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THE INVESTIGATION OF LED CONVERSION PRINCIPLES IN STREET LIGHTING THROUGH A SAMPLE PROJECT

Abstract

Street lighting is important for people to travel safely and comfortably. At night, our eyes are greatly diminished in sight; The risk of accidents on night voyages increases about 3 times compared to the day (Turkish National Police Traffic Services Presidency, 2018). Today, mercury vapor(MV) and sodium vapor lamps are mainly used in street lighting. Although the installation costs of these lamps used in street lighting are lower than those of LED lamps, efficiency factors are more efficient due to their life and electricity costs. As it is in the whole world, LED lamps are given more importance in new projects in Turkey; the existing lighting lamps are also replaced by LED lamps. Existing 6.5 million street lights across Turkey will be replaced by a specific planning. The Ministry of Energy established the "Procedures and Principles for the Use of LED luminaires in General Lighting" on January 2015. In this study, the LED efficiency ratio (LEVO) and the LED application efficiency (LUVO) ratio criteria are applied to LED lamp replacement of existing street lamps, which are published in the Ministry of Energy. It is LUVO, which is used to indicate the order of priority in the decision phase.

Keywords: Led lighting, LED conversion, Energy efficiency, LED advantages

SOKAK AYDINLATMASINDA LED DÖNÜŞÜM ESASLARININ ÖRNEK BİR PROJE ÜZERİNDEN İNCELENMESİ

Özet

Sokak aydınlatması insanların güvenli ve konforlu yolculuk yapmaları için önem arz etmektedir. Gece şartlarında gözlerimizin görme yeteneği son derece azalmakta; gece yolculuklarında kaza riski, gündüze oranla yaklaşık 3 kat artmaktadır (Emniyet Genel Müdürlüğü Trafik Hizmetleri Başkanlığı, 2018). Günümüzde sokak aydınlatmasında cıva ve sodyum buharlı lambalar ağırlıklı olarak kullanılmaktadır. Sokak aydınlatmasında kullanılan bu lambaların kurulum maliyetleri LED lambalara oranla düşük olmasına rağmen etkinlik faktörleri, ömürleri ve elektrik giderleri yönünden daha verimlidir. Bütün dünyada olduğu gibi ülkemizde de yeni projelerde LED lambalara ağırlık verilmekte; ayrıca mevcut aydınlatma lambaları LED lambalarla değiştirilmektedir. Türkiye genelinde mevcut 6,5 milyon sokak lambası belli bir planlama ile değiştirilecektir. Enerji Bakanlığı Ocak 2015 tarihinde "Genel Aydınlatma Kapsamında LED Armatürlerin Kullanımına İlişkin Usul ve Esaslar" belirlemiştir. Bu çalışmada Bakanlığın yayınlamış olduğu usul ve esaslarda yer alan mevcut sokak lambalarının LED lambalara dönüşümünde uygulanacak LED verimlilik oranı (LEVO) ve LED uygulama verimlilik (LUVO) oranı kriterleri örnek bir tesis üzerinden incelenmiştir. Karar aşamasında Öncelik sırası belirmek için kullanılan LUVO'dur.

Anahtar Kelimeler: LED aydınlatma, LED dönüşüm, enerji verimliliği, LED avantajları

1. INTRODUCTION

Road lighting helps pedestrians to see better at night; while for drivers it provides safe and comfortable driving during the night (Feng et al., 2010). Good road lighting can provide effective traffic movement and encourage overnight driving. Most importantly, it can prevent accidents when road lighting is switched on (Fusheng et al., 2009). In a comprehensive review of the CIE (International Commission on Illumination (CIE), 1993), road lighting has resulted in an average 30% reduction in overnight accidents for all road types (rural, urban, motorways and intersections). One of the features of road lighting is economic lighting. Lighting accounts for 15-20% of the world's annual electricity consumption and 3% of the total electricity consumption is spent on road lighting (Fusheng et al., 2009).

The most important component of road lighting is the lamp selection. The cost of installation of lamps, consumption cost, lighting life are directly related to the economic aspect of the early.? New lamps have been developed in parallel with technological developments over time. From the past to the present, the lamps used in road lighting have had advantages and disadvantages compared to each other from the development process and these lamps. Mercury vapor(MV) lamps, high-pressure sodium(HPS) lamps, low-pressure sodium(LPS) lamps, high-pressure metal halide(HPMH) lamps and LED lamps can be used in street lighting installations (Gutierrez-Escolar et al., 2017).

At the moment, road lighting renewal is being dealt with in settlements all over the world. Some light sources have been replaced by more efficient luminaires at the end of their economic life while others are not yet completed (Lecce et al., 2017).

2. LED LIGHTING SYSTEMS and ADVANTAGES

LEDs are the fourth and newest generation of light sources following first generation incandescent lamps, second generation fluorescent lamps and third generation HID lamps (Bessho & Shimizu, 2011). As a fourth generation light source, light emitting diodes (LEDs) have many advantages over traditional light sources such as uniform color, energy and space saving, reliable and long service life (Wang et al., 2011). Some basic features of LED lamps (Lamp 83, 2017):

- They are more durable, longer lasting and energy efficient than other traditional light sources.
- They provide low power consumption and low heat dissipation.
- They save energy and does not need maintenance.
- They create a natural light.
- They possess a long life span of 50,000-100,000 hours/life.
- They have very low temperature and low light pollution.
- Color Rendering Index(CRI) can reach up to 95%.

3. LED CONVERSION PRINCIPLES

As a result of changing lighting systems, the Light Emitting Diode (LED) lighting system has been widely used instead of traditional lighting system. LED lighting importance is increasing day by day due to less energy consumption, control algorithm, low production cost, long life (Kaplan et al., 2013).

Turkey Electricity Distribution Company (TEDAŞ) revised the "LED Light Source Road Lighting Fixtures Technical Specification" which was published in September 2010 in March 2015. According to this specification, LED luminaires will be manufactured and tested according to the latest edition of the standards and documents in Table-1 (TEDAŞ, 2015).

TABLE 1. ***Standards and Documents Used in Lighting (TEDAŞ, 2015)***

Standard No	Standard Name
TS 8700 EN 60598-2-3	Luminaires - Part 2: Particular requirements - Section 3: Luminaires for road street lighting
TS 8700 EN 60598-1	Luminaires - Part 1: General requirements and tests
TS EN 13201-1	Road lighting - Part 4: Methods of measuring lighting performance
TS EN 13201-2	Road lighting - Part 2: Performance requirements
TS EN 13201-3	Road lighting - Part 3: Calculation of performance
TS EN 13201-4	Road lighting - Part 4: Methods of measuring lighting

	performance
TS EN 62031	LED modules for general lighting – Safety specifications
TS 3033 EN 60529	Degrees of protection provided by enclosures (IP code) (For electrical equipments)
IES LM 80-08	Measuring Lumen Maintenance of LED Light Sources
IES LM 79-08	Electrical and Photometric Measurements of Solid-State Lighting Products
IES TM-21-11	Projecting Long Term Lumen Maintenance of LED Light Sources
TS EN 62262	Degrees of protection provided by enclosures for electrical equipment against external mechanical impacts (IK code)

Important technical specifications included in this technical specification are as follows (TEDAŞ, 2015):

- The color temperatures (CCT) of the LED packages used in the design of LED luminaires will be 4000 K ± 5%
- Color Rendering Index(CRI) of the LED packages used in the design of LED luminaires will be at least 70.
- The luminaire efficacy factor with LED will be minimum 115 lm/w. The efficiency factor will be measured and documented in a laboratory with photometric accreditation.
- The luminous flux rate (ULOR) that LED luminaires transmit to the top will not be more than 5%.
- The efficiency of the drives used in LED luminaires will be at least 90% as designed.
- The required luminous flux value at the place where the luminaires with LED are installed can be dimmed (dimmable) so that it can be adjusted to the desired light flow levels.
- As a result of the design calculations, the required lighting quality criteria will be provided so that the average road glare level does not exceed 5% of the required value.
- Luminaires with LEDs shall have at least IP 66 (dust and moisture) protection class according to TS 3033 EN 60529.
- LED luminaires will be resistant against external mechanical impacts.
- LED luminaires will have protection classes I or II against electric shocks.
- Luminaires with LEDs will operate with minimum 50.000 hours in operating conditions together with all the components (LED module, driver, cable, gasket, body etc.).

Within the general lighting that TEDAŞ has prepared, there is a publication titled "Procedures and Principles on the Use of LED Luminaires in General Lighting" covering the procedures and principles regarding the investments for the use of LED luminaires and the acceptance of the installations. Some important technical specifications of the LED fixtures to be used in general lighting based on the principles and procedures should be as follows (T.C. Enerji ve Tabi Kaynaklar Bakanlığı Enerji İşleri Genel Müdürlüğü, 2014):

- LED luminaires will be used in new facilities starting from 01.01.2016 (Postponed to 2018).
- Products with LED Efficiency Ratio (LEVO) of less than 40% will not be included in luminaires to be used in LED conversion applications. According to technological developments, the lowest LEVO of luminaires to be used in the facilities will be re-evaluated at the end of each two years and announced by the Ministry.
- The return period for investments in LED conversion plants will not exceed 6 years.
- In the Lighting Conversion Plan, the general road lighting, streets and streets, places will be classified according to the road classes specified in the standards. The conversion process will be done considering these classes.
- All installations where mercury vapor luminaires are used are replaced by LED luminaires within 3 years, and those with sodium vapor luminaires are replaced by LED luminaires within 10 years and older ones within 5 years.
- Dimmable luminaires with dim feature are necessary to ensure that the lighting level is reduced in lighting installations with LEDs.

3.1. LED Application Efficiency Ratio (LUVO)

LUVO is defined as the power saving rate in LED conversion applications between the kW/km value calculated with existing luminaires and calculated the kW/km value when the lowest lighting criteria (recommended values for the road lighting class in the standard) are provided using LED luminaires for the same installation. It is calculated with the following formula (Onaygil et al., 2017):

$$LUVO = \frac{MAP-LAP}{MAP} * 100 \quad (1)$$

In this formula, MAP, the total power unit per kilometer of existing luminaires in the facility (kW/km); LAP represents the total power per unit kilometer (kW/km) of LED luminaires that provide the proposed minimum criteria. Priority order will be determined according to the LED Application Efficiency Ratio of the facilities to be transformed in the Illumination Conversion Plan (Onaygil et al., 2017). In the lighting conversion plan, priority order will be determined according to the LED application efficiency ratio of the facilities to be converted.

3.2. LED Efficiency Ratio (LEVO)

LEVO is defined as the power saving rate in LED conversion applications between the kW/km value calculated with HPS luminaires provided by the lowest lighting criteria (recommended values for the road lighting class in the standard) and the kW/km value calculated in case the lowest lighting criteria that are provided using the same parameters with LED luminaires in the same facility. It is calculated with the following formula (Onaygil et al., 2017):

$$LEVO = \frac{SAP-LAP}{SAP} * 100 \quad (2)$$

In this formula, SAP calculates the total power per unit kilometer (kW/km) of the HPS luminaires that provide the minimum recommended illumination qualities; LAP represents the total power per unit kilometer (kW/km) of LED luminaires that provide the minimum recommended lighting quality (Onaygil et al., 2017).

LED conversion applications will be used in the LED efficiency ratio of 40% under the products will not be included. According to technological developments, the lowest LED efficiency ratio of luminaires to be used in plants will be re-evaluated at the end of each year and announced by the Ministry (T.C. Enerji ve Tabi Kaynaklar Bakanlığı Enerji İşleri Genel Müdürlüğü, 2014).

3.3. Led Conversion Application in Street Lighting

In this study, LED efficiency ratio (LUVO) and LED efficiency ratio (LEVO) were calculated for the conversion of current street lamps on a road in Antalya, Turkey, which is seen in Graph-1.



GRAPH 1: *Test Road*

The measured road has 2 lanes, 7 m wide and M3 road standards. There are luminaires with high-pressure sodium-vapor lamps in the 250 W capacity on the road with a clearance between electric poles 28 m, pole height 10 m. The minimum luminous value required for the M3 lighting class is L_{ort} = 1 cd/m^2.

LED conversion analysis for the road was made in DIALux 4.13 program. The same way was designed in the DIALux program and the LED luminaires with the following features were used to provide the desired photometric values for illumination of the road. The information on the LED luminaires is given in Table-2.

TABLE 2. ***LED Luminaires Specifications***

	Luminous Flux (lm)	Power (W)	Luminous Efficacy (lm/W)	Life (Hours)
LED lamp	11.800	95	124	100.000

The LUVO = ((MAP-LAP)/MAP) *100 equation is used for the LED Application Efficiency Ratio (LUVO) account in Section 3.1. According to this equation MAP is calculated as 7 kW/km, LAP is calculated as 1.13 kW/km. As a result of the obtained data and calculations, the LUVO value is calculated as 62%.

The LEVO = ((SAP-LAP)/SAP) * 100 equation, described in Section 3.2, is used for the LED Efficiency Ratio (LEVO) For this, the values of HPS and LED lamps, which provide the most decline lighting criteria for the M3 road standard, have been determined using the DIALux program. HPS and LED luminaire values are given in Table-3.

TABLE 3. ***HPS and LED Luminaires Values***

	Luminous Flux (lm)	Power (W)	Luminous efficacy (lm/W)	Life (Hours)
HPS	17.000	169	100	32.000
LED lamp	11.800	95	124	100.000

According to the calculations made, SAP: 4.2 kW/km, LAP: 1.96 kW/km. As a result of the obtained data and calculations, LEVO value was calculated as 43,78%.

4. CONCLUSION

Using LED lighting in street lighting will provide significant energy savings and economic benefits. According to the procedures and principles published by the Ministry of Energy, the LED Efficiency Ratio (LEVO) must be at least 40%. LED conversion projects are aimed at significant energy savings compared to HPS, and projects that do not do so will not be allowed. In this study, the planned way to convert is providing significant energy savings (43.78%) compared to HPS. LED conversion in street lighting is a process that requires time and cost. Therefore, it is necessary to process the projects prepared in a certain order. In determining priority ranking, projects with high LED Application Efficiency Ratio (LUVO) ratio will be prioritized. The aim is to start converting from lighting that consumes more energy than it is necessary. In this study, the LUVO value is calculated as 62% and the priority of this project will be decided by TEDAŞ with the data obtained from other projects.

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