Exploring Energy Savings Potentials in a Building through Energy Audit & Implementing Occupancy Based Lighting Control Techniques

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Abstract: It is a concerted attempt in achieving improved lighting energy performances by measuring the occupancy status in a building. This study aims to highlight several opportunities to create and implement an energy management plan within a College Hostel Building in BRCM-CET campus. In this paper we have considered the academic sector for evaluation of energy audit and energy conservation of engineering college of BRCM CET Bahal. By measuring the occupancy status of deployed ultrasonic and PIR sensors the proper switching of the lights can be controlled and the lights turn off automatically when not in use. In order to reduce lighting energy use, the luminaries employed integral occupancy sensors.

Keywords: Energy Audit, Microcontroller, Occupancy Sensors, PIR Sensors, Ultrasonic Sensors.

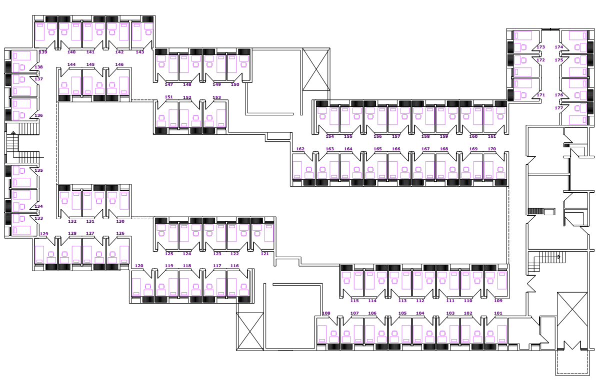
INTRODUCTION

An occupancy sensor turns lights ON automatically upon the detection of motion then turns the lights OFF automatically soon after an area is vacated. A vacancy sensor requires manual activation of the lighting by the occupant then turns the lights OFF automatically soon after an area is vacated. An occupancy sensor is a lighting or heating control device that detects occupancy of a space by people and turns the lights and/or Heating, Ventilation, and Air Conditioning (HVAC) system on or off automatically, using infrared, ultrasonic, microwave, or other technology. A careful audit in any organization will lead to manage energy system in organization at minimum energy cost. In development process to cope with increasing energy demands, energy conservation and energy audit are two parallel paths. Occupancy sensors are known by different names such as motion sensors or switches, movement detectors or even automatic light switches and presence detectors. There are 5 main different kinds of Occupancy sensors available in the market today based on the technology used to detect occupancy. These are PIR sensors, Ultrasonic sensors, Microwave sensors, CW Radar sensors and Thermal Imaging sensors. All the above mentioned technology sensors except for the thermal image processing sensor use the primary factor of motion or movement of an object as the key determinant to flag for occupancy. The application of these sensors has been mostly in the field of security, residential and industrial automation and electrical energy conservation.

PROBLEM FORMULATION

The parameters we consider here for the energy audit is to replace the conventional lights and fans installed in the hostel by the low power energy efficient lights and fans and it is further aimed that these lights and fans be switched ON/ OFF automatically by sensing the occupancy status of rooms, bathrooms and galleries using occupancy sensors to reduce the energy wastage.

- It is proposed that a general audit will be conducted for a college hostel building to calculate total lighting load of galleries, washrooms and individual rooms.
- The Fluorescent Tube Lights will be replaced by energy efficient LED bulbs of nearly same luminosity and less wattage values.
- A survey will be conducted to measure the lighting load during peak-hours when the human traffic is maximum as well as during idle hours i.e. during late night hours when the human traffic is minimum.
- The potential locations will be identified as per the survey data collected for high and low traffic zones.
- The type of sensor need to be deployed at a specific location.
- Design, development and testing of microcontroller based occupancy status measurement devices using PIR sensors and ultrasonic sensors to control switching of light bulbs.
- Deployment and Calibration of occupancy sensors as per the need of a specific location.
- To carry out the measurement of occupancy controlled lighting load consumption and do its comparison with conventional lighting load consumption.
- To find out the experimental results by calculating the net energy conservation achieved by the deployment of occupancy sensors and also find out the net cost reduction achieved.
- A survey will be undertaken to ensure that the installed lighting system has associated with higher occupant satisfaction.



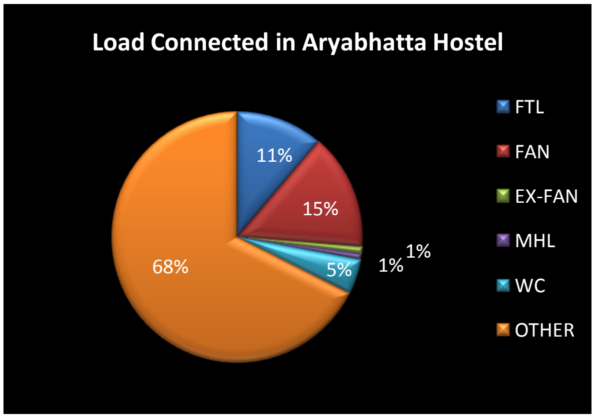


Figure-1 Architecture of Aryabhatta Hostel & Total Load Connected

PROPOSED WORK

Sr. No.	Area	Total Rooms	Total FTLs	C. Fans	E. Fans
1	Single Seated Rooms	240	240	240	--
2	Warden Office	1	1	1	--
3	Warden Room	2	2	2	--
4	Supervisor Room	1	1	1	--
5	Attendant Room	1	1	1	--
6	Galleries/ Lobbies	--	46	--	--
7	Bathrooms/ Toilets	6	18	--	6
8	Common Room	1	5	7	--

Table-1 Total Load of Potential Areas in Hostel Building

The lighting audit in Aryabhatta boy's hostel, BRCM-CET Bahal was set up to fill many of the gaps in the understanding of savings achievable with lighting controls. This work focuses on the energy savings possible through the use of occupancy and switching controls. The ground, first and second floors of the building were set aside for examining the energy savings and cost effectiveness of different types of lighting control systems in rooms, open day-lighted areas, galleries, office spaces. There are a total of 240 rooms on three floors of the hostel building. These zones have a size of 188 sq ft. The Fluorescent Tube Lights (FTLs) are available nearly everywhere as overhead fixtures in the open parts as well as rooms and offices. An approach to explore energy savings potentials in buildings through energy audit has been considered.

METHODOLOGY ADOPTED

Energy Audit

Total Load Consumption by FTLs
Load of single tube light = 36W
Luminosity = 2000+ lumens
Cost of tube light with fixture = Rs. 250
Total fluorescent tube lights fitted in academic block = 313
Total load of FTL available in academic block = 313*36W = 11.268kW
Number of FTL running at an average of 12hrs/day = 313
Estimating kWh for single FTL running 8hrs/day = (36W * 12hrs/day) / 1000 = 0.432 kWh
Total kWh for 313 FTLs running 8hrs/day = 313 * 0.432 kWh = 135.216 kWh
Total Kilowatt Hours of all FTLs per day = 135.216 kWh
Total Kilowatt Hours of FTL per year = (135.216 kWh/ day) * (300 days/ year) = 40564.8 kWh
Per year cost of running FTLs = (Rs.7/- per kWh) * (40564.8kWh per year) = Rs. 283953.6/-

Replacement of FTLs by 20W CFLs
Load of single CFL = 20W
Luminosity = 2000+ lumens
Cost of CFL with fixture = Rs. 115
Total CFL fitted in academic block = 313
Total load of CFL available in academic block = 313*20W = 6.220 kW
Number of CFL running at an average of 12hrs/day = 313
Estimating kWh for single CFL running 12hrs/day = (20W * 12hrs/day) / 1000 = 0.24 kWh
Total kWh for 313 CFLs running 12hrs/day = 313 * 0.24 kWh = 75.12 kWh
Total Kilowatt Hours of all CFLs per day = 75.12 kWh
Total Kilowatt Hours of CFL per year = (75.12 kWh/ day) * (300 days/ year) = 22536 kWh
Per year cost of running CFLs = (Rs.7/- per kWh) * (22536 kWh per year) = Rs. 157752/-

Replacement of FTLs by 18W LEDs
Load of single LED = 18W
Luminosity = 900
Cost of LED with fixture = Rs. 85
Total LED fitted in academic block = 313
Total load of LED available in academic block = 313*18W = 5.634 kW
Number of LED running at an average of 12hrs/day = 313
Estimating kWh for single LED running 12hrs/day = (18W * 12hrs/day) / 1000 = 0.216 kWh
Total kWh for 313 LEDs running 8hrs/day = 313 * 0.216 kWh = 67.608 kWh
Total Kilowatt Hours of all LEDs per day = 67.608kWh
Total Kilowatt Hours of LED per year = (67.608 kWh/ day) * (300 days/ year) = 20282.4 kWh
Per year cost of running LEDs = (Rs.7/- per kWh) * (20282.4 kWh per year) = Rs. 141976.8/-

Total Load Consumption by Ceiling Fans
Load of single ceiling fan = 60 W
Total ceiling fan fitted in academic block = 249
Total load of ceiling fan available in academic block = 249*60W = 14.940 kW
Number of ceiling fan running at an average of 16hrs/day = 249
Estimating kWh for single ceiling fan running 16hrs/day (60W * 16hrs/day)/1000 = 0.960 kWh
Total kWh for 249 ceiling fan running 16hrs/day = 249 * 0.960kWh = 239.4 kWh
Total Kilowatt Hours of all ceiling fans per day = 239.4 kWh
Total Kilowatt Hours of ceiling fans per year = (239.4kWh/day)*(300 days/year) = 71712 kWh
Per year cost of running ceiling fans = (Rs.7/- per kWh) * (71712 kWh/year) = Rs. 501984/-

Replacement of 60W Fans by 40W Orient PSPO Fans
Load of single ceiling fan = 40W
Total ceiling fan fitted in academic block = 249
Total load of ceiling fan available in academic block = 249*40W = 9.960 kW
Number of ceiling fan running at an average of 8hrs/day = 249
Estimating kWh for single ceiling fan running 16hrs/day =(40W * 16hrs/day) / 1000 = 0.64 kWh
Total kWh for 249 ceiling fan running 16hrs/day = 249 * 0.64 kWh = 159.36 kWh
Total Kilowatt Hours of all ceiling fans per day = 159.36 kWh
Total Kilowatt Hours of ceiling fans per year = (159.36 kWh/day)*(300 days/year) = 47808 kWh
Per year cost of running ceiling fans = (Rs.7/- per kWh)*(47808 kWh per year) = Rs. 334656/-

TESTING & RESULTS

Final Analysis of Collected Data

- **Analysis of FTL Replacement**

The difference between FTL and CFL in energy consumption = (40564.8 kWh 22536 kWh) = 18028.8 kWh
Cost difference between FTL and CFL = (283953.6-157752) = Rs. 126201.6/-
The difference between FTL and LED in energy consumption = (40564.8 kWh-20282.4 kWh) = 20282.4 kWh
Cost difference between FTL and LED = (283953.6-141976.8) = Rs 141976.8/-
The difference between CFL and LED in energy consumption = (22536 kWh-20282.4 kWh) = 2253.6 kWh
Cost difference between CFL and LED = 157752-141976.8) = Rs 15775.2/-

- **Analysis of Ceiling Fan Replacement**

The difference between 60W ceiling fan and 40W ceiling fan in energy consumption = (71712-47808) = 23904 kWh
Cost difference between 60W ceiling fan and 40W ceiling fan = (501984-334656) = Rs 106416.8/-

Testing of Ultrasonic Sensors for Occupancy Detection

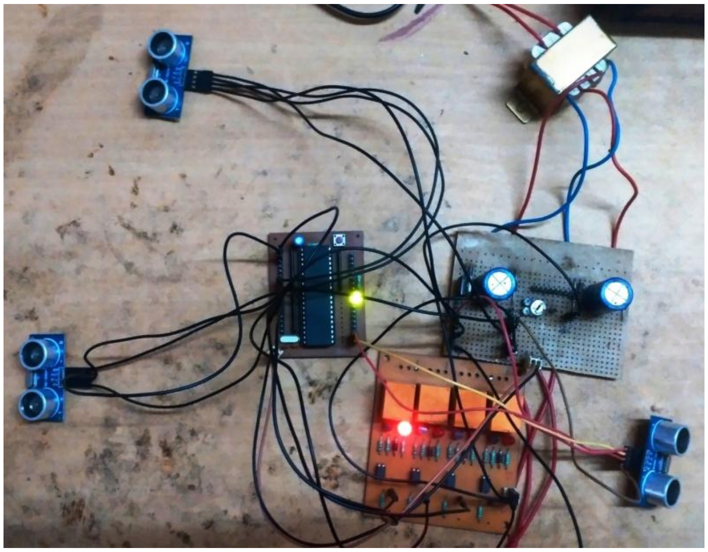


Figure-2 Testing of Ultrasonic Sensors

- Two ultrasonic sensors are correspondingly mounted onto the wall of a hostel room to count the number of persons moving to and fro in both the directions i.e. either the person will enter the room or exit the room.
- When any person enters in the room the counter value will be incremented and when a person is exiting the same counter value will be decremented in the program.
- The electrical appliances are connected to the relay and these relays are interfaced to the microcontroller. The relay will be triggered to switch OFF the electrical appliance only if the counter shows a zero otherwise the electrical appliance will remain ON.
- The PIRs mounted at different positions inside the room are according to the dimensions of the room and provides information about the presence of any person inside that room. Once the PIR is triggered the appliance will turn OFF if the person exits the room and if the two ultrasonic sensors mounted on the wall near the door detects the exit of a person from the room.
- The counter has been programmed to count with a fixed delay of 200ms to avoid any false triggering if two or more persons comes frequently inside the room or goes out of the room continuously.
- For optimum results the PIRs inside the room must be mounted with proper care so that it can cover the maximum room area.
- If due to some errors of continuous coming of persons the counter get decremented to zero ,the it will also depend on the PIR i.e. once PIR is triggered and if counter is zero it will incremented independent of the Ultrasonic values.
- If any person come with absorbent polymer seat which can absorb the ultrasonic waves, then counter will count in such a case because the distance between the door and the sensor is fixed in that case the distance is infinite and hence it will count.

Testing the PIR Sensors for Occupancy Detection

The most widely used sensors in the market in terms of utility, energy savings and cost savings are PIR (Passive Infrared) based sensors. These sensors detect human or automobile motion or movement and switches ON any electrical/electronic device to which it is connected to. One important aspect of PIR sensors is that the front end sensor is a passive energy component which implies that it does not actively emit energy in order to detect motion. Hence, during prolonged idle operations when there is little or no movement that is to be detected, these sensors are more energy efficient. Further, this feature attains higher prominence when these sensors are being used for electrical energy conservation through applications such as automated light switches since the self energy consumption of PIR control switches is minimal. So, here in this system the number of PIR sensors is deployed on a wall maintaining a significant gap to sense any human motion. The sensors are mounted in a hostel corridor to detect the occupancy status at night and to control the relays accordingly for the switching of the lights. The PIR sensors provide digital output and are therefore directly interfaced with AT89S52 microcontroller I/O pins. The overall status could be seen on a 2x16 line LCD screen that shows the number of times the PIRs were triggered when there is occupancy during night. Also it shows the total energy saved in percentage.

CONCLUSION

Thus occupancy sensors play a vital role in determining the occupancy status of an area and these can be well utilized to conserve energy. These sensors can be utilized to switch the lights ON/ OFF as per the occupancy status. These sensors are cheap, easy to install, and requires less maintenance.

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