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Lighting Control System in a Building Using Dynamic Daylight and Occupancy Analysis

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Abstract—*Intelligent building design is the future of building industries and most of the modern public and residential buildings are planned with an objective to decrease expenses by reducing the consumption of energy. Enhancing energy preservation techniques and using approach to sustainable design are necessary factors in developing the field. Eight quality condition components are considered as primary factors for environmental effectiveness of a building namely space flexibility, cost-effectiveness, client comfort, working efficiency, safety, culture, and technology and environmentally friendly. In recent years, the trend of intelligent buildings (IBs) has become increasingly popular due to their potentials for deploying design initiatives and emerging technologies towards maximized occupant's comfort and well-being with sustainable design. However, various definitions, interpretations, and implications regarding the essence of IBs exist. Various key performance indicators of IBs have been proposed in different contexts. This study explores the notion of IBs and presents an analysis of their main constituents. Through a comparison of these constituents in different contexts, this study aims to extract the common features of IBs leading to an evolved definition which could be useful as a reference framework for design, evaluation, and development of future IBs. Findings also scrutinize the long run benefits of IBs, while demonstrating the constraints and challenges of the current international interpretations. A room under consideration is equipped with passive infrared sensors, LDRs, presence detectors or occupancy sensors giving output as either low or high i.e. 0 or 1 for the presence and absence in an area providing signals to the microcontroller for switching operations using firmware resulting in effective saving in energy consumption.*

Introduction

The Intelligent Building Institute of the United States defined an intelligent building as one that provides a productive and cost-effective environment through optimization of its four basic elements, including: (1) structures, (2) systems, (3) services and management, and (4) the interrelationships between them. The UK-based European Intelligent Building Group defines an intelligent building as one building that creates the environment that maximizes the effectiveness of its occupants, while at the same time enables the efficient management of resources with minimum life-time costs of hardware and facilities. The concept of intelligent building is to develop building automation and management systems (BAS/BMS) for building management staff who can gain access to any building system via the BAS/BMS to accomplish the goals of monitoring, real-time control, and condition-based maintenance inside the shift duty room. Learn more in: Extend the Building.

Key Benefits of Smart Buildings

Smart buildings integrate technology and the IoT to provide solutions to the age-old issues of overspend and inefficiency in building construction and use. Within a smart building all the systems are connected, from air conditioning to security and lighting.[6] With the use of sensors, such as occupancy and people counters, actionable data about how the buildings is really used can be gathered to enable it to perform better. These are five of the key benefits of smart buildings:

i. Reduce energy consumption: Figures vary depending on systems and buildings, but you could reduce the energy consumption in a building by around 5% -35% with the use of smart technology. This translates into significant financial savings, as well as a much more efficient and effective approach to meeting green goals.

ii. Improve building efficiency: Appropriate sensors provide data about how the building is being used. This enables smart systems to make adjustments about where heat and light are required, for example, and on the use of infrastructure such as air conditioning. Sensors also help to identify overused and underused areas in the building, providing the opportunity to optimize space utilization, which in turn can facilitate growth.

iii. Predictive maintenance: Maintenance costs can be substantial when handled manually. However, without maintenance building equipment requires far more frequent replacement, which takes chunks out of budgets. Smart buildings enable simpler predictive maintenance. Sensors can detect building performance and activate maintenance procedures before an alert is triggered. When we have a more insightful overview of how the building is operating and used it's far easier to implement maintenance at the right time.

iv. Increase productivity: Smart buildings have been specifically designed to deliver a more comfortable experience for their occupants. They can raise standards and ensure that health and safety considerations are being met, as well as ensure that this is implemented in a cost- efficient way. Smart buildings make people more productive by continually monitoring building use and adjust systems to ensure that occupants have the facilities that they need.

v. Better use of resources: The data generated by a smart building provides key insights that can be fed into planning and make use of resources more efficient. There removes the need to rely on guesswork or anecdotal data as this can be informed by real-time, genuine intelligence.

Characteristics of smart buildings

i. **Target based efficiency performance on given aspect concerned with any sort of energy:** A builder group generally own a number of buildings and for every new building smart parameters take reference of earlier building and tend towards further improvement.[7]. The photograph shows a typical building utilizing its inclined roof fitted with solar panels facing south in order to get maximum solar energy incident on solar panels and provision of sunlight entry in the building.

ii. **Data Storage and Consistency:** Data storage and the consistency of information is one of the most critical aspects to having a smart building. How data is stored and entered, including terminology and nomenclature, can make or break an organization's analytical capabilities. The adage that garbage in equals garbage out is true for building data, and intelligent properties have systems that can limit those issues.

iii. **Software and Analytics:** Along with data storage is the need to analyze information in meaningful ways. Software continues to be a key part of any intelligent building, converting raw data points into virtually any output imaginable. Financial analysis, reporting, scenario testing—these are all driven by software and high-level analytics.

iv. **Energy and Sustainability:** The ability to control energy use is also a part of an intelligent building. Today's HVAC, water and electricity systems are less about monitoring as they are about controlling and adjusting for environmental factors throughout the day. This "active" energy control is becoming more common in commercial properties, with realized energy cost savings.

v. **Environmentally friendly:** sustainable design for energy and water conservation; effective waste disposal; zero pollution.

vi. Space utilization and flexibility.

vii. Value-giving quality for economic whole lifetime costs.

viii. Human health and well-being.

ix. Working efficiency and effectiveness.

x. Safety and security measures – fire, earthquake, disaster, and structural damages.

xi. Culture; meeting client expectations.

xii. Effective innovative technology.

xiii. Construction and management processes.

xiv. .Health and sanitation.

Sensors used in smart building

Thermal sensors: Temperature sensors measure heat to detect changes in temperature. They've been used for years to control things like heating and air conditioning but, thanks to the emergence of the Internet of Things, have found many more uses. For example, many machines used in manufacturing and computing are sensitive to temperature and have to be protected from overheating. With smart temperature sensors, businesses can automate heating, ventilation and air conditioning controls to maintain ideal conditions and automatically detect failure or faults as they happen. Not only is the right temperature vital to people's comfort, it can also prove dangerous. Anyone in control or a business premises or renting out a property has a responsibility to reduce the risk of exposure to legionella. The bacteria can spread in hot and cold-water systems and can thrive if water in any part of the system is between 20 and 45°C.

Humidity sensors: Humidity, also known as relative humidity, is defined as the amount of water vapor in the atmosphere. Just as many machines don't tolerate certain temperatures, humid conditions also present difficulties. Too much moisture in the air causes condensation, which can cause some machinery to corrode. Humidity sensors let you maintain ideal conditions and take action straight away if there's a change. In homes and business, they're used to control heating, ventilating, and air conditioning systems. They're used in manufacturing plants, hospitals, museums, greenhouses and weather stations any environment that's sensitive to moisture.

Motion / occupancy sensors: Motion sensors pick up on physical movement – whether that's a person, animal or object – in a given area and transform that information into an electric signal. Motion detection has been used in the security industry for years to alert businesses to intruders. They're found in appliances we use every day, like automatic doors, toilet flushes and hand dryers. And they can also be used to automate building controls like heating and lighting depending on whether or not a space is occupied – helping to reduce both energy consumption and running costs. Lately though, they've found a further use: helping businesses understand how rooms and spaces are used. By detecting the presence of people or objects in real time, occupancy sensors allow organizations to understand which spaces get the most use, or know which desks or meeting rooms are available at any one time. In a large organization, being able to use space more efficiently can lead huge cost savings, not to mention increased productivity. Motion or occupancy sensors work by detecting infrared energy or by sending out ultrasonic waves or radio waves and measuring their reflection off a moving object. We currently supply under-desk passive infrared (PIR) motion sensors. These small, wireless device two slots made of a material that's sensitive to infrared light. When the sensor is idle, both slots detect the same amount of ambient infrared radiation. When a person enters the sensor's field of view, the movement reaches one half of the sensor before the other. It's this change between the radiations detected by the two slots that tells the sensor someone is present.

Contact sensors: Contact sensors are also known as position or status sensors, or building monitoring sensors. Contact sensors are a simple way to tell whether a door, window or other similar mechanism is open or closed. The sensors come in two pieces one that's fixed to the door or window and another that's fixed to the frame. The two parts use magnetic fields to detect when they're touching (meaning the door or window is closed) and when they're moved apart (as the door or window is opened).For a range of reasons, including safety, security and energy efficiency, it's useful to know what's going on around your building at any one time. Building monitoring using contact sensors lets you see the live status of doors and windows around your building, including doors on cupboards, cabinets and fridges. You can automatically detect unlocked doors or cabinets, open or broken windows or a presence in a room, and automate building controls based on live occupancy.

Gas / air-quality sensors: Gas sensors are used to monitor changes to air quality and detect the presence of various gases. They're used to monitor air quality, detect toxic or combustible gases, and monitor hazardous gases in manufacturing, pharmaceutical, petrochemical and mining industries. Depending on use, you could monitor carbon dioxide, carbon monoxide, hydrogen, nitrogen oxide, oxygen, air pollution or gas. While many applications are concerned with safety, the effects of poor air quality aren't always severe, or even that easy to spot. In today's well-insulated buildings, rising carbon dioxide levels can lead to stale, stuffy air and complaints like tiredness and headaches. It can affect people's comfort and wellbeing as well as productivity. And seeing as employers have a responsibility to provide a healthy working environment, it's not surprising more businesses are using environmental monitoring to maintain temperature and air quality.

Electrical current monitoring sensors: Electrical current sensors measure real-time energy consumption at a circuit, zone or machine level. Knowing how much energy is being used has two main uses. Firstly, one can identify where you use and waste the most energy, allowing one to make savings. One can also automatically switch off assets when they're not in use.

Sensors finding application in smart lighting of a smart building

Smart buildings technology helps us make smart decisions about space. One probably doesn't need to tell us that your office space is under-utilized. Take a walk around your building and the fact becomes obvious: half or more of your workspace sits empty at any given time. So, we are not only wasting money heating and cooling a space that no one is using, we are wasting a lot more money paying for that space. That's what's driving so many companies to move to smart workspaces with a non-assigned seating model. These agile work environments are designed to provide the right number of work points based on actual utilization patterns. Instead of assigning each person to a cubicle or desk, each team is assigned to a "neighborhood" and people choose a spot to work each day. Or even better, move around throughout the day to task-specific spaces like meeting rooms, quiet desks for focus work, or collaboration spaces. That means no more wasted space: one can reduce the size of his office space, or avoid taking on additional space one doesn't need.

Occupancy sensors

It uses tracking technology provide intelligence about how our space is actually being used in real time. That data helps you make the best possible use of our space, which can save millions. Figure shows a typical occupancy sensor or presence detector.

A presence detector will give its output high (1) in digital form if even a single person is present whereas if nobody is present in a given area then it will give output as low (0) and digitally it is used for switching lighting circuits on and off respectively. Tracking utilization data allows companies to accurately pinpoint which parts of their property portfolio are working for them, and address problem areas. For example, a recent study at one of our large financial clients found booked meeting rooms are only used 50% of the time. This smart building technology provides concrete, indisputable data to support decisions to consolidate footprint or move to modern agile workspaces that are significantly more efficient and provide a better employee experience.

PIR sensors

It works on heat difference detection, measuring infrared radiation. Inside the device is a hydroelectric sensor which can detect the sudden presence of objects (such as humans) who radiate a temperature different from the temperature of the background, such as the room temperature of a wall.

Environmental sensors, such as temperature, humidity and CO2 sensors which detect the change in the environment due to the presence of a human.

Ultrasonic sensors, similar to radar. They work on the doppler shift principle. An ultrasonic sensor will send high frequency sound waves in area and will check for their reflected patterns. If the reflected pattern is changing continuously then it assumes that there is occupancy and the lighting load connected is turned on. If the reflected pattern is the same for a preset time then the sensor assumes there is no occupancy and the load is switched off.

Microwave sensors. Similar to the ultrasonic sensor, a microwave sensor also works on the doppler shift principle. A microwave sensor will send high frequency microwaves in an area and will check for their reflected patterns. If the reflected pattern is changing continuously then it assumes that there is occupancy and the lighting load connected is turned on. If the reflected pattern is the same for a preset time then the sensor assumes there is no occupancy and the load is switched off. A microwave sensor has high sensitivity as well as detection range compared to other types of sensors.

Keycard light slots, used in a hotel energy management system to detect when a hotel room is occupied, by requiring the guest to place their key card in a slot to activate lights and thermostats. Smart meters, which work by detecting the change in power consumption patterns that exhibit distinct characteristics for occupied and vacant states.[8]

Light Sensors

Light Sensors are photoelectric devices that convert light energy (photons) whether visible or infra-red light into an electrical (electrons) signal. A Light Sensor generates an output signal indicating the intensity of light by measuring the radiant energy that exists in a very narrow range of frequencies basically called “light”, and which ranges in frequency from “Infra-red” to “Visible” up to “Ultraviolet” light spectrum. The light sensor is a passive device that convert this “light energy” whether visible or in the infra-red parts of the spectrum into an electrical signal output. Light sensors are more commonly known as “Photoelectric Devices” or “Photo Sensors” because the convert light energy (photons) into electricity (electrons).Photoelectric devices can be grouped into two main categories, those which generate electricity when illuminated, such as Photo- voltaic or Photo-emissive etc, and those which change their electrical properties in same way such as Photo-resistors or Photo-conductors.[7] Practically light sensors when expose to sunlight may provide signals to the micro controller to switch off the lamps.

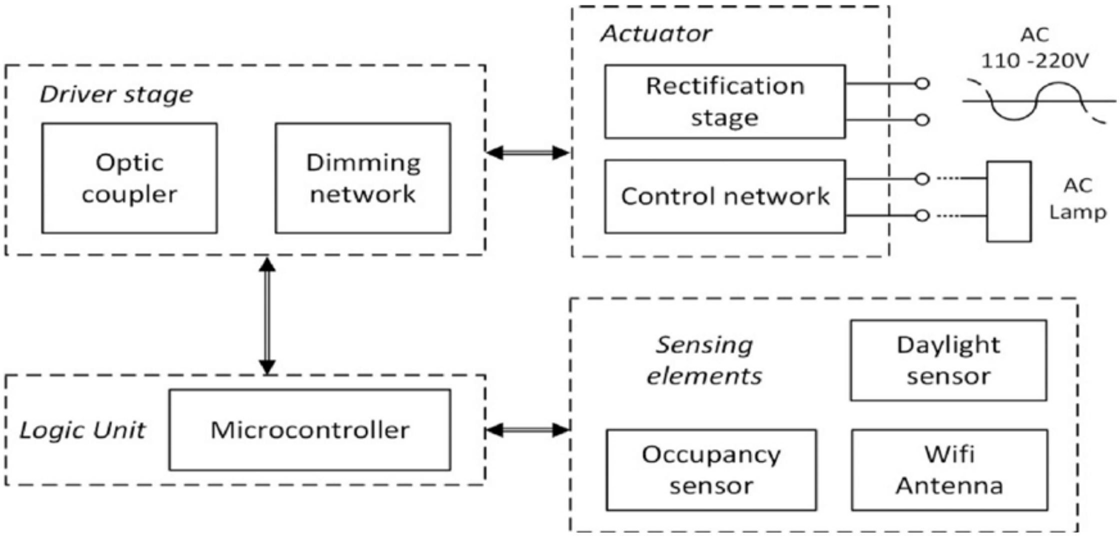
The Light Dependent Resistor

As its name implies, the Light Dependent Resistor (LDR) is made from a piece of exposed semiconductor material such as cadmium sulphide that changes its electrical resistance from several thousand Ohms in the dark to only a few hundred Ohms when light falls upon it by creating hole-electron pairs in the material. The net effect is an improvement in its conductivity with a decrease in resistance for an increase in illumination. Also, photo resistive cells have a long response time requiring many seconds to respond to a change in the light intensity. Materials used as the semiconductor substrate include, lead sulphide (PbS), lead selenide (Pb Se), InSb which detect light in the infra-red range with the most commonly used of all photo resistive light sensors being Cadmium Sulphide (CdS). Sulphide is used in the manufacture of photoconductive cells because its spectral response curve closely matches that of the human eye and can even be controlled using a simple torch as a light source. Typically then, it has a peak sensitivity wavelength (λp) of about 560nm to 600nm in the visible spectral range.

To increase the dark resistance and therefore reduce the dark current, the resistive path forms a zigzag pattern across the ceramic substrate. The CdS photocell is a very low cost device often used in auto dimming, darkness or twilight detection for turning the street lights "ON" and "OFF", and for photographic exposure meter type applications.

Dynamic Lighting consumption control in a room using sensors

Here we a consider a room in which the presence of people is time based and not uniform throughout the working hours and the room is also subjected to good sunlight for few hours [2]. It is advisable to install some occupancy sensors in the room which will dynamically provide the data as when there is presence in a given area in the room. It will give output high (1) for presence and low (0) for nil presence and accordingly the lights of the room will be on and off.



Daylight sensors and LDRs will be installed to detect sunlight and accordingly the lights will be put on and off of the room. Light may be dimmed also using dimmers.[2] These sensors may either be wire connected or may be wi-fi connected to send their signals to controller which receives data from it. Lights are to be put on when occupancy signal is high and at the same time LDR signal shows lesser sunlight and the controlling unit analyses the lights are to be put on. We have various kind of such sensors having various range and cost hence the system installed must take into account the cost factor and the corresponding payback period also.

Conclusion

Buildings in our country are consuming a big percentage of the total power consumption and hence saving of energy in building sector is of utmost importance. Energy efficient smart buildings have emerged as a very good concept of energy saving using solar power, biomass power and natural cooling with provision of considerable sun light in the building. High efficiency sensors including passive presence sensors, light detecting sensors, LDRs photo diodes equipped with wi-fi connected micro controllers have taken the energy efficiency to the next level. Payback period of such energy efficient saving can be further reduced by using highly advance sensors and as the cost of such sensors are decreasing day by day the payback period will also be economic.

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