# Lighting Control
## – possibilities in cost and energy-efficient lighting control techniques

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**130 years ago, when Thomas Edison demonstrated his invention of the incandescent light bulb, he said: "we will make electricity so cheap that only the rich will burn candles". Unfortunately the non-rich are still burning candles and the electrical energy cost is still a significant part of the total operational cost of buildings. With increasing use of electricity for lighting some action must be taken in order to reduce the cost.**

In order to reduce the cost related to energy consumption caused by lighting,

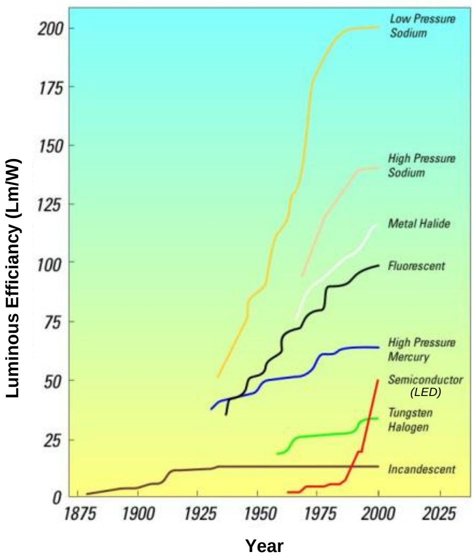


Figure 1: Progressions of some common light sources efficiency.

a good start is by investigating the light sources used and their efficiency. There are many available artificial light sources on the market with different characteristics and one of them is the efficiency. As shown in Figure 1 the progression during last years has been in favor of fluorescent lights and LED lighting. At the same time the Incandescent lamps have such low efficiency that they are being phased out in many countries.

By selecting an energy efficient artificial light source, the possibilities to reduce the energy consumption are good. To do even better, these sources can be combined with a lighting control system.

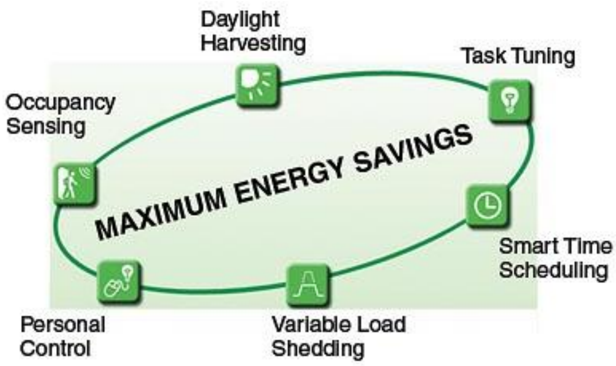


Figure 2: Common lighting control strategies for energy saving.

There are a few common strategies within the lighting control technique, as seen in Figure 2. Occupancy sensing is perhaps the most common and is intended to limit the use of artificial lighting when there is no occupancy. The daylight harvesting works in a similar way, but instead it uses a measurement of available daylight to reduce the use of artificial light sources, usually by dimming them. In buildings with periodic activity of users, time scheduling can be used. The scheduling can vary the lights based on some time schedule and the task tuning can alter the light scenes in a room based on the current activity. This is becoming more popular within offices including the personal control, where users can control their personal light, from their own panel or even from their computers. Variable load shedding is not as common but can be useful in circumstances where some predefined energy maximum to is to be avoided.

## The environmental aspect

Energy management is a key for payback of a 'green' buildings and with the focus on commercial and office buildings, the lighting is a good place to start. In a store, for example, the lighting often accounts for over 40% of the energy bill so by making the lighting more energy efficient it is possible to reduce the electrical cost considerably. But is there more to it than just saving money? Yes there is! The main source for the emission of $CO_2$ is combustion and not only the combustion of gas, oil and coal, but all combustion, including the combustion of biofuel. According to the International Commission on Illumination, lighting accounts for about 19% of the electricity used in the world and therefore $CO_2$ emission related to electricity production for lighting is approximently 1,775 billion ton of $CO_2$ per year.

## Standards and regulations

The standard, EN 15193 Energy performance of buildings, *Energy requirements,* which was published in November 2007 is a part of EU's measure to satisfy the Kyoto Agreement concerning the reduction of greenhouse gases by improving the energy efficiency within EU. With this directive, all properties regarding power consumption must be declared. By this the focus is set on energy use (power use/time unit) instead of just the installed power output. The European Performance of Buildings Directive also requires an energy certificate for buildings (EPCs). This certificate gives information about the energy efficiency and environmental impact of the building. In the EN 15193 standard, the methodology for calculating lighting energy consumption for a building per year is defined.

## LENI

The Light Energy Numeric Indicator, LENI, has been developed to show how much energy is needed each year to light up each square meter in a building so that its illumination and specifications are fulfilled.

$$LENI_{calculated} = W_{total}/A(kWh/m^2/year)$$

where A is the building's total interior area in square meters and $W_{total}$ is:

$$W_{total} = W_{light} + W_{parasitic}$$

$W_{light}$ estimates the energy consumption needed for lighting for a certain period and include all light sources and ballasts. $W_{parasitic}$ contains the standby energy consumption, that is the energy used by the ballast in standby mode, e.g. when charging batteries for emergency lights.

## ELI

Even though the LENI index is important for estimating how much energy is needed for each square meter in a building, it does not take things like appearance and emotion into account. Therefore another index, the ELI index, has been designed to work in parallel with LENI. The Ergonomic Lighting Indicator, ELI, takes into account lighting requirements, as stated in standard EN 12464, 'Lighting of workplaces'.

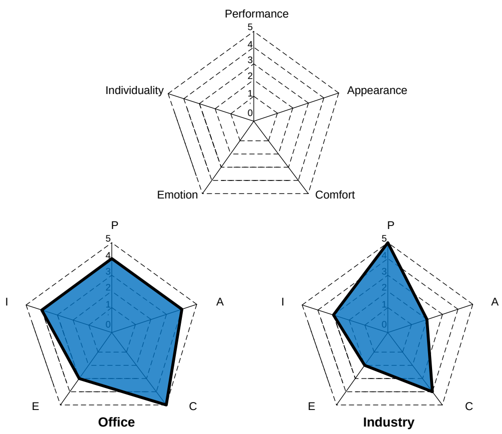


Figure 3: Graphical representation of the ELI index and an example of two different installations.

To form the ELI index 5 different parameters, shown in Figure 3, are observed and graded from 0 to 5. By summing up the values for these parameters we get the ELI index for the building. In the Figure we have two examples showing the different emphasize in requirements. By applying both these indexes, LENI and ELI, we can calculate the 'Energy-to-ergonomic' ratio of an installation, which is simply done by dividing the LENI with the ELI index.

## How does it work in reality ?

Schenker office in Växjö includes a hub for its transport network where trucks bring in and pick up goods. The activity within each zone of the warehouse is different during the day because trucks mostly arrive in the morning and then again in the afternoon. In 2007, an occupancy based lighting control system was installed in the warehouse. Each zone of the building is monitored and the light level keep at 15% of full power when there is no activity. When activity is detected the light level is raised to 95%.

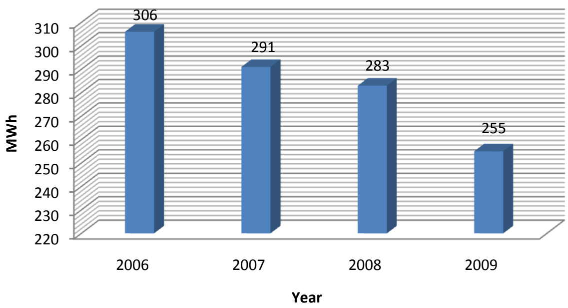


Figure 4: Electrical use in MWh for the first two quarters of each year.

According to Thomas Sandström the local director at Schenker, lighting accounts for 80% of the total electrical use. The cost of installing the lighting controls system in the office in Vaxjö was 159 600 SEK. Therefore it can be estimated that around mid 2010 a complete payback has been achieved. The payback time is therefore only three and half year with this simple installation.

## Systems on the market

There are numerous lighting control systems on the market today. Dedicated lighting control systems exist, which are often produced by the illuminator producers. In addition to them, many Building Automation Systems, BAS, supports lighting control among other operations. To investigate the different parts of BAS, an hierarchical model is introduced, which structures the automation field in three layers.

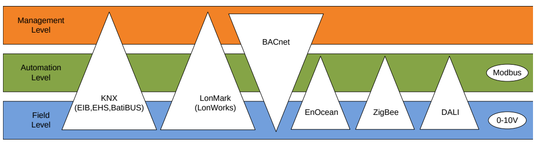


Figure 5: Mapping of the systems on the BAS model.

There is a difference between protocols, which level they span and in what way. The KNX protocol is for example built up from the field level to the management level but BACnet has its focus on the management level and is not as defined in the field level. The systems that have been investigated are: KNX, LonMark, BACnet, EnOcean, ZigBee, DALI, Modbus and the 0-10V protocol. Comparisons of these systems are shown in Figure 6 and each common factor is graded or specified.

| | KNX | LonMark | BACnet | EnOcean | ZigBee | DALI | Modbus | 0-10 V |
|---|---|---|---|---|---|---|---|---|
| Data rate | 9.6 kbps | 1.25 Mbps | 78.4 kbps | 120 kbps | 250 kbps | 1.2 kbps | 38.4 kbps | |
| Power consumtion | Good | Good | Good | Best | Very good | Best | Best | Best |
| Versatility | Best | Best | Best | Very good | Very good | Good | Sufficient | Sufficient |
| Implementation | Very good | Very good | Very good | Best | Best | Best | Best | Good |
| Installation cost | Good | Good | Good | Very good | Very good | Best | Very good | Very good |
| Maintenance cost | Good | Good | Good | Very good | Very good | Best | Very good | Very good |
| Max number of nodes | 61455 | 32385 | unl. | 2^32 | 2^16 | 64 | 247 | Outp. Depend. |
| Integration with EXO-systems | Best | Best | Very good | Very good | Very good | Very good | Best | Best |
| Market position in EU | Best | Best | Very good | Very good | Very good | Best | Very good | Best |

Best / Very good / Good / Sufficient

Figure 6: Selection matrix for protocols.

As can be seen in the selection matrix, the systems can be divided into three groups. The first group contains the three systems to the left, a full functioning BAS where lighting control is included as one of many possible options. The next group includes EnOcean and ZigBee, wireless systems that mainly focus on energy consumption of system parts and ease of implementation. The last group contains the systems covering the lowest two levels of the BAS model.

## Implementation

After evaluation of the systems in question, the DALI system is the one with most potential, with good market position within EU and an increasing number of producers supporting the protocol, both for drivers and sensors. Part of the system is integrated in the lamps supported, where as well, part of the program is stored. The protocol is quite simple and already there exists gateways to DALI from many other protocols.

Implementing DALI on AB Regin's platform is accomplished with the construction of a DALI master unit. The master unit is built around the ATmega168 microcontroller from Atmel.

The DALI master unit serves as an interface between the two protocols, EXOline and DALI line. The DALI line interface is constructed with two separate circuits, a transmitting circuit and an receiving circuit. These two circuits are then connected in parallel at the DALI line end. The DALI line interface is electronically isolated from the Master Controller by using an inverting optocoupler. The EXOline interface is a circuit built around the Differential Bus Transceiver integrated circuit and connected to the USART pins of the microcontroller.

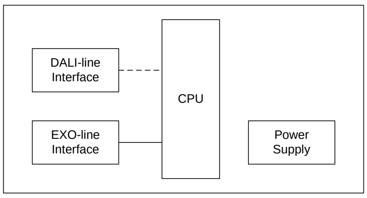


Figure 7: Block diagram of the DALI master unit.

The program of the DALI master unit uses interrupts for communications on both lines. For EXOline communication the USART functionality is used. For the DALI line two types of interrupts are used. A timer interrupt is used to provide the 1200 baud transmission speed. The other interrupt used by the DALI line is a external interrupt, triggered by interrupt pin of the microcontroller.

## This is how it works

To test the DALI master unit a computer running EXO software is connected to the EXOcompact controller using RS232/RS485 converter as shown in Figure 8.

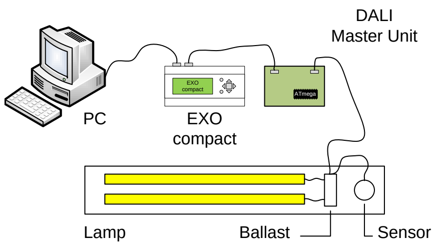


Figure 8: Setup of equipment for the testing.

By using a test program from Regin on a PC, called EXOtest, it is possible to pipeline commands between EXOtest and the DALI master unit through the EXOcompact. By entering a broadcast addresss and a command in the interval 0 to 254, in EXOtest, and execute the command the light output of the lamp varied from 0% to 100% of full power.

## The future

Event though the basic concept of the implementation has been proved and a prototype exists, there is still much work to be done. It is, however, clear that there are great potentials in cost- and energy savings by using energy efficient light sources and a well designed lighting control systems. For a company such as AB Regin, which is leading in the HVAC systems, the addition of a lighting protocol to its system will strengthen its market position as a full scale BAS provider.

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