

Performance of an Automatic Lighting Control System – A Case Study

Mark C. Tatum, MSEE, PE
Auburn University
Auburn, Alabama

One method of reducing the energy consumption in buildings is to reduce the usage of artificial lighting. Current LEED guidelines offer credits for the implementation of automated lighting control systems. This study investigates an office/classroom building where an automated lighting control system has been installed to evaluate how effective the system is after the system has been in use for several years. There are different types of systems currently being used which incorporate different automation components. The study revealed that building occupant knowledge and use of automatic lighting control systems can be a deciding factor for system effectiveness.

Key Words: Lighting Controls, Light Sensors, Automated Lighting Controls, Motion Sensors

Introduction

The M. Miller Gorrie Center (Gorrie Center) at Auburn University houses the School of Building Science. The building facilities include classrooms, faculty offices and conference rooms. When constructed in 2006 it received a Leadership in Energy and Environmental Design (LEED) gold certification and is in its fourth year of operation. Lighting associated controls may contribute to obtaining up to 40 points in LEED 2009 for New Construction and Major Renovations credit categories. Minimum LEED certification requires 40 points (Lutron, 2010).

Many states have now adopted energy codes. Many of these codes require compliance with the American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc. (ASHRAE) Standard 90.1 Lighting and HVAC Provisions. Under this standard, a point system is used and each type of lighting control system is awarded a certain number of points (Wattstopper, 2010a).

According to data compiled by the Energy Information Administration (EIA), electricity expenditures account for 72% of energy costs in educational buildings and of that, more than half is for lighting energy costs. The use of lighting controls can reduce these expenditures significantly. Expected savings from the use of occupancy sensors in classrooms alone can range from 10-50% (Wattstopper, 2010b). The EIA has estimated that the use of daylighting controls can result in savings ranging up to 40%.

The automated lighting controls installed in the Gorrie Center include three different operating systems including motion sensors, a daylight harvesting system, and a programmable on/off controller. This research focused on the functionality of the programmable control system to determine how effective it is as an energy saving tool. The three systems are described below.

In the first system, individual offices have motion sensors which control local lighting according to sensed occupancy. If no motion is sensed for a preset time, the lights in the office are turned off. Upon sensing motion, the lights are turned on. This system is simple and quite effective in reducing power consumption by turning off lights when they are not needed.

The second system type installed in the building is commonly referred to as a daylight harvesting system (daylighting controls) and is installed in classrooms which have exterior windows. Light sensing photoelectric cells are placed in the ceiling several feet from exterior walls that contain windows. If outside daylight is providing sufficient lighting in this area, the row of lights along the exterior wall is turned off. This system is automatic and can be effective if it is not defeated by the closure of window blinds which block the outside light. Window blinds have been installed in the Gorrie Center and are often closed due to the use of projection screens for classroom presentations. This was considered a design issue and would require relocation of the projection screens, replacement of projectors with higher output units, or some other physical modifications to keep outside daylight from becoming a problem while still allowing it to supplement the interior artificial lighting.

The third system type installed in the Gorrie Center utilizes a programmable control unit to turn off lights in classrooms and corridors according to a programmed time of day schedule. Pushbuttons are installed in areas controlled by this system to override the system if occupancy is necessary “after hours”. This system requires some knowledge of building occupants to operate and requires programming changes after initial installation should the anticipated usage schedule change. This system became the primary focus of the study. It is most dependent on operator intervention after initial installation to maintain proper operation.

Methodology

In order to test the effectiveness of the programmed lighting control system, monitors were placed in 6 classrooms for a period of one month. The monitors used were model IT-200 produced by The Watt Stopper, Inc. These monitors sense both occupancy via a motion sensor and lighting on/off status via a photocell. A log is created which records time of day and the status of artificial lighting (either on or off). The log also records data reported by the occupancy sensor and reflects whether the space is occupied or vacant.

One sensor was placed in each room. The motion sensor portion of the sensor did not have sufficient coverage for the entire area so some errors could be introduced if the room was partially occupied. Since these rooms are classrooms, it was not felt that this type error would be significant. The sensors were placed to cover areas most likely to be occupied and covered entrances. There is a 5 minute time delay set for the motion sensing, and some errors due to inactivity could be detected and corrected in the data.

The light sensing portion of the monitor was attached to one lighting fixture in the room. The placement was checked to make sure outside lighting would not cause a false signal when lights were turned off. The fixture monitored was not included in the daylight harvesting system and was not part of the emergency lighting system, but was connected to the general room lighting that is controlled by the programmed lighting system.

In order to calculate costs associated with the classrooms, the data presented uses the actual quantity and power consumption of the lighting fixtures installed in the rooms. An average cost of 11 cents per kilowatt-hour was used to determine the costs.

Data

Room 205 is a 35 seat classroom with desktop computers. It contains twenty 3-lamp fluorescent fixtures utilizing a total of 1920 watts of electrical input. It was monitored from February 8, 2010 to March 5, 2010. Of the total elapsed time (564 hours), the lighting remained on with the room vacant 44% of the time. Figure 1 below shows the breakdown of the three basic conditions: on and occupied, on and vacant, off and vacant. Based on the measurements, the estimated annual energy cost to power the lights with the space unoccupied is approximately $765.

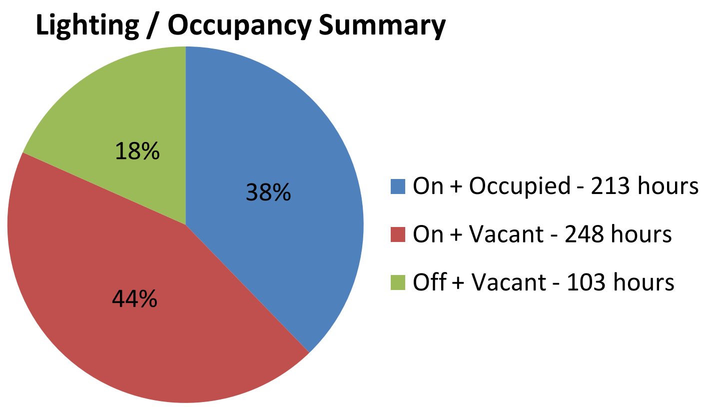

Figure 1: Room 205

Room 227 is a 60 seat classroom with tables and chairs only – no computers installed. It utilizes twenty four fluorescent lighting fixtures consuming 2304 watts. It was monitored from February 8, 2010 to March 5, 2010. Of the total elapsed time (593 hours), the lighting remained on with the room vacant 60% of the time as shown in Figure 2 below. Based on the measurements, the estimated annual energy cost to power the lights with the space unoccupied is approximately $1,316.

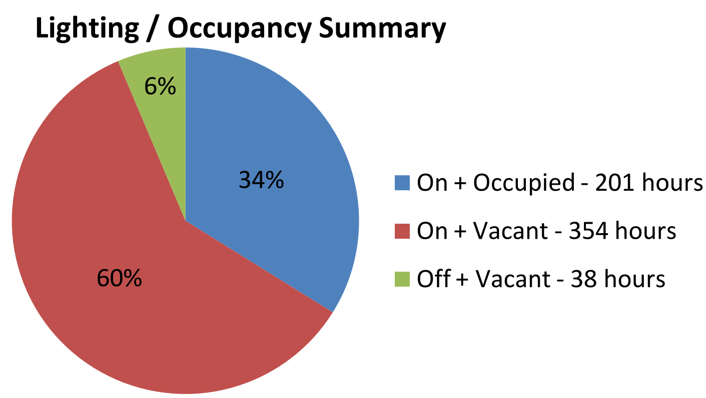

Figure 2: Room 227

Room 303 is a 30 seat classroom with tables and chairs only – no computers installed. It utilizes sixteen fluorescent lighting fixtures consuming 1536 watts. It was monitored from March 5, 2010 to April 2, 2010. Of the total elapsed time (643 hours), the lighting remained on with the room vacant 43% of the time as indicated in Figure 3 below. Based on the measurements, the estimated annual energy cost to power the lights with the space unoccupied is approximately $615.

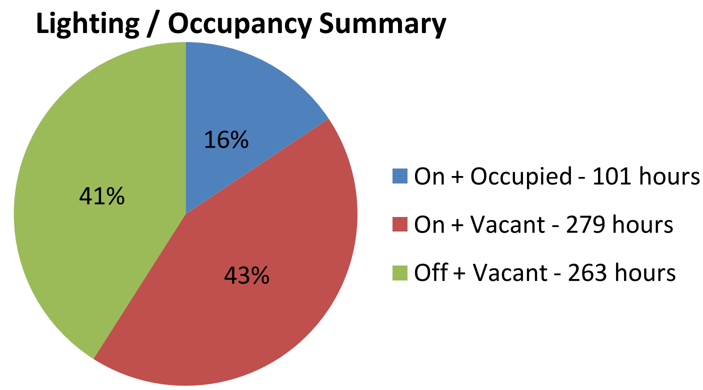

Figure 3: Room 303

Room 307 is a 20 seat classroom with desktop computers. It utilizes twelve fluorescent lighting fixtures consuming 1152 watts. It was monitored from March 5, 2010 to April 2, 2010. Of the total elapsed time (662 hours), the lighting remained on with the room vacant 61% of the time as shown in Figure 4 below. Based on the measurements, the estimated annual energy cost to power the lights with the space unoccupied is approximately $674.

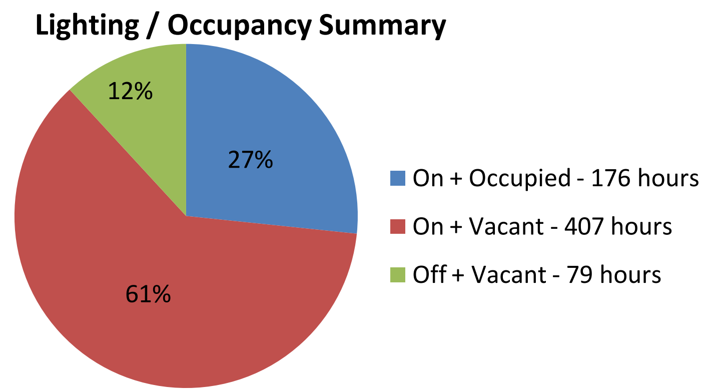

Figure 4: Room 307

Room 325 is an 8 seat computer peripheral room with desktop computers, printers, plotters and scanners. It utilizes four fluorescent lighting fixtures consuming 384 watts. It was monitored from March 5, 2010 to April 2, 2010. Of the total elapsed time (670 hours), the lighting remained on with the room vacant 69% of the time as shown in Figure 5 below. Based on the measurements, the estimated annual energy cost to power the lights with the space unoccupied is approximately $253.

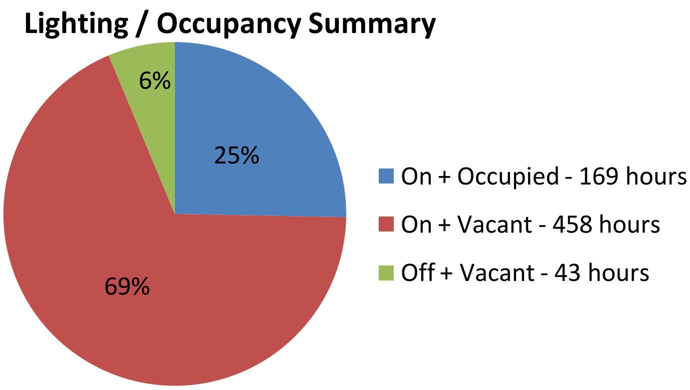

Figure 5: Room 325

Room 327 is a 25 seat senior thesis work room with desktop computers and larger work areas. It utilizes twenty five fluorescent lighting fixtures consuming 2400 watts. It was monitored from February 8, 2010 to March 5, 2010. Of the total elapsed time (597 hours), the lighting remained on with the room vacant 64% of the time as shown in Figure 6 below. Based on the measurements, the estimated annual energy cost to power the lights with the space unoccupied is approximately $1,486. Since this room is the largest room and is often partially occupied, its data is more prone to error due to insufficient occupancy coverage. Where this was evident, appropriate corrections were made to the data.

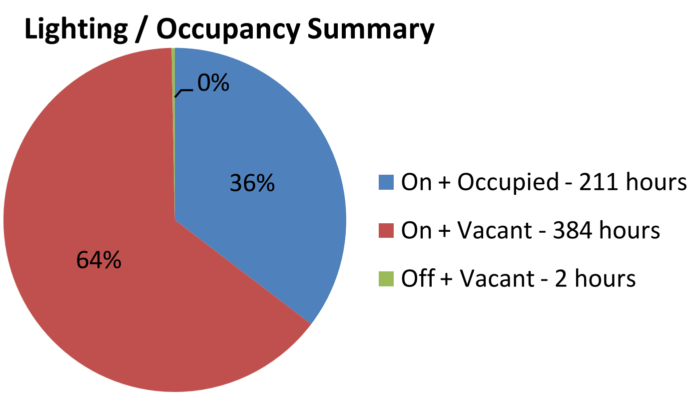

Figure 6: Room 327

The following Figure 7 shows an overlay of the average "on" and "occupied" data during 24 hour weekday periods for room 227. This was typical for all the rooms and reflects a failure of the programming to turn the lights off even during night time hours. This is further explained in the conclusions.

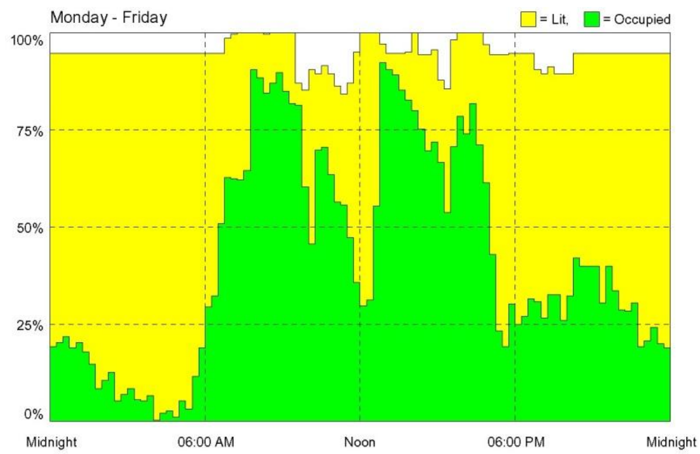

Figure 7: Room 227 Average Usage

Results and Conclusions

The investigation revealed that for the Gorrie Center, two of the lighting controls systems worked satisfactorily – the office motion sensor system and to a lesser degree the daylighting controls. The main control system used for the classrooms is a time of day system and did not provide satisfactory service. During the course of the investigation one of the time of day system control panels was found to have a defective battery where all programming had been lost. The other panels were also found to lack a proper schedule program. This resulted in lighting that remained on most of the time.

The failure of the time of day system can be traced to two deficiencies in the Gorrie Center. One was lack of routine maintenance to maintain the battery function which retains programming during power outages. The other problem was lack of knowledge of the building occupants in the operation and programming of the system. The study found that at the time the building was completed, the contractor did provide the specified time of day programming but none of the occupants had ever received any training in the operation or programming of the system. The university facilities division has a centrally programmed lighting control system which covers many campus buildings; however, the Gorrie Center is not connected to this system. Had this been done, the failure of the program would have likely been corrected.

The overall energy which could have been saved for all the classrooms in the study totals $5,109 annually. The original program allowed lighting to be on from 6:00am to 10:00 pm daily and turned them off at night. From Figure 7 it is evident that a large part of the wasted energy was due to failure of the program to turn off lights after hours. Even if the program had not failed, it is also evident from Figure 7 above that energy is wasted during the normally programmed "on" hours. The authors decided to modify the data and recalculate the savings as if the original program had been functional – turning lights off between 10 pm and 6 am. The revised results for all 6 rooms combined can be found in Figure 8 below.

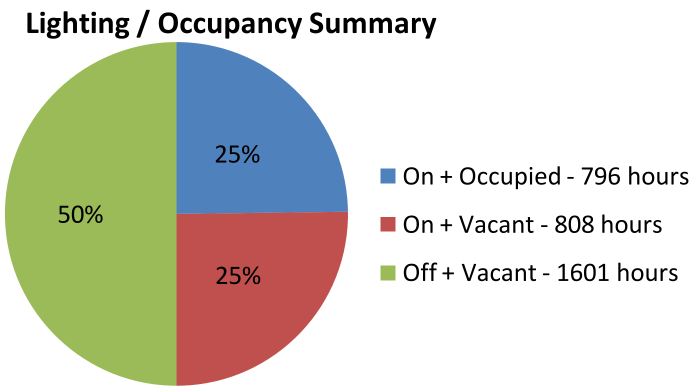

Figure 8: All Rooms Combined With Original Programming in Place

Even if the programming had not been lost, and if the system were connected to the campus facilities system (which would implement the same time of day programming remotely) a savings of $1,844 annually would still be obtained by turning lights off when the classrooms are vacant during normal "on" hours.

The study further concluded, through talking with several of the professors who use the classrooms, that even though the rooms have a means to manually turn off the lighting when not in use, the lights are not turned off because occupants know there are automatic controls and they rely on that for energy savings. As a result, this study indicates that for the Gorrie Center, the time of day controls utilized in the classrooms are ineffective as an energy saving feature. In fact, lack of occupant knowledge of the system, has likely resulted in additional energy being used during the day due to the fact that the system is in place (by not manually turning lights off).

The existing classroom time of day system should be replaced with an occupancy sensor system which turns lights off anytime classrooms are unoccupied for a preset period of time. The existing time of day control panel can be used and motion sensors added to the existing system to provide this function. It is estimated that the average size classroom would require 4 motion sensors at an estimated cost of $600 installed. Building occupants should be trained in the system operation and someone should be capable of programming the system. Periodic testing should be scheduled to ensure continued operation. The upgrades to the system under the current circumstances are estimated to result in savings that would pay for the upgrades in 1 year or less.

References

Lutron (2010). Energy Codes, Rebates & Incentives. Retrieved on September 5, 2010. URL: http://www.lutron.com/Education-Training/EnergyCodes/Pages/LEED.aspx

Wattstopper (2010a). Technical Bulletin Issue #TB113. Retrieved on September 8, 2010. Available at: http:/www.wattstopper.com

Wattstopper (2010b). Lighting Control Best Practice Guide - Schools. Retrieved on October 25, 2010. Available at: http:/www.wattstopper.com