

# Lighting System Efficiency in the Industrial Plants

Mircea Draghici, Francisc Sisak and Anca Manolescu

**Abstract** The article presents the most important elements of a lighting installation of the existing industrial building, how to choose from the various optimization solutions and efficient power consumption for the facility using advanced equipment control and the proper use of them in order to reduce the time of using of the artificial lighting. Energy efficiency is one of the important issues concerning lighting system control. A very significant part of building consumed energy is the lighting systems consume. Providing lighting only in the areas and in the periods lighting is needed and providing the right level of lighting as needed are effective means of reducing the energy use of the lighting system. The main control action for this purpose are on/off switching and dimming using a central control system BMS. There are presented and simulated some efficiency solutions of the lighting system within an industrial production plant that currently uses fluorescent lighting T8. The main conclusion of this article is that replacing conventional lighting systems in the industrial sector with modern lighting systems using LED technology controlled by a centralized automated intelligent BMS type, leads to increased energy efficiency. The article shows that in certain moments of time when natural light enters the building from exterior spaces through the walls or ceiling glass by automatically adjusting light intensity of lighting or just by switching some of the lamps off via light sensors and an integrated BMS system can achieve a saving of electricity consumption of approx. 30 %. By replacing lamps using T8 fluorescent tubes with new LED based lighting electricity, consumption can be reduced to approx. 60 %, and if additionally use a lighting management system centralized BMS type, saving power consumption can reach up to approx. 70 %.

**Keywords** Lighting installation · Efficiency · Control intelligent · BMS

---

M. Draghici (✉) · F. Sisak · A. Manolescu  
Faculty of Electrical Engineering and Computer Science, Transilvania University  
of Brasov, Brasov, Romania  
e-mail: draghici@mircea@gmail.com

© Springer International Publishing Switzerland 2014  
I. Visa (ed.), *Sustainable Energy in the Built Environment - Steps Towards nZEB*,  
Springer Proceedings in Energy, DOI 10.1007/978-3-319-09707-7\_5

## 1 Introduction

The main objective of the European Union in the energetic field is particularly achievement by 2020 of a 20 % reduction in greenhouse gas emissions, increasing to 20 % the share of renewable energy and increasing energy efficiency by 20 % [1].

The new energy strategy focuses on five priorities:

1. Achieving an energetic efficiency Europe;
2. Building a truly pan-European integrated energy market;
3. Empowering consumers and achieving the highest level of safety and security;
4. Extending Europe's leadership in energy technology and innovation;
5. Strengthening the external dimension of the EU energy market.

Energy efficiency is the most cost-effective way to reduce emissions, improve energy security and competitiveness, make energy consumption more affordable for consumers as well as create employment, including in export industries. Above all, it provides tangible benefits to citizens: average energy savings for a household can amount to €1 000 per year [1].

Fluorescent lamps are discharge lamps, mercury vapor, with or without addition of gases; light rays are not obtained because of this phenomenon but because of a substance (luminophore) placed on the inner surface of those.

Discharge in these environments is very rich in ultraviolet radiation.

Luminophore layer (covering the walls of the glass on the inside) is to convert the emitted energy spectrum ultraviolet radiation, fulfilling the following conditions:

- Good conversion efficiency,
- Transparency to visible radiation,
- Radiation resistance during time,
- Shockproof irradiation caused by frequently connections-disconnections

Luminophore layer composition determines the color of light source and also the color rendering index value.

The ignition is done by surge discharge (shock voltage), decreased slow ionization, and environmental resistance discharge or by combining the two systems.

To stabilize the discharge is necessary ballast [2].

Tubular fluorescent lamps are discharge lamps, mercury vapor at low pressure. Discharge fluorescent lamp type is "positive column" the majority of radiation in this type of lamps (95 %) occurring in the ultraviolet spectrum (253.7 and 185 nm bands) and only 5 % in the visible spectrum.

Electroluminescence as a phenomenon was discovered in 1907 by the British experimenter H. J. Round of Marconi Labs, using a crystal of silicon carbide and a cat's-whisker detector [3].

Russian Oleg Losev reported creation of the first LED in 1927. His research was distributed in Russian, German and British scientific journals, but no practical use was made of the discovery for several decades [3].

In 1961, James R. Biard and Gary Pittman found gallium arsenide (GaAs) emitted infrared light when electric current was applied [4].

The first visible-spectrum (red) LED was developed in 1962 by Nick Holonyak, Jr., while working at General Electric Company [5].

The first high-brightness blue LED was demonstrated by Shuji Nakamura of Nichia Corporation in 1994 and was based on InGaN [6].

## 2 Presentation of Existing Situation

Given the above issues, this paper focuses on reducing the power consumption, offering an alternative solution to optimize existing lighting system used in the production halls of a factory located in Brasov.

Production in this plant is organized around the clock (24 h/day), except on Sundays (just 2 shifts, 16 h) and public holidays resulting in 8,100 h/year of lighting operations.

The lighting performance connection is of 1.3 MW; consequently, the annual consumption is of approx. 8,340 MWh and the annual costs are (computed at an estimation of 0.33 lei/kWh) of approx. 2,75 mil lei, equivalent to some 610,000 €.

Every area of the production halls has few (3...6) electrical switchboards providing electrical energy for the lighting system in monophasic or three-phasic circuits mode, every three-phasic circuits supplying approx. 30...40 fluorescents lamps.

This analysis will focus on a reference area (Fig. 1), situated in one of the areas used as production space, which is considered later as the reference for the entire study.

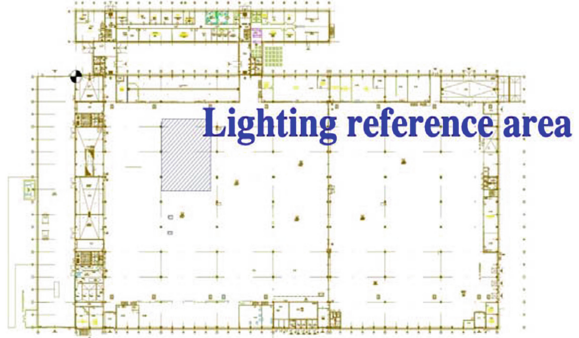
The space is considered to be fit in areas with low height ( $h < 6$  m), the hall is equipped with machines and technological designed production components and equipment for the automotive industry, having installed a lighting system evenly distributed lighting plan being placed height of 4.5 m above the finished floor and the lighting environment considered useful work level height ( $h = 1$  m) of 300 lux (for example uses the picture of Fig. 2).

The lighting used in the analyzed room consist of lighting lamps with  $1 \times 58$  W and  $2 \times 58$  W type, degree of protection IP 20 (Fig. 3).

The current situation in the reference area is as follows:

- Number of lamps in room with  $1 \times 58$  W 245 pieces.
- Number of lamps in room with  $2 \times 58$  W 596 pieces.
- Number of lamps in the reference area with  $1 \times 58$  W 90 pieces.
- Power installed in a luminaire  $1 \times 58$  W with ballast included 60 W.
- Power installed in a luminaire  $2 \times 58$  W with ballast included 120 W.
- The lighting power installed on the entire analyzed room 86.22 kW.
- The lighting power installed on the reference analyzed area 5.4 kW.

**Fig. 1** Architectural plan of the building analyzed in Brasov/Romania, specifying the reference area chosen to be analyzed



**Fig. 2** Picture that shows the layout of the lighting installation in the production hall analyzed



Using a measurement instrument I made measurements of the lighting in the reference area in the working plane ( $h = 1$  m above ground level) resulting information in the below table.

The measurement instrument is a Lux meter Type: Tiede HD 2302.0, produced by DeltaOhm firm.

The HD2302.0 is a portable instrument with a large LCD display.

It measures illuminance, luminance, PAR and irradiance (across VIS-NIR, UVA, UVB and UVC spectral regions or measurement of irradiance effective according to the UV action curve).

The probes are fitted with the SICRAM automatic detection module: in addition to detection, the unit of measurement selection is also automatic. The factory calibration settings are already memorized inside the instruments.

**Fig. 3** Fluorescent lamp used in the existing building



The *Max*, *Min* and *Avg* function calculate the maximum, minimum or average values.

Other functions include: the relative measurement REL, the HOLD function, and the automatic turning off that can also be disabled.

The instruments have IP67 protection degree.

I used for ILLUMINANCE measurement probe type: LP 471 PHOT with the followings characteristics, Table 1.

Measurement was done as follows:

- During daylight
  - Grid 5 by 5 m
  - Not considering additional lighting on specific workplaces
  - Excluding all the areas separated by walls in the production hall (i.e. storage, offices, etc.)
  - According the SR EN 12464 the measurement of the values starts after 100 h working of the lighting system.
- (a) **Actual measured situation for the lighting in the existing industrial plant, chosen reference area** (Table 2, Fig. 4)
  - (b) **Actual simulated situation for the lighting in the existing industrial plant with Relux simulation program** (Table 4, Fig. 5)

Using simulation software Relux for the reference lighting area (the same grid of measurement points 5 m × 5 m) were obtained the following values (Fig. 5, Tables 3 and 4):

**Table 1** Characteristics of the probe type: LP 471 PHOT

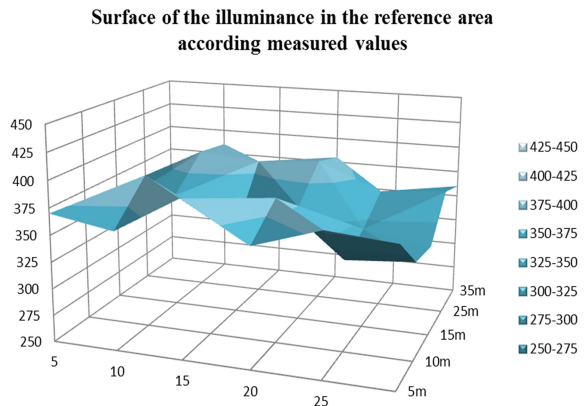
ILLUMINANCE measurement probe LP 471 PHOT				
Measurement range (lux)	0.01... 199.99	... 1999.9	... 19999	... 199.99*10 <sup>3</sup>
Resolution (lux)	0.01	0.1	1	0.01*10 <sup>3</sup>
Spectral range	In agreement with standard photopic curve V(λ)			
Class	C			
Calibration uncertainty	<4 %			
f' 1 [in agreement with pho-topic response V (λ)]	<8 %			
f2 (response according to the cosine law)	<3 %			
f3 (linearity)	<1 %			
f4 (instrument reading error)	<0.5 %			
f5 (fatigue)	<0.5 %			
α (temp. coefficient) f6 (T)	<0.05 % K			
Drift after 1 year	<1 %			
Functioning temperature	0...50 °C			
Reference standards	CIE n.69—UNI 11142			

**Table 2** Measured values of the illuminance (lx) in the reference area

Measured values of the illuminance light intensity (lx)					
m	5	10	15	20	25
5	370	360	345	360	350
10	360	395	360	390	385
15	395	360	330	385	325
20	360	385	360	390	380
25	380	335	345	365	325
30	375	340	335	370	360
Average of the illuminance Em (lx) =					363

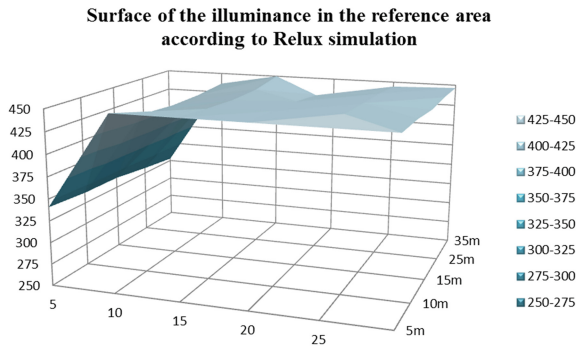
Grid of measurement points [m]

**Fig. 4** Graphic of the measured values for the illuminance light intensity



**Table 3** Relux simulated values of the illuminance light intensity

Relux simulated values of the illuminance light intensity (lx)					
m	5	10	15	20	25
5	341	337	337	332	328
10	450	436	433	433	436
15	462	446	443	444	489
20	464	449	446	441	406
25	462	451	449	448	444
30	455	450	446	447	447
Average of the illuminance $E_m$ (lx) =					428
Grid of measurement points [m]					



**Fig. 5** Graphic of the simulated values for the illuminance light intensity

**Table 4** Relux simulated values of the illuminance light intensity with LED lamps

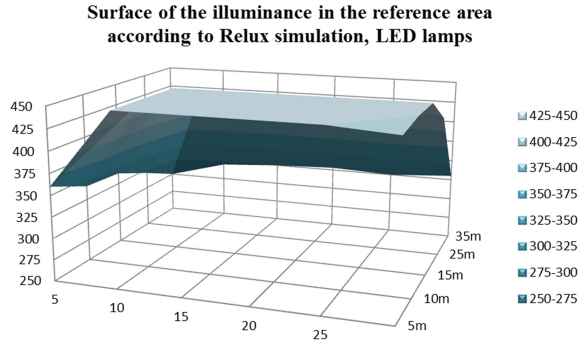
Relux simulated values of the illuminance light intensity (lx)					
m	5	10	15	20	25
5	360	341	338	320	300
10	451	462	464	432	320
15	472	482	470	434	325
20	460	483	471	431	328
25	465	480	469	418	325
30	445	467	476	419	330
Average of the illuminance $E_m$ (lx) =					415
Grid of measurement points [m]					

### 3 The Proposed Solution

(a) **Simulated situation for the lighting with changing of the fluorescent lamps with LED lamps**

Using simulation software Relux for the reference lighting area (the same grid of measurement points 5 m × 5 m), this time changing fluorescent lighting lamps with equivalent lighting as characteristics, LED lamps, built by the same manufacturer were obtained the following values (Table 4, Fig. 6):

**Fig. 6** Graphic of the simulated values of the illuminance light intensity, LED lamps



**Table 5** Comparison led lamps with florescent lamps

Lamp type	Watts	Lumens	Operating lifetime (hrs)
CFL	58	5,000	8,500
LED lamps	32	4,800	50,000

The chosen LED lighting having similar characteristics of the emitted light intensity and have a power of 32 W/lamp.

In this situation in the reference chosen area the situation show as follows:

- Number of lamps in the reference area with (LED 32 W) 90 pieces.
- Power installed in a luminaire 32 W 32 W
- The lighting power installed on the reference analyzed area 2.88 kW

## 4 Results and Discussions

In the measurements and simulations above I wanted to show the following:

- Between measured values and calculated values derived from Relux simulation software, using the same type of lamp, there are some differences due to the influence of external light, shading or reflectance of equipment and machinery installed in the reference areas,
- The difference between the illuminance curve obtained from Relux simulation for fluorescent lamps and the illuminance curve obtained from Relux simulation for lamps with LED technology are relatively small, which leads to the conclusions sion that, in reality the measurement for the reference area with the Lux meter, using this time the LED lamps will be similar with the measurement for fluorescent lamps.

LED lightings represent a viable replacement of the T8 tubular fluorescent lamps, because there will be a reduction in energy consumption by 53 % from the



same stream of light the same area. Light cones as well as the amount of lumens are comparable to those of T8 fluorescent tubes. If the first generation LED lighting did not lend itself to production halls, further developed products can be applied successfully in them.

It can be seen that due to the influence of natural light during the day, light intensity measured in the reference is greater than the proposed 300 lux.

By implementing a lighting control system to measure light intensity in two measurement points on each circuit, closing one phase circuit if the measured light intensity is higher by 50 % than the 300 lux required, we can record savings an additional power to 10 % (Table 5).

## 5 Conclusions

The main conclusion of this article is that replacing conventional lighting systems in the industrial sector with modern lighting systems using LED technology controlled by a centralized automated intelligent BMS type, leads to increased energy efficiency.

Given the above analysis we can draw the following conclusions:

Fluorescent tubes contain mercury and phosphor, which present a number of health and environmental risks. The lights require ballast, which adds to the cost of the lamp and can cause a buzzing noise. Finally, they frequently flicker.

Installing a management system LMS to an existing lighting system which is uses fluorescent lighting do not show a high decrease of the cost to the fluorescent lamps is required to replace the electronic ballast with an dimmable electronic ballast, which represents also supplementary cost and even if this is done dimming light intensity can be achieved with less than 20 % because of the risk that lamp to is switched OFF during the dimming.

On the other hand, LED lamps live is longer than fluorescents, and they don't contain harmful ingredients like mercury. Perhaps most significantly, LEDs use much less power than fluorescent lamps and there are many other benefits, as well.

The article shows that in certain moments of time when natural light enters the building from exterior spaces through the walls or ceiling glass by automatically adjusting light intensity of lighting or just by switching some of the lamps off via light sensors and an integrated BMS system can achieve a saving of electricity consumption of approx. 30 %.

By replacing lamps using T8 fluorescent tubes with new LED based lighting electricity, consumption can be reduced to approx. 60 %, and if additionally use a lighting management system centralized LMS type, saving power consumption can reach up to approx. 70 %.

The LMS will decrease the electricity consumption at certain times of day when natural light affects the amount of artificial light, also can control switching ON/OFF lighting circuits in areas where at certain times light is not necessary due to lack of working staff.

Installing a LMS on a facility that uses LED lighting has the advantage that it can adjust the light intensity emitted by luminaries from 0–100 %.

Another important advantage that it shows the LED lighting to their lifespan is about 5,5 times longer than fluorescent lighting.

The main disadvantage is that the LEDs are currently more expensive, price per lumen, on an initial capital cost basis, than most conventional lighting technologies. As of 2010, the cost per thousand lumens (kilolumen) was about \$18. The price is expected to reach \$2/kilolumen by 2015 [7].

In conclusion, by replacing fluorescent lighting throughout the production hall with LED lighting and supplementary to install a LMS system will result in energy savings of up to 65 ... 70 %. The total investment will have a cost of about 125,000 Euro and the economy will be about 45,000 Euro leading to a depreciation cost in about 3 years.

Similar results were obtained in a study conducted by a team of engineers from the University of Cluj. They analyzed lighting lamps mounted in suspended ceilings, fitted with fluorescent lighting comparing with lamps using the LED technology and controlled by a LMS system, similarly mounted [8].

## References

1. Oettinger, G. H. (2013, November 10). Energy 2020\_A strategy for competitive, sustainable and secure energy.
2. Manualul de instalatii electrice. (2002). Editura Artecno.
3. Round, H. J. (1907). A note on carborundum. *Electrical World*, 19, 309.
4. <http://ro.wikipedia.org/wiki/LED>.
5. Holonyak, N., Jr. (2004). Lemelson-MIT prize winner. Lemelson-MIT program. Retrieved August 13, 2007.
6. Nakamura, S., Mukai, T., & Senoh, M. (1994). Candela-class high-brightness InGaN/AlGaIn double-heterostructure blue-light-emitting-diodes. *Applied Physics Letters*, 64(13), 1687.
7. LED Lighting Explained: Questions and Answers. [www.energy.ltgovernors.com](http://www.energy.ltgovernors.com).
8. Mihai-Adrian Poop. (2013). Ingineria instalatiilor, editie studenteasca, nr. 2/2013 article Reabilitarea sistemelor de iluminat, studio de caz pe Aula facultatii de instalatii, Universitatea Tehnica din Cluj-Napoca.