ELECTRONICS AND ELECTRICAL ENGINEERING
ISSN 1392 – 1215 2012. No. 4(120)
ELEKTRONIKA IR ELEKTROTECHNIKA

ELECTRICAL ENGINEERING
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ELEKTROS INŽINERIJA

Possibilities of Energy Savings through Conversion to LED Lighting in Western Region of Lithuania

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crossref http://dx.doi.org/10.5755/j01.eee.120.4.1448

Introduction

The usage of methodology of sustainable innovation and the practical experimentation in introduction of LED quality into public lighting in Klaipeda city, Lithuania, is presented in this article. The scientific research has been carried out within the frame of international South Baltic programme project „LED - Increasing Energy Saving through Conversion to LED lighting in public space“.

The main aim of the research is to evaluate the qualitative state of technical decisions in Klaipeda city public lighting and to mark the possibilities of energy saving trough conversion to the LED lighting.

Main tasks are: to evaluate the qualitative state of existing technical equipment by use of virtual modeling methodology [1], and to estimate the possibilities of saving energy by change of high pressure sodium (HPS) to LED in experimental street.

Qualitative state of Klaipeda city public lighting

The history of artificial lighting in dark time is very old. It starts from occurring of ancient towns, where were used fire, torch, lamps, etc. which were operated on the ground of firing liquid and solid fuel. The new ages were started with use of electricity. *Incandescent* lamp was invented in 1802 (*Humphrey Davy*), later the *neon* lamp in 1911 (*Georges Claude*) and the *light diodes* in 1962 (*Nick Holonyak Jr.*). For many years only the electric lamps were spread and became indistinguishable part of modern towns.

Conventional incandescent lamps occupied town streets for the most long time period by implementing traditional quality $A(t)$ of street lighting (thesis) for around hundred years (Fig.1,a, equation 1). It was replaced by gas sparking day light, neon lamps as new qualitative leap (antithesis) of street lighting $B(t)$ equipment [1]

$$R(t) = A(t) + B(t) + C(t) = 1\,, \qquad (1)$$

here $R(t)$ – trichotomical virtual model of street lighting qualitative transition.

However, the next qualitative leap – the stage of light diodes $C(t)$ (synthesis) occurred only in last years. It seems that this stage should very quickly replace gas sparking lamps in street lighting by LED.

Incandescent (including halogen) $A(t)$ lighting quality is very low and counts only 66 lamps which covers 0,5% of total number of installed lamps in Klaipeda public lighting (Table 1.).

Table 1. Distribution of lamps in Klaipeda city, 2010

Lamp capacity, W/type /number of pcs.	Incandescent	High voltage halogen	Mercury lamps	Tubular fluorescent	Compact fluorescent	Metal Halide	High pressure sodium	Low pressure sodium	LED	Number of pcs.
Abbreviation	ICD	HVH	ML	TF	CF	MH	HPS	LPS	LED	Total
11					60					60
18					119					119
26					12					12
40				34						34
50		42								42
60	9									9
70						17	3435			3452
100	15						1690			1705
150						37	4671			4708
200										0
250							2691			2691
400						3	278			281
1000						19				19
Number of pcs.	24	42	0	34	191	76	12765	0	0	13132
Average capacity, W	85	50	0	40	16	354	148	0	0	147
%	0,18	0,32	0	0,26	1,45	0,58	97	0	0	100

Klaipeda city public lighting quality is strongly related to the day light lamps. 13066 or 99,5% of lamps belongs to quality $B(t)$. HPS lamps make 97% of the lighting. No LED or quality $C(t)$ were installed in beginning of 2010 year. In comparison of the presented data of 2010, it must be said that the lighting equipment has been changed in 2001 [2]. At that point the equipment of Klaipeda lighting system was distributed differently - incandescent lamps were already in a low quantity, and the dominant lamps were the mercury ones (nearly 9000 pcs.), and high pressure sodium lamps were just starting to be established in Klaipeda lighting system (about 1000 pcs.). The annual consumption of annual electrical energy per inhabitant was 40 kWh in 2001. This factor was one of the highest in the Lithuania [2], and the total annual consumption was approximately $8 \cdot 10^6$ kWh [2]. The change of mercury lamps to mostly high pressure sodium (HPS) lamps is presented in table 1. The next stage of advancing the energy saving in the lighting area is changing from gas sparkling light lamps to the LED lamps.

Occurring of synthetic $C(t)$ quality stage of lighting equipment is regular phenomenon. LED lamps enable to save energy, to reduce the maintenance costs and to guaranty the longer life span of the equipment. So, replacement of gas sparking lamps GS(t) by the LED(t) is provided as shown in Fig.1, b) in upcoming years.

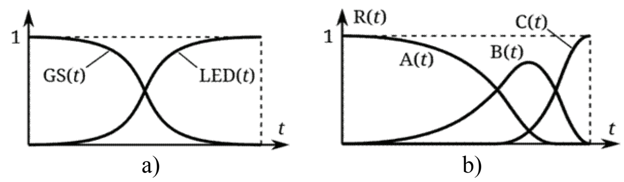

Fig. 1. a – Trichotomical virtual model of street lighting qualitative transition; b – Dichotomical virtual model of conversion of gas sparking lamps to LED

Total capacity of installed gas sparking lamps is 1,9MW. Lighting time (when the lamps are switched on) is 3.894 hours or 44% of overall time per year. Taking into account of 0.48 Lt/kWh of electricity costs, yearly public lighting electricity expenses are 3.632.149 Lt. Maintenance costs per year are 2.169.539 Lt. So, the total expenses on the city public lighting reach 5.801.688 Lt.

These expenses are significant for municipality. Taking into account total number of inhabitants of 176 thousand, the yearly expenses on city lighting are 33Lt per inhabitant. Seeking to reduce electricity expenses the every third luminary were disconnected at the crisis time.

So, conversion to LED lighting is reasonable for city of Klaipeda. The stated facts show at the high importance of evaluation what economy on electricity consumption and maintenance costs could be achieved when the gas sparking lamps will be replaced by the LED lighters.

The significance of the LED lighting is increasing in recent years, but the main obstacles, as it was stated by municipality, which slow the usage of such efficient [3] lighting are: the high cost of installation in comparison to the HPS lamps; the insufficient funding for lighting equipment in the municipalities; the installed HPS lamps are just now starting to payoff and the change to the other system is not acceptable since the payoff is insufficient for the moment; the need of rearmaments of the control system of the lighting of the city, which is in times more manual than an automated one. So the main obstacles are not the technological, but the economical ones. The comparison of the LED and other used lamps in the lighting system is presented in table 2 [3]. CRI is colour rendering index.

The LED has a much higher colour rendering index than HPS lamps that is very important for drivers and safety especially in the dark period of time. The lifetime is as better as four times for LED than HPS while the lumen per watt is adequate. But, according to the article [3], there is still a gap of high power LED equivalent installations at the moment, but within the one or two of upcoming years the tendencies trend to create the LED available to power up to 200 or more lumen per watt, which would solve the problem of existence of the gap [3].

Table 2. Comparison of Light sources [3]

Light source	CRI	Lumens/ watt	Lifetime in hours (x1000)
High Pressure Sodium	30	60-120	10-24
Low Pressure Sodium	5	200	10-24
Mercury Vapour	50	50	10
Metal Halide	70-95	60-100	6-20
Fluorescent	60-90	40-100	6-45
Compact fluorescent	60-90	50-75	6-15
Incandescent	5-25	100	1
Induction	50-90	60-90	100
Light Emitting Plasma	50-90	60-90	100
LED	70-90	Up to 150	100+

Compared with the HPS lamp, the human eyes feel the same brightness and natural colour at much lower light intensity. Therefore, even 100W LED light is equivalent to 400W high-pressure sodium lamp. It can be obtained at the lower power consumption if compared with the HPS lamp. Under the same visual conditions, energy can be saved up to 70%. Compared with the incandescent lamp, the amount of energy can be saved up to 90%. LED has the high light source utilized rate, about 90%. When LED emits light, it has certain angle, mostly of direct exposure to a specific area. Only a small portion of light is reflective. Hence, the light source utilization rate is high. Because of long lifespan there are low maintenance costs. LED street light has composition of 10 or more LED components, so, even in case of some LED damages, it will not cause a significant impact on operation on the whole, unlike the HPS lamp cutoff if damaged. As a result, LED is a much more reliable device than the HPS lamp. Despite of relatively higher purchase price of LED street light, however, the early total investment including cables, transformers, etc. is lower cost than the HPS lamp. So, the long term usage of long life LED as well as the low maintenance costs and energy saving obviously prove that LED street light is much cheaper than the HPS lamp [4–8].

Measurements and research results of public lighting

The LED lighting was installed in Klaipeda, Palanga and in some other cities of Lithuania. Popular and renewed marine bridge in Palanga was opened in 14 May of 2011. There were installed 46 units of 39W City spirit Philips LED illuminators which replaced former 70W HPS lamps. Palanga municipality is leader of LED installation in Klaipeda region and in overall Lithuania. 90 units of 40W LED illuminators were installed in Meiles avenue. In

Klaipeda Galinio Pylimo Street there were installed 3 types of LED's and 1 type of HPS for the comparison. LED luminaries from South Korea SE-STA130, NSLT-90G, Italy "Archilide" and Belgium HPS "Sintra" were used. Each type was installed in 3 nearby mountings to examine the manufacturers' declaration of the nominal power and light emitting capabilities. Lamps were on the same side of the street, distance between poles was 18 m, the same type of luminary was mounted on the 3 poles in a row, the height of the pole was 9 m. The measurements were done on the ground of street area 3 by 3m. Results are presented in Figs. 2-5 and for comparison – in Fig. 6–Fig. 10. So, the study of energy consumption before and after the replacement of luminaries allows us to notice the energy savings owing to the newly installed LEDs.

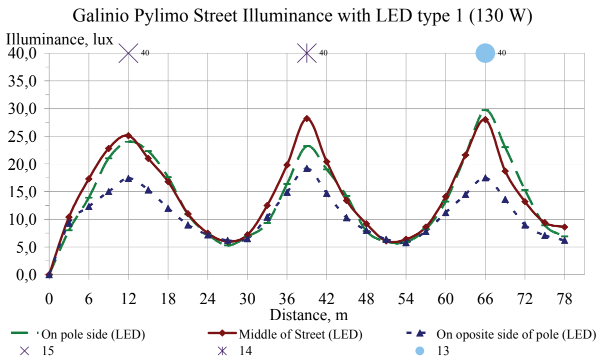

Fig. 2. Illuminance with LED 1 of 130 W (3 pcs)

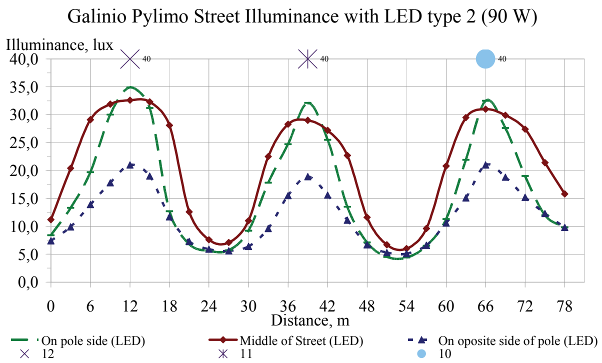

Fig. 3. Illuminance with LED 2 of 90 W (3 pcs)

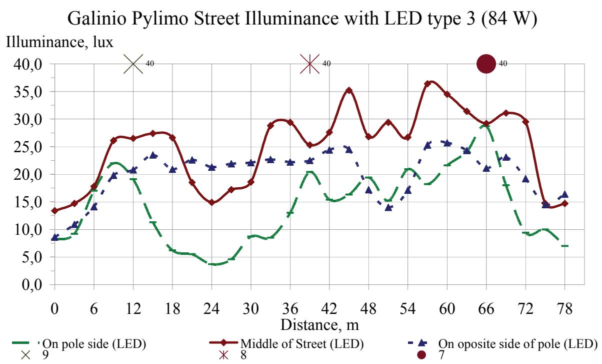

Fig. 4. Illuminance with LED 3 of 84 W (3 pcs)

The research discloses the LED luminaries having the higher peak of the flux as compared with the HPS lamps (Fig. 6), but the illuminance of LED lamps is more uneven in comparison with the HPS lamps (Fig. 9). This is the result of the usage of retrofit system which, at the start of street lighting system, was designed for the incandescent lamps, but not for the HPS or even for the LED luminaries.

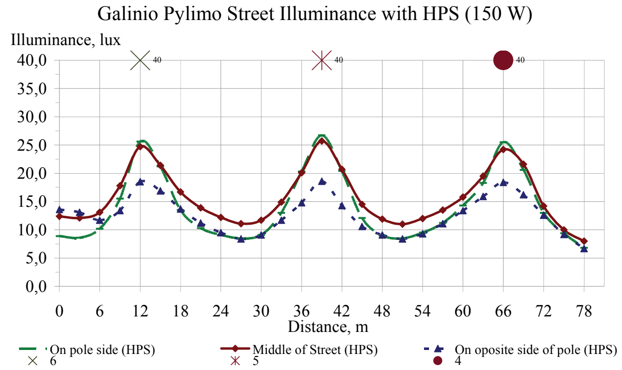

Fig. 5. Illuminance with HPS of 150 W (3 pcs)

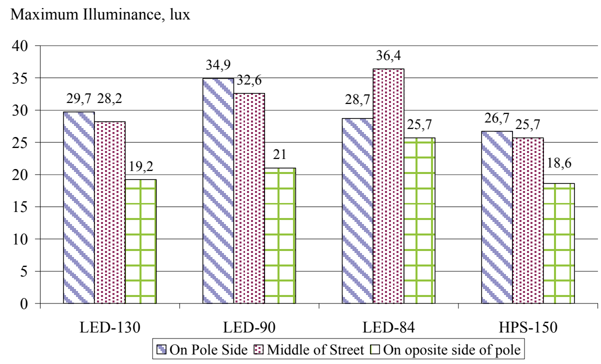

Fig. 6. Maximum illuminance for all types of luminaries on the different position of street

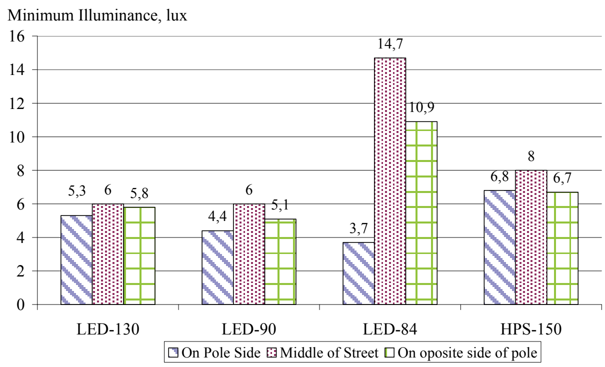

Fig. 7. Minimum illuminance for all types of luminaries on the different position of street

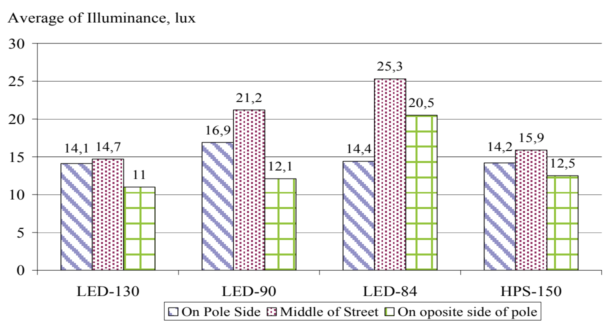

Fig. 8. Average of illuminance for all types of luminaries on the different position of street

The deeper analysis could be done by analyzing not only the luminaries' retrofit system, but by searching the optimal pole distribution and luminaries' height. As a result, the HPS lamps have higher illuminance in the darkest point between the poles (Fig. 7).

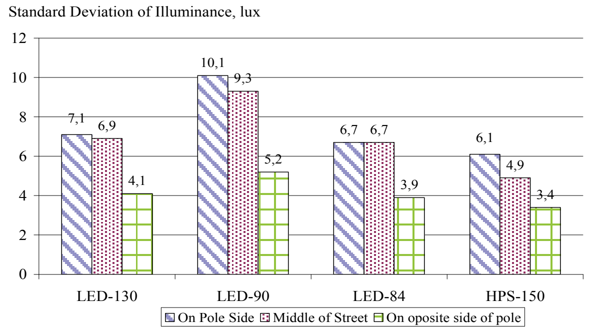

Fig. 9. Standard deviation of illuminance of all types of luminaries on the different position of street

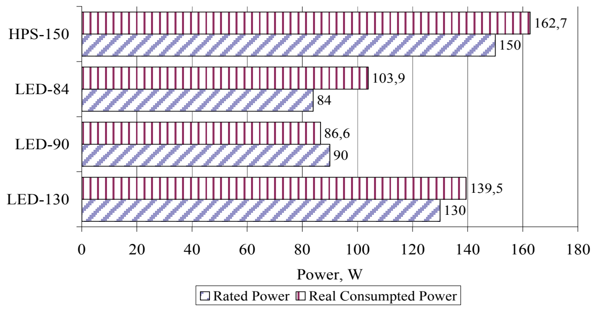

Fig. 10. Power consumption of tested luminaries

The findings indicate that in total the new LED lights use less energy than the HPS lights they replaced. The combination of the energy savings, reduced maintenance and disposal costs and the environmental savings show that now LED lighting is a real alternative to traditional lights.

Conclusions

This paper presents some detailed data gained at the experimental research of various types of LEDs used for street lighting application in terms of power and quality of the light. As compared to the other lighting technologies, LED consumes less power, lasts longer, performs better in the extreme conditions, and generates a better quality of light. LED suppliers provide a technology that gives us access to a new generation of energy-saving lighting options for our municipal infrastructure. LED lighting enables cities to save energy and preserve the environment. With future improvements in the LED technology and the integration of advanced dimming and remote monitoring, the intelligent lighting solutions will further enhance a facilities allowing for more control and predictability.

Acknowledgements

This paper has been written as a result of the project "LED-Increasing Energy Saving through Conversion to LED lighting in public space", financed by the EU and Ministry of the Interior of Republic of Lithuania within the South Baltic Cross-Border Co-operation Programme 2007-2013 as well as with supporting by Klaipeda UAB "Gatvių apšvietimas".

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Received 2011 09 08
Accepted after revision 2011 12 27

E. Guseinoviene, A. Senulis, J. Vaupsas, J. Januteniene, B. Rudnickij, S. Paulauskas, A. Paulauskas. Possibilities of Energy Savings through Conversion to LED Lighting in Western Region of Lithuania // Electronics and Electrical Engineering. – Kaunas: Technologija, 2012. – No. 4(120). – P. 35–38.

Significant improvements in performance and reliability made in the LED technology have enabled them to be used instead of traditional lighting solutions. This article deals with the advantages and disadvantages of LED, based on the experimental researches carried out in Klaipeda city, and presents some results of comparison of luminance in relationship with the various characteristics of LEDs and HPS lamps. Ill. 10 bibl. 8, tabl. 2 (in English; abstracts in English and Lithuanian).

E. Guseinovienė, A. Senulis, J. Vaupšas, J. Janutėnienė, B. Rudnickij, S. Paulauskas, A. Paulauskas. Energijos taupymas pereinant prie LED apšvietimo Vakarų Lietuvoje // Elektronika ir elektrotechnika. – Kaunas: Technologija, 2012. – Nr. 4(120). – P. 35–38.

Šviesos diodų (LED) technologija sparčiai tobulėja, todėl jie vis plačiau naudojami vietoj įprastinių šviestuvų, ypač viešosioms erdvėms apšviesti. Straipsnyje pateikiami eksperimentiniai Klaipėdos miesto Galinio Pylimo gatvėje sumontuotų LED šviestuvų galios ir apšviestumo matavimo rezultatai ir jų palyginimas. Il. 10, bibl. 8, lent. 2 (anglų kalba; santraukos anglų ir lietuvių k.).