratory application. Variable frequency drives will be used to change their speeds. The motors of the water chilling plant will be running at single speed but with on-off control for achieving a constant temperature of the water in the turbine test circuit, thereby achieving minimum cost and energy both..

In order to reduce the power required for fans in AHU to force the air through ducting system, pressure losses should be reduced. Lower friction factor, duct length and air velocity in ducts can decide the energy required for the fans to overcome the frictional losses [4]. It is proposed to make use of galvanized iron or aluminum sheets, which are smooth and have low friction factors, for ducting. Dynamic losses in the ducting will be minimized by using duct fittings that have lower loss coefficients. It will also be ensured that sudden changes in direction will beavoided and, wherever it is necessary, bends will be used instead of sharp elbows.

To check blockage of air filters placed in the AHU system due to dust particles getting accumulated on it is proposed to be detected with a sensor installed at filter giving the alarm when filter is required to be replaced. Energy savings can

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be achieved by replacing or cleaning the filter when the pressure drop reaches the maximum value allowed by the design [4].

As far as water chilling plant is concerned, it is proposed to use air chilling principle. To obtain maximum efficiency the chiller should be operated at 60 to 100% of its rated capacity, therefore the sizing of this chiller will be decided based on peak cooling load and will be always operated at its maximum rated capacity.
The energy efficiency of lighting systems and quality of the visual environment provided are determined by the selection of lamps, the architectural layout and the control [8]. The energy efficiency of the lighting system in the laboratory building will be achieved by using energy efficient lamps like compact fluorescent lamps(CFLs) which are having higher lamp efficacy compared to incandescent lamps. Their life is also longer about 8000 hours as compared to filament lamps having 1000 hours life [5]. In order to enhance the lighting utilization and avoid the wastages, painting of the interior of the building should be done such that it will act as good reflector, maximizing the lighting utilization.

III. ENERGY OPTIMIZER

An energy optimizer is proposed to be designed for the hydro-turbine laboratory. The main idea behind this optimizer design is to find out the energy saving opportunities by analyzing the energy usage patterns in the laboratory building. Unless one knows where and how exactly the energy is getting consumed in the building, it is not possible to find out the ways and means to optimize the energy consumption. For this purpose energy optimizer discussed in this section is an arrangement that monitors the energy consumption of major equipment / systems of the building and the energy data is collected at work station placed in control room of the laboratory. Energy optimizer software exercises certain control so as to optimize the energy consumption.

a. Energy Optimizer 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.

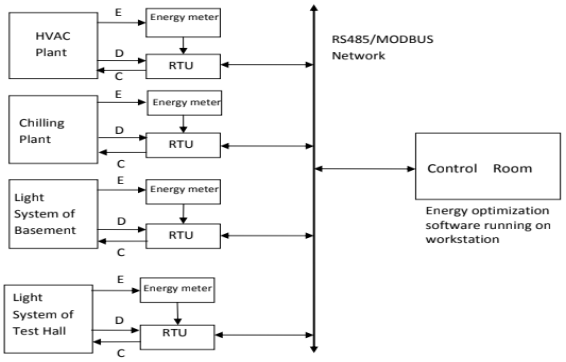

Figure 1: Energy optimizer model

b. Energy Optimizer Software

The basic aim of this software is to optimize the energy consumption in the proposed hydro turbine laboratory by ensuring the thermal comfort, visual comfort and air quality for the occupant and testing needs of the laboratory. For continuous monitoring of the energy consumption of the systems, software is developed in LabVIEW. It captures the

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online energy consumption data from the wireless energy meters and display it, along with date and time on the GUIs developed for user. The software compares the current energy data of the equipment's / systems under supervision with the base value (Ideal expected energy consumption) and generates the alerts for the user. With the generated alert user comes to know which equipment is consuming extra energy. By getting energy alerts one can diagnose the reason behind the extra consumption, whether it is due to the malfunctioning of the equipment/ system or failure of the control used. Thus it helps in diagnosing the health of the equipment/system. In the laboratory building ,equipment / systems whose energy consumption is monitored are, Lighting , ventilation and air handling unit of earth air tunnel in basement, lighting and air conditioner in control room, lighting system in test hall, lighting system and air conditioner in test hall. All the energy data is displayed on display panels developed for individual section. The GUI displaying the energy of basement section is shown in figure2

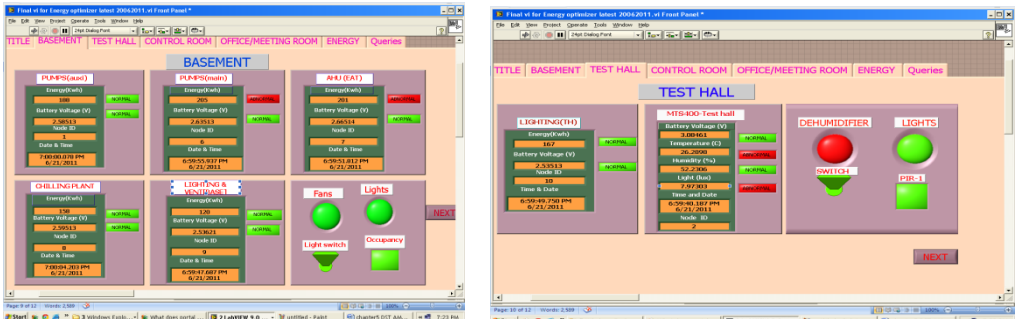

Figure :2 LabVIEW GUI for Energy monitoring of basement& Test Hall section

GUI displayed shows energy reading, battery status of the node and the date and time at which the data is received. The energy displays are provided for displacing energy consumption of main pumps, auxiliary pumps, fans(ventilation), chilling plant and air handling unit(AHU) of earth air tunnel(EAT) . This GUI also shows the status of the occupancy sensor and the status of lighting and fans (ventilation) in the basement. Depending on the status of occupancy the lights and fans in the basement are operated.

The energy optimizer also includes the indoor environment monitoring system. The software monitors the indoor environment parameters like temperature, humidity and light intensity. This monitoring is also done with the wireless zigbee based crossbow sensor boards MTS400CA. The purpose of this monitoring is to know whether above parameters are crossing desired comfort level of the occupants and the testing needsof the hydro-turbine laboratory. GUI in LabVIEW is developed to display these parameters and alerts are generated to inform the user about, which parameter is crossing the desired comfort value. Accordingly an appropriate action can be taken by the user to maintain the desired level of these parameters in the laboratory.

Similar GUIs for the control room and office/meeting room are shown in figure number 3

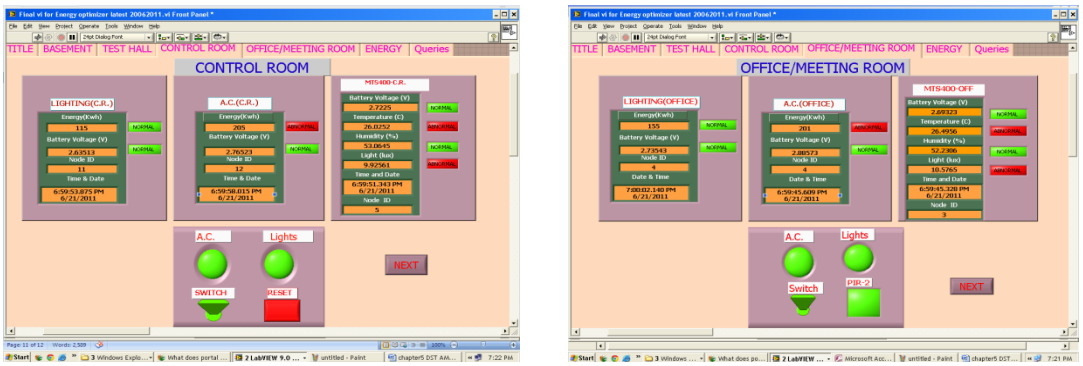

Figure:3 LabVIEW GUI for Energy and environment monitoring of Control& OfficeMeeting room

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The physical layer of communication system is an RS-485 two-wire network, chosen for its simplicity, low cost and adequate data bandwidth. The occupancy sensors are interfaced through this wired network and the sensor data is given to the pc through RS-232. This sensor data is read into the energy optimizer software written in LabVIEW. 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.

Thus the energy optimizer designed in this work gives the total picture of the energy consumption of major energy consuming equipments/ systems to the laboratory building administrator. Making the administrator aware about where exactly the extra energy is getting consumed. Depending upon this, certain preventive measures can be taken by the administrator to reduce energy consumption.

V. CONCLUSIONS

Different energy saving and sustainable measures are suggested for the proposed laboratory. An energy optimizer developed in the work for prototype monitors the energy consumption of the major equipment, systems in the different sections of the building using wireless ZigBee protocoland exercises different control to optimize the energy consumption for the desired comfort level of laboratory occupants and testing needs of the laboratory through RS-485/MODBUS protocol.

LabVIEW GUIs are prepared for displaying real time energy consumption and status of environment parameters like temperature, light intensity and humidity. A database in Microsoft access is created to store the history of the energy consumption of the building. These GUIs also includes the alerts generated in case of the energy and environment parameters are crossing the preset limits.

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