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Improving the Energy Efficiency of Lighting Systems

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Abstract

Energy efficiency is one of the main focuses of research in electrical engineering at the present time. The increased attention and study to identify more efficient and smarter ways to use electrical energy comes directly from the growing need to conserve dwindling global resources, as well as growing concerns over the environmental impact of the conventional energy sources.

Index Terms: Energy; lighting; energy efficiency; Photovoltaic; control

1. Introduction

A decreased use of energy means less to pay for energy bills, reduced load on the grid and less environmental impact. Lighting is the most common and naturally the most constant form of load. It represents a significant portion of the total electricity consumption all building types, and it is more prominent in commercial buildings (lighting consumes 25 – 30% of energy in commercial buildings) [1].

In next pages I am going to write verify about the different methods to improve the efficiency of lighting system.

The energy efficiency in lighting is defined as optimization of energy consumption, with no effect on lighting quality. The challenge is how to provide illumination at best practice standards while, at the same time, using the minimum amount of electricity necessary [2].

This paper discusses about some methods that Contribute to Improving the energy efficiency of lighting systems.

The paper structure is as follows: Section 2 proposed methods that Contribute to Improving the energy efficiency of lighting systems.

2. Improving the Energy Efficiency of Lighting Systems:

- Design light quantity and quality for the task and occupants' needs:
- Replace incandescent lamps with the most energy efficient types of lamps:
- Replace magnetic ballasts with electronic ballasts:
- Maintenance & Operation of lighting system:
- Use of Daylight in Buildings to reduce energy used.
- Use photovoltaic to lighting the streets and outdoor facilities:
- Use Energy efficiency label for Light appliances:
- Use lighting control technologies:

2.1 Design Light Quantity And Quality For The Task And Occupants' Needs:

Effective lighting design starts with a comprehensive evaluation of various factors to address the lighting needs of occupants, which are influenced by the specific tasks carried out in the workspace. The lighting system should be crafted to deliver both the appropriate quantity and quality of light that aligns with these requirements. Important considerations include color, availability of daylight, glare, and light distribution. Retrofits that overlook this assessment risk continuing outdated designs that may no longer meet the needs arising from workspace reconfigurations or shifts in task types (for instance, from paper-based to computer-based activities) [3].

2.2 Replace Incandescent Lamps With The Most Energy Efficient Types Of Lamps:

To enhance efficiency, it is essential to utilize energy-saving lamps. There are various types of lamps available, each suited to specific tasks and applications, such as outdoor, indoor, or industrial use. Important factors to consider include luminous efficacy, color temperature, color rendering index (CRI), cost, lifespan, and other relevant parameters [4].

Below briefly definition about some of the terms mentioned above which will help us understand and compare the different types of lamps.

- **Luminous Efficacy:** quotient of the luminous flux emitted by the power consumed by the source. Its unit: lm /W.
- **Colour Rendering Index (CRI):** measure of the degree to which the psychophysical colour of an object illuminated by the test illuminant conforms to that of the same object illuminated by the reference illuminant, suitable allowance having been made for the state of chromatic adaptation.
- **The color temperature:** The light produced is compared to the perceived color of a black-body radiator at the corresponding temperature on the absolute temperature scale.
- **Life (of a Lamp):** The total time for which a lamp has been operated before, it becomes useless.

2.3 Replace magnetic ballasts with electronic ballasts:

Ballasts play a crucial role in lighting systems, as they directly influence light output. A ballast regulates the electrical current needed to start a lighting fixture and maintain a consistent light output. Therefore, it is essential to replace outdated core and coil technology with electronic ballasts to enhance the efficiency of the lighting system.

Electronic ballasts offer numerous advantages, including dimmability, energy savings of up to 13%, a 30% increase in lamp lifespan, reduced audible noise, elimination of flickering, and a compact size [5].

In other side there are some of disadvantages of electronic ballasts which can be summarized in the following points:

- Relatively expensive.
- short lifetime (typically one to five years).
- not environmentally friendly (toxic and/or not biodegradable electronic waste that is not recyclable).
- no self-recovery features.
- high maintenance and repair costs.

2.4 Maintenance & Operation of lighting system:

A lighting upgrade goes beyond merely installing efficient equipment. Often, cost-effective opportunities for reducing energy and maintenance expenses, as well as enhancing occupant satisfaction, are overlooked because operational and maintenance considerations are either ignored or addressed sporadically after the upgrade. It is essential to incorporate the following decisions into your upgrade design from the outset [6].

All lighting systems experience a decrease in light output and efficiency over time from three factors:

- Lamp light output decreases (lamp lumen depreciation).
- Dirt accumulates on fixtures (luminaire dirt depreciation).
- Lamps burn out.

Over time, these factors can reduce a system's efficiency by as much as 60%, leading to wasted energy and maintenance costs, while also compromising safety, productivity, and the overall aesthetics of the building. Implementing a planned maintenance program that includes group relamping and regular fixture cleaning can minimize this waste and optimize system performance. It's important to remember that the cheapest lamp to purchase may not be the most economical option in terms of operational costs [7]. Figure (1) shows the efficiency loss over time.

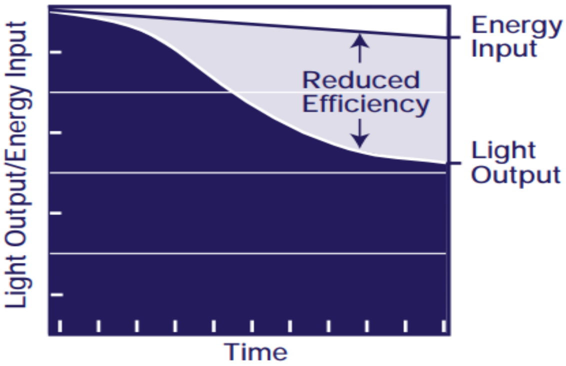
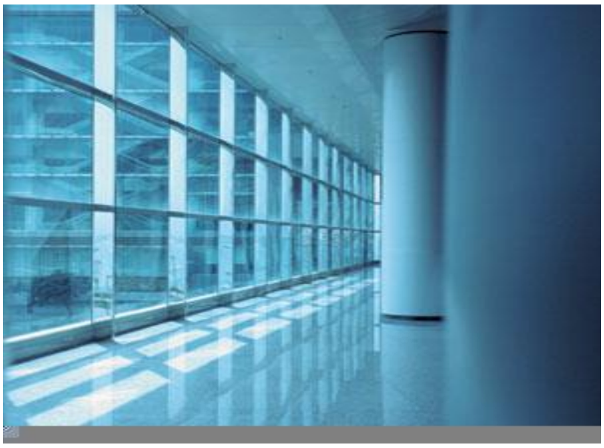


Figure 1: Efficiency loss over time

2.5 Use of Daylight in Buildings to Reduce Energy Use:



Improving a building's energy efficiency by reducing energy consumption can be achieved in various ways. One effective approach in public buildings is utilizing daylight to illuminate interior spaces. Standards and regulations establish the required light intensity in buildings based on their intended use. By harnessing natural daylight, we can decrease the energy needed for artificial lighting while ensuring the necessary light levels are maintained [8].

This can be accomplished through effective lighting control, which allows for the switching on, off, or dimming of light sources. A well-designed lighting control system aims to provide consistent, adequate illumination while minimizing power consumption. This solution not only enhances the building's energy efficiency but also improves user comfort and safety [9].

Architects should design buildings to maximize the use of day lighting. And there is important items that must take in account during the design that is daylight factor and other point related to this topic as will explain below:

- The daylight factor (DF) is commonly used to determine the ratio of internal light level to external light level and is defined as follows:

DF = (Ei / Eo) x 100%

where: Ei = illuminance due to daylight at a point on the indoors working plane

Eo = simultaneous outdoor illuminance on a horizontal plane from an unobstructed hemisphere of overcast sky.

Factors affecting Ei are:

- The sky component (SC): direct light from a patch of sky visible at the point considered.
- The externally reflected component (ERC): the light reflected from an exterior surface and then reaching the point considered.
- The internally reflected component (IRC): the light entering through glazing and reflected from an internal surface.

The illuminance level (lux) at any point being considered is the sum of these:

Lux = SC + ERC + IRC

Each of these components may be adjusted by the designer (e.g. the reflectivity of internal surfaces) to achieve the required level of lighting.

- **Techniques for using natural light:**

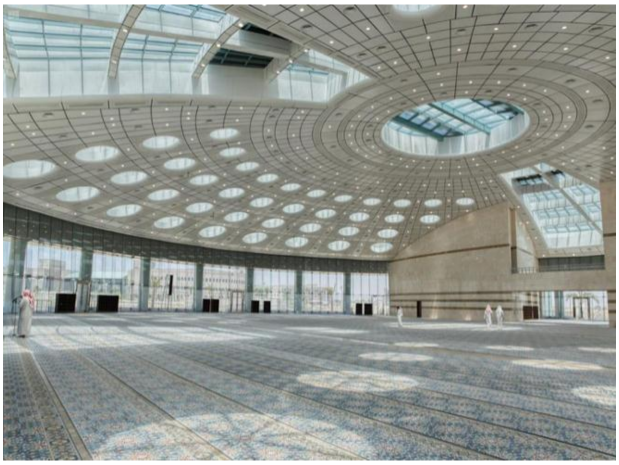
Passive daylighting is a system of collecting sunlight to maximize its benefits for lighting, in a controlled manner to avoid unwanted glare. The following tactics may be deployed:

- window size, shape, position, and orientation.
- glazing coatings.
- reveal angles.
- shading devices (interior and exterior) .
- skylights and roof lights.
- light wells.
- tubular daylight devices (sun pipes) .
- reflective or pale painted surfaces and interior decor.
- daylight responsive electric lighting control (more explain in next ways to improve efficiency by management control of lighting system).

Where possible, ceilings might be sloped to direct lighter inward.

It is vital to prevent direct daylight reaching critical visual task areas, and so it needs to be filtered. Artificial light should be brought in gradually further within spaces, so that there is not a sudden contrast between natural and artificially lit areas. The intention is to direct low daylight high into a space (to reduce the likelihood of excessive brightness) [10].

One of the unique architectural examples in the exploitation of natural lighting is the Mosque University of Tabuk, where the mosque is characterized by a natural lighting system from the dome of mosque and glass walls made of double glass with a high degree of light transmittance.



Pic 1: Tabuk University Mosque and the role of natural lighting is clear.

2.6 Use Photovoltaic to Lighting the Streets and Outdoor Facilities:

Solar radiation possesses significant energy potential that can enhance the energy efficiency of lighting systems by decreasing electrical power consumption for lighting purposes. This approach not only reduces reliance on traditional energy sources, which often contribute to environmental pollution, but also promotes the use of renewable and clean energy sources, fostering greater sustainability. The working principle of these lights is fundamentally simple. During daytime, the PV cells absorb sunlight and store energy in a battery. As the sun sets, an automated switch, which also acts as a photoreceptor sensitive to light intensity, detects the reduced sunlight and triggers the system to activate the solar streetlight [11].

However, a challenge arises when insufficient energy is stored due to clouds or dust. Overcast days, solar cells may not charge effectively, resulting in limited electricity production from the batteries. Consequently, this may prevent the lights from lasting throughout the night. If the sky suddenly becomes overcast, the photoreceptors will activate the grid to power the lights instead.

Figure (2) shows how the system works.

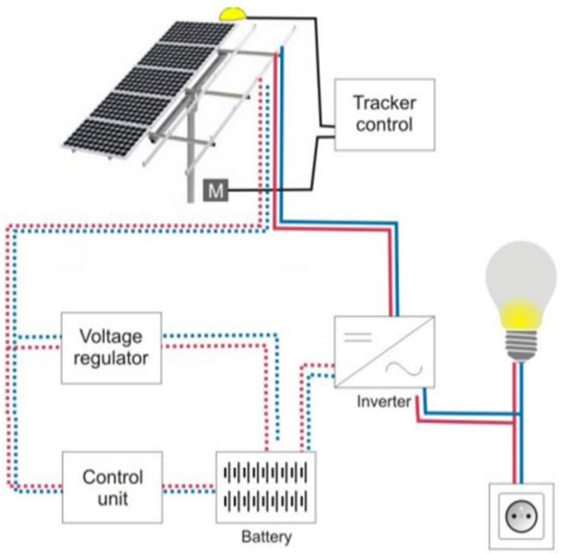


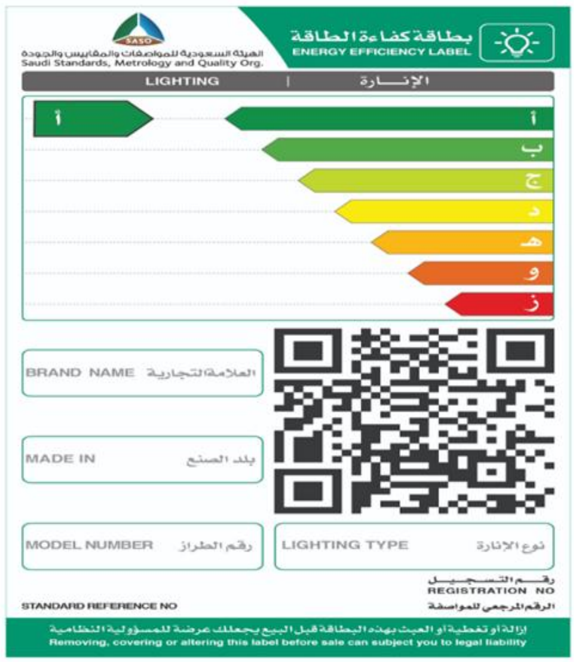
Figure 2: System components and their connections

Still the initial cost of purchasing a solar system is high. This includes paying for solar panels, inverter, batteries, wiring, and the installation. Nevertheless, solar technologies are constantly developing, so it is safe to assume that prices will go down in the future.

2.7 Use Energy Efficiency Label For Light Appliances:

The Saudi Energy Efficiency Center (SEEC) in cooperation with the relevant authorities prepared the Energy Efficiency Card for the most energy consumption appliances such as air conditioners, refrigerators, freezers, and washing machines and adding lighting that is our topic in the paper.

It is a label that aims to raise a consumer awareness and give him approved ways to compare electrical appliances as per their efficiency in consuming electrical energy before purchasing them, to help him choose the appliance that has the best performance and the least consumption of electric energy. It explains the electrical energy efficiency consumption at different levels so that green represents the highest levels of appliance, most efficient and least energy-consuming electric energy [12]. The energy efficiency label shall be clearly installed on the home appliance, enabling the consumer to easily see its contents. The minimum of energy efficiency coefficient depends on the type of product and will be determined as per the type of product and according to the technologies available in KSA and global markets. It intended to reduce the spread of appliances in the KSA's markets. Below is an example of an energy efficiency label for lighting that was prepared by SEEC.



Pic 2: example for energy efficiency label

As shown in the picture above, the energy efficiency label has been added to all electrical products and the labels state the following data:

- Product type.
- Product technical data
- QR Code of the product
- The brand Name
- Country of manufacture.
- Model number.
- Energy efficiency levels so that the higher the efficiency of the product, green level become higher [13].

2.8 Use Lighting Control Technologies:

Automatic lighting control systems reduce energy consumption by decreasing operating time of lamps based on various factors like occupancy, time of day, availability of daylight. Various technologies exist that perform lighting control. These technologies differ in their input parameters, their control method, control algorithm, cost of installation, complexity of commissioning, etc. Each of the control schemes has a unique set of factors that affect their performance in terms of energy savings as well as user acceptance [14].

In this paper I am going to write about some of the techniques used in controlling lighting:

2.8.1 Occupancy-based control schemes:

Among the various control schemes for lighting automation, occupancy sensor technologies have been widely used for many years. These sensors employ motion detection techniques to determine the presence of occupants within a designated area. Lights are activated when an occupant is detected and switched off after a pre-defined delay when no movement is sensed.

Occupancy sensors come in various types and price ranges, including Passive Infrared (PIR), Ultrasonic, Acoustic, and Microwave sensors, each with its advantages and disadvantages. Some sensors are prone to "False-On" errors, triggering in response to non-human movement, while others may turn off even when occupants are present.

Research has shown that instead of relying on a single occupancy sensor for a room or area, using multiple sensors can significantly reduce these errors. This can involve deploying sensors of the same type or, for improved detection accuracy, integrating different sensor technologies. Figure (3) show the algorithm that used.

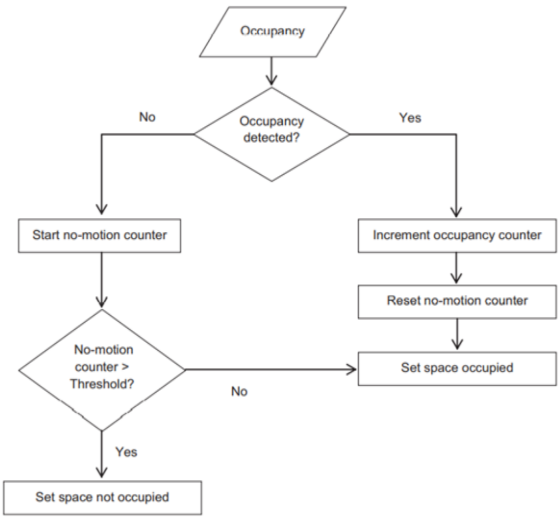


Figure 3: Occupancy sensor algorithm

2.8.2 Daylight- lighting controls:

For buildings or rooms that receive daylight, lighting control schemes linked to daylight availability can yield significant savings, provided factors such as orientation and potential obstacles are favorable. Spaces with sufficient daylight penetration can effectively utilize natural light, supplementing electric lamps to achieve adequate illumination levels [15].

Daylight-linked controls can either be configured to switch lights on or off, which is particularly applicable for outdoor and common area fixtures or used in conjunction with dimmable electronic ballasts to maintain the desired level of artificial lighting when daylight is available. In outdoor common spaces like sports facilities, hallways, and parking lots, simple daylight-controlled on-off switches can be implemented. This approach not only ensures that lights are turned off during the daytime but also eliminates the need for manual supervision, saving both time and labor costs [16]

2.8.3 Lighting control by time scheduling:

Lighting control systems that rely on scheduling operate on a straightforward principle: they set specific operating times for light fixtures. The lights controlled by these systems are turned on and off according to a predetermined schedule. Scheduling systems are time-based, making them ideal for areas where occupancy patterns can be accurately predicted. Rooms or spaces used for events during specific time frames are particularly well-suited for the implementation of scheduling systems [17].

Scheduling can be done using simple control devices called time switches or time clocks. Fixed routine indoor areas, common spaces and outdoor lightings are appropriate targets for time switch use. Time switches can be manual mechanical devices, but more advanced digital versions are also available. Some digital time switches can be programmed via personal computer interface to run through a daily, weekly, monthly, or even annual cycles [18].

Scheduling controllers can be standalone units or integrated into lighting control panels, which serve as central systems for automating lighting across multiple rooms or floors. When properly commissioned, time-based control systems can deliver significant savings, typically ranging from 10% to 40% in office building applications. Scheduling systems are often used in conjunction with other control technologies, such as occupancy sensors and photocells [19]. A few savings report from such combinations is mentioned in this paper.

Conclusion

In conclusion, energy efficiency remains a pivotal area of research in electrical engineering, driven by the urgent need to conserve limited global resources and address the environmental challenges posed by traditional energy sources. As the demand for sustainable solutions increases, the development of smarter and more efficient energy systems is essential. Continued innovation and research in this field will not only help mitigate the negative impacts of energy consumption but also pave the way for a more sustainable future. By prioritizing energy efficiency, we can ensure that both current and future generations have access to reliable and environmentally responsible energy solutions.

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